ZFEL

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Hilton Malmö City, Sweden, August 23-27, 2010

Conference Programme

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Abstracts

Conference Programme & Abstracts

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MAX-lab

August 23

Scientific Programme

Monday

8:30–10:30	**Opening, New Lasing, FEL Lecture**
8:40	**FEL Prize Lecture: The Limits of Beam Brightness from Photocathode RF Guns** *D. Dowell (SLAC)*
9:10	**FEL Prize Lecture: Emittance Growth Mechanisms in Linac-Based FELs** *P. Emma (SLAC)*
9:40	**First Lasing at FLASH with 4.45 nm** *S. Schreiber (DESY)*
9:45	**SPARC Operation in Seeded and Chirped Mode** *L. Giannessi (ENEA C.R. Frascati)*
9:50	**MAX-lab Test FEL** *S. Werin (MAX-lab)*
9:55	**60 nm FEL Seeding at the SCSS Test Accelerator** *T. Hara (SPring8)*
10:00–10:30	Coffee break
10:30–11:00	**Opening, New Lasing, FEL Lecture,** *Continued*.
10:30	**FEL Prize Lecture: Electron Beam Diagnostics For High Current FEL Drivers** *P. Evtushenko (JLAB)*
11:00–12:00	**Status Reports**
11:00	**Progress in SDUV-FEL and Development of X-Ray FELs in Shanghai** *Z.T. Zhao (SINAP)*
11:20	**XFEL/SPring-8 Construction and SCSS Operation Status** *T. Shintake (RIKEN/SPring-8)*
11:40	**Status of the PSI X-ray Free Electron Laser "SwissFEL"** *T. Garvey (PSI)*
11:50	**The EuroFEL Consortium of Free Electron Lasers in Europe** *J. Feldhaus (DESY)*

12:00–13:30	Lunch
13:30–15:00	**Poster session**
15:00–15:30	Coffee break
15:30–17:00	**FEL Theory**
15:30	**FEL Simulations: History, Status and Outlook** *S. Reiche (PSI)*
16:00	**Coherence Properties of the Radiation From X-Ray FELs** *M.V. Yurkov (DESY)*
16:30	**Spontaneous Emission Sub-Radiance and Coherence Limits of FEL** *A. Gover (University of Tel-Aviv, Faculty of Engineering)*
16:45	**The Effect of Undulator Harmonics Field on Free-Electron Laser Harmonic Generation** *Q.K. Jia (USTC/NSRL)*
17:15–18:15	**Tutorial**
	How an FEL Works *B.W.J. McNeil (USTRAT/SUPA)*

August 24

Tuesday

8:30–10:00	**Storage Ring and ERL FELs**
8:30	**Radiation from Laser-Modulated and Laser-Sliced Electron Bunches in UVSOR-II** *M. Katoh (UVSOR)*
9:00	**The Elettra Storage-Ring Free-Electron Laser: a Source for FEL Studies and User Experiments** *G. De Ninno (ELETTRA)*
9:30	**Feasibility Study of Short-Wavelength and High-Gain EFLs in an Ultimate Storage Ring** *K. Tsumaki (JASRI/SPring-8)*
9:45	**Use Of Multipass Recirculation And Energy Recovery In CW SRF X-FEL Driver Accelerators** *D. Douglas (Thomas Jefferson National Accelerator Facility (JLAB))*
10:00–10:30	Coffee break
10:30–12:00	**X-Ray and Short Wavelength FELs**
10:30	**LCLS-II: An Upgrade for the Linac Coherent Light Source** *J. Wu (SLAC)*
11:00	**FLASH Upgrade and First Results** *S. Schreiber (DESY)*
11:30	**A Comparison Study of High Harmonic Characterizations in EEHG Operation of SDUV-FEL** *H.X. Deng (SINAP)*
11:45	**Second and Third Harmonic Measurements at the Linac Coherent Light Source** *D.F. Ratner (SLAC)*

12:00–13:30	Lunch
13:30–15:00	**Poster session**
15:00–15:30	Coffee break
15:30–17:00	**FEL Oscillator and Long Wavelength FELs**
15:30	**The THz-FEL FELBE at the Radiation Source ELBE** *W. Seidel (FZD)*
16:00	**Tunable Soft X-Ray FEL Oscillator** *J.S. Wurtele (LBNL)*
16:30	**Modeling and Operation of an Edge-Outcoupled Free-Electron Laser** *M.D. Shinn (JLAB)*
16:45	**Radiation Characteristics of the Long-Wavelength FEL at FELIX in the Vicinity of a Tuning Gap** *A.F.G. van der Meer (FOM Rijnhuizen)*
17:15–18:15	**Tutorial**
	Generation and Properties of HHG Radiation *A. L'Huillier (Lund University, Division of Atomic Physics)*

August 25

Wednesday

8:30–10:00	**Seeding and Seeded FELs**
8:30	**Pulse-Splitting in Short Wavelength Seeded Free Electron Laser** *M. Labat (SOLEIL)*
9:00	**sFLASH – First Results of a Direct Seeding at FLASH** *J. Boedewadt (Uni HH)*
9:30	**Commissioning the Echo-Seeding Experiment ECHO-7 at SLAC** *S.P. Weathersby (SLAC)*
9:45	**First Results of Coherent Harmonic Generation at the MAX-Lab Test Fel** *S. Werin (MAX-lab)*
10:00–10:30	Coffee break
10:30–12:00	**Short Pulse Length FELs**
10:30	**The Push Towards Short X-Ray Pulse Generation Using Free Electron Lasers** *A. Zholents (ANL)*
11:00	**Ultra-Short Low Charge Operation at FLASH and the European XFEL** *I. Zagorodnov (DESY)*
11:30	**A Single-Shot Method for Measuring Femtosecond Bunch Length in Linac-Based Free-Electron Lasers** *Z. Huang (SLAC)*
11:45	**ECHO Enhanced Harmonic Emission in FERMI** *E. Allaria (ELETTRA)*

12:00–13:30	Lunch
13:30–15:00	**Poster session**
15:00–15:30	Coffee break
15:30–17:00	**FEL Technology I (Injector and LINAC)**
15:30	**Review of Laser Pulse Shaping for High Brightness Beam Generation** *Y.L. Li (ANL)*
16:00	**Fast Distribution of Pulses in Multiple Beam Line Facilities** *W. Decking (DESY)*
16:30	**Construction of 8-GeV C-band Accelerator for XFEL/SPring-8** *T. Inagaki (RIKEN/SPring-8)*
16:45	**Phase Space Measurements with Tomographic Reconstruction at PITZ** *G. Asova (DESY Zeuthen)*
17:15–18:15	**Tutorial**
	About Accelerators for X-Ray FELs *M. Dohlus (DESY)*

Thursday

8:30–10:00	**Synchronization and Stability (Technology III)**
8:30	**Femtosecond Synchronization for Next Generation FELs** *J.M. Byrd (LBNL)*
9:00	**Intra-train Longitudinal Feedback for Beam Stabilization at FLASH** *W. Koprek (DESY)*
9:30	**RF-based Synchronization of the Seed and Pump-Probe Lasers to the Optical Synchronization System at FLASH** *M. Felber (DESY)*
9:45	**On-Line Arrival Time and Jitter Measurements Using Electro-Optical Spectral Decoding** *N. Cutic (MAX-lab)*
10:00–10:30	Coffee break
10:30–12:00	**New Concepts**
10:30	**Laser-Wakefield Accelerators as Drivers for Undulator-Based Light Sources** *M. Fuchs (LMU)*
11:00	**Practical Solution for Compact X-Ray FEL Laser Based Undulator** *V. Yakimenko (BNL)*
11:15	**Preliminary Study for the OFFELO** *Y. Hao (BNL)*
11:30	**Mode Locked Optical Klystron Configuration in an FEL Cavity Resonator** *B.W.J. McNeil (USTRAT/SUPA)*
11:45	**Using the Longitudinal Space Charge Instability for Generation of VUV and X-Ray Radiation** *E. Schneidmiller (DESY)*

12:00–13:30	Lunch
13:30–15:00	**Poster session**
15:00–15:30	Coffee break
15:30–17:00	**FEL Technology II (Undulator and Beamlines)**
15:30	**Design of Photon Beamlines at the European XFEL** *H. Sinn (European XFEL GmbH)*
16:00	**Characterization of Second Harmonic Afterburner Radiation at the LCLS*** *H.-D. Nuhn (SLAC)*
16:30	**Variable-period Permanent Magnet Undulators** *N. Vinokurov (BINP SB RAS)*
16:45	**Improvement in High-Frequency Properties of Beam Halo Monitor Using Dimond Detectors for SPring-8 XFEL** *H. Aoyagi (JASRI/SPring-8)*
17:15–18:15	**Tutorial**
	Diagnostics for Free Electron Lasers *J.C. Frisch (SLAC)*

Friday

8:30–10:00	**X-Ray Optics and Detectors**
8:30	**X-Ray Diagnostics Commissioning at the LCLS** *J.J. Welch (SLAC)*
9:00	**Non-Invasive Diagnostics on FEL Photon Beams: General Remarks and the Case of FERMI@Elettra** *M. Zangrando (ELETTRA)*
9:30	**Beam Diagnostic at SDUV-FEL** *Y.Z. Chen (SINAP)*
9:45	**Feasibility of X-Ray Cavities for Hard X-Ray FEL Oscillators** *Yu. Shvyd'ko (ANL)*
10:00–10:30	Coffee break
10:30–12:00	**Application of FEL Radiation**
10:30	**Ultrafast Single-Shot Diffraction Imaging of Nanoscale Dynamics** *A. Barty (CFEL)*
11:00	**The LDM Beamline at FERMI@Elettra** *C. Callegari (ELETTRA)*
11:30	**Photofragmentation of Complex Ti Clusters Under EUV-FEL Radiation** *P. Piseri (Università degli Studi di Milano)*
12:00–13:30	Lunch
13:30–18:15	**Lund Visit**

Poster Session Topics

Monday (MOPC)

Status Reports
FEL Theory
X-Ray and Short Wavelength FELs

Tuesday (TUPC)

Storage ring and ERL FELs
FEL Oscillator and Long Wavelength FELs
Seeding and Seeded FELs

Wednesday (WEPC)

Short Pulse Length FELs
FEL Technology I (Injector and Linac)

Thursday (THPC)

Synchronisation and Stability
X-Ray Optics and Detectors
Application of FEL Radiation
New concepts
FEL Technology II (Undulator and Beamlines)

Tutorials

Room: Svansjön

Monday 17:15–18:15

How an FEL Works

Brian McNeil, University of Strathclyde, SUPA

This tutorial will give an introduction to the physics of how FELs work and will be targeted at a 1st/2nd year post-graduate level audience. I will try to give the audience a conceptual understanding of the basic electron-field interactions that allow the electrons to bunch and emit coherently. Some of the physics that tends to inhibit the FEL interaction will also be described.

Tuesday 17:15–18:15

Generation and Properties of HHG Radiation

Anne L'Huillier, Lund University

When an intense laser field interacts with an atomic gas, nonlinear processes take place, leading to the emission of high-order harmonics of the laser radiation. In the spectral domain, a comb of odd-order harmonics is obtained, while in the temporal domain, the emission consists of a sequence of extremely short pulses of light, in the attosecond range. This talk will review the basic physics of high- order harmonic generation, the performances that can be obtained as well as some of the applications.

Wednesday 17:15–18:15

About Accelerators for X-ray FELs

Martin Dohlus, DESY

Linac-based X-ray-free-electron lasers require very short bunches of high-brightness electron beams with peak currents of the order of kilo-Amperes and energies of the order of 10GeV. Essential components of a typical drive linac are a laser driven photo injector, the accelerator and a bunch compression system. Non linear effects from external fields (f.i. rf curvature and higher order longitudinal dispersion) as well as self effects due to space charge, wakes and coherent synchrotron radiation have to be considered for machine design. These main components will be described in principle, the layout of some drive linacs will be discussed and the magnitude of higher order effects and of self effects will be estimated.

Thursday 17:15–18:15

Diagnostics for Free Electron Lasers

Josef Frisch, SLAC National Accelerator Laboratory

Free Electron Lasers require a variety of beam diagnostics for tuning and feedback. This tutorial will cover radio frequency analog and digital signal processing as used in a variety of instrumentation including beam position, bunch length and arrival time monitors. It will also cover beam profile monitors including wire scanners, fluorescent screens, and optical transition radiation foils, including the issues with coherent emission from high brightness beams. In addition, it will discuss the unique requirements for X-ray instrumentation for existing and future XFELs.

Table of Contents

Welcome

We wish you all very welcome to Malmö!

It's a pleasure for us to be able to organize the 32nd International Free Electron Laser conference, and we very much look forward to have you all with us in Malmö. Malmö is the third largest city in Sweden with a mere 250.000 inhabitants. Traditionally this was the workers town with ship-yards and industry and 20 km north-east you would find the university town Lund, the "Cambridge of Sweden". Time has changed, most of the industry is gone, new visions and institutes have grown, we now have the bridge to Copenhagen and a town with many people moving in, both from abroad and the rest of Sweden.

The FEL conference is if course an important step-stone for FEL interest in Sweden, but more so all around the world we are moving into the era of user facilities. We believe that during FEL2010 we will see several important steps in the FELs maturing, growing and prospering.

The conference program has been chosen with the excellent skills of the Scientific Program Committee chair Dr. Atoosa Meseck (Helmholtz Zentrum Berlin). You will be able to enjoy a thrilling program and in addition the new tradition of tutorials will be continued. There is slightly more time than before, but we think that you in this way will be able to listen and see more of FEL science.

Of course, in the back of our heads we know that in the streets of Malmö the annual Festival is going on, which might diverse your interest. A festival for the citizens of Malmö, but also for all you visitors. It might be noisy, it might be crowded but it will definitely give you something else than conference daily life.

Finally we just want to say that we hope the conference will have the flavor of a small town in a small country but with the same international weight as always. Informal, friendly and of course creative!

Once again, feel yourself most welcome!

Nils Mårtensson Sverker Werin

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DESY

Malmö stad

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THE ROYAL SWEDISH ACADEMY OF SCIENCES

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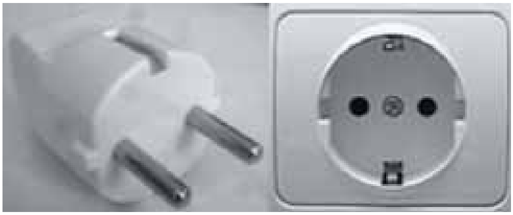
Useful Information

Electricity

230 V / 50 Hz, F type of socket.



Currency

Swedish crown (krona). If you are paying with cash the bill will be rounded to nearest 0.5. If you use your credit/debit card exact amount is used. All major credit cards are accepted in shops, taxis and cash machines. Exceptions are some small shops, minor taxi companies and busses. Sometimes American Express cards might not be accepted.

10 crowns = 1 Euro, 7 crowns = 1 USD

Time zone

UTC/GMT +2 hours (current time zone offset during daylight saving time)

Emergency number

112

VAT and tipping

Tips in bars and restaurants are already included in the bill. Anything extra is of course appreciated by the personnel. It is not uncommon to round up your bill. All prices in shops are including the value added tax (MOMS in Swedish, which is 25%).

Mass transportation

Busses cost about 20 SEK and work on zone basis, meaning that the tickets are valid for a certain period for a certain zone. Your ticket from Kastrup to Malmö is valid for buses in Malmö until you get to your destination. Train/bus for a trip somewhere in Skåne costs around 40-100 SEK depending on destination (bus drivers do not accept cards).

More information is available at:
www.skanetrafiken.se (transport company)
www.resrobot.se (travel planner)
kartor.eniro.se (more detailed maps than Google maps)

Water

It is OK to drink the tap water.

Hours of Business

Most shops are open untill 6 pm, and most supermarkets are open longer (10 pm).
Bars and pubs close around 11 pm – 3 am on weekends, but earlier on weekdays.

Insurance and liability

The organizers of FEL2010 do not accept liability for medical, travel or personal insurance. Delegates are strongly recommended to arrange their own personal insurance.

Conference Venue

The conference will take place at

Hilton Malmö City hotel
in the heart of Malmö.
The hotel holds 16 business meeting rooms with wireless internet access, a gym with views from the 20th floor and a Lean Grill & Bar.

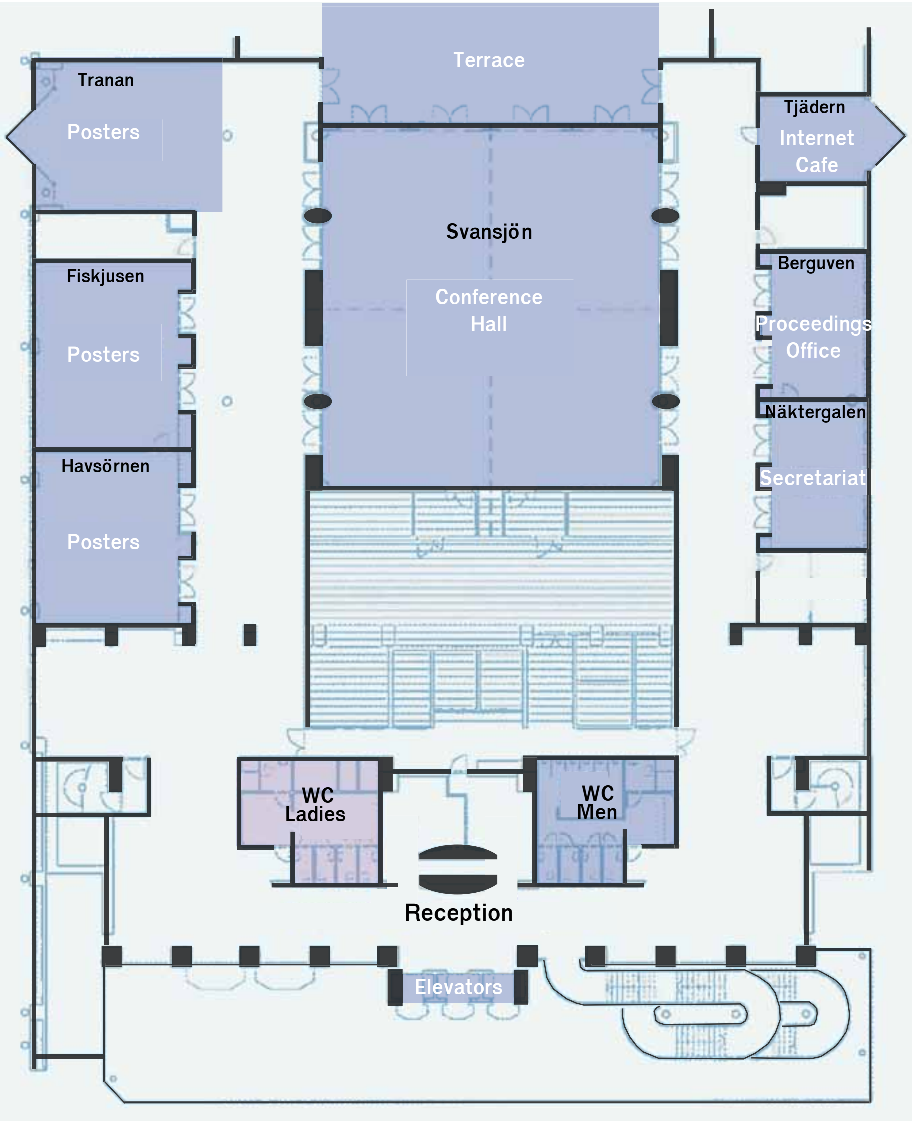
Registration

Registration with refreshments will be at the conference venue on **Sunday 22nd at 18:00-20:00**.

Registration will also be possible on **Monday 23rd at 08:00-12:00**.

Conference Venue Layout

The Conference Floor



Social Events

Reception

Monday 23rd: Conference Reception in the evening at

Malmö Town Hall

In the city centre of Malmö you'll find the impressive Town Hall, built in late Gothic style in the Middle Ages. The facade was redecorated in the 1860's in Dutch Renaissance style.

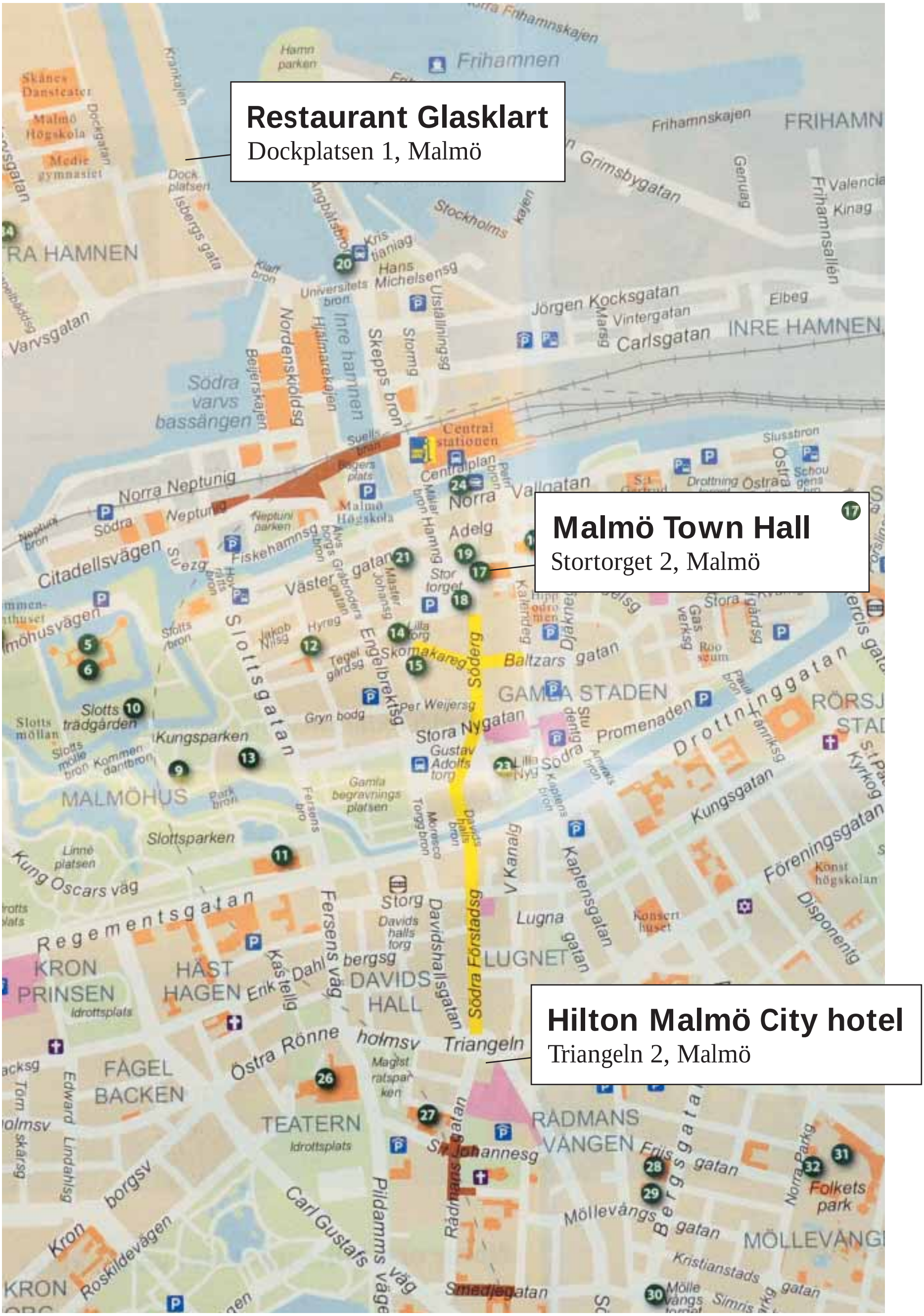
Today the Town Hall is used for official receptions and other special occasions.

Conference Dinner

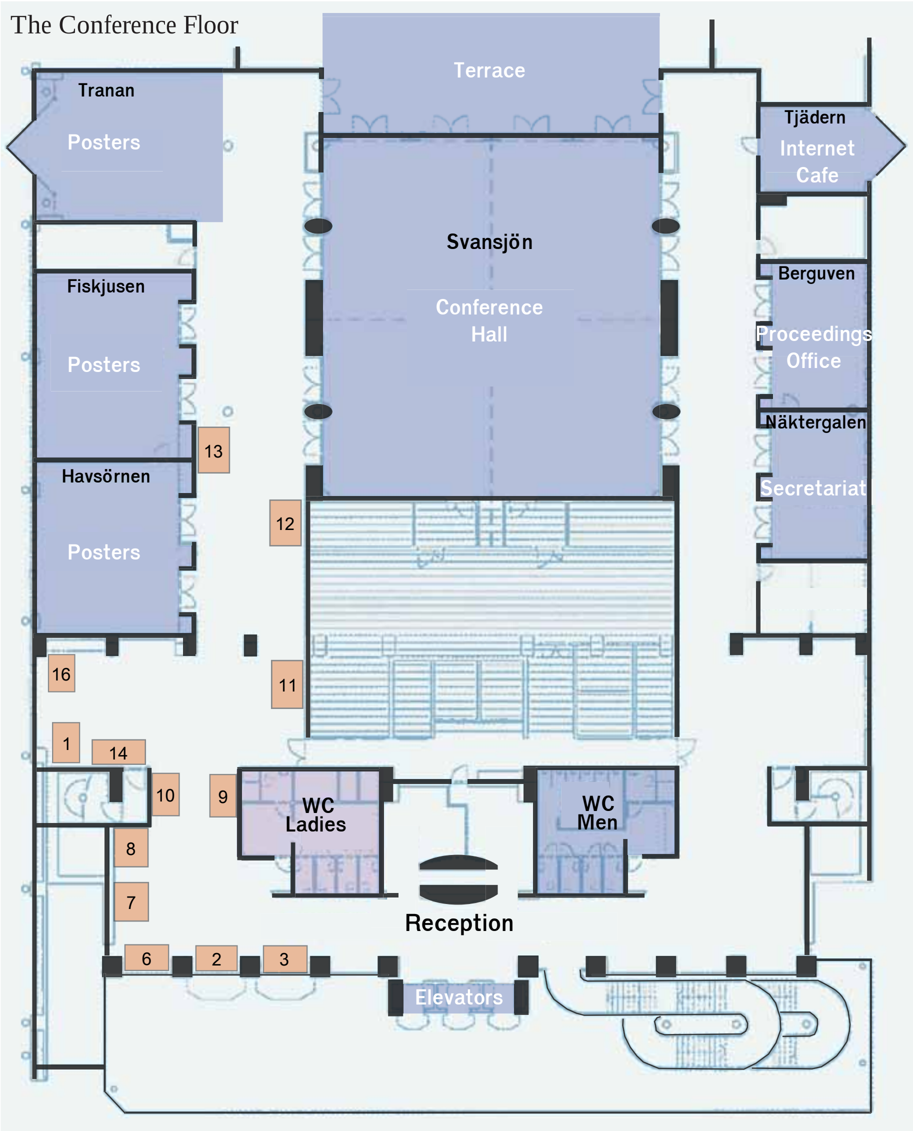
Wednesday 25th: Conference Dinner in the evening at

Restaurant Glasklart

The restaurant is located in the Western Harbour area at the side of the old dock where Supertankers were built into the 1980'ies. The area is now refurbished with new residence areas, Malmö University, fancy boats, a 1800 sqm skateboard park and more.


Restaurant Glasklart
Dockplatsen 1, Malmö
Malmö Town Hall
Stortorget 2, Malmö
Hilton Malmö City hotel
Triangeln 2, Malmö

Industrial Exhibition



List of Exhibitors

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hivolt	7
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RI Research Instruments GmbH	14
Scandinova Systems AB	2
Tech- X corp.	6
Thales Electron Devices	11
Toshiba	12
VG Scienta	9
WME Power Systems GmbH	7

Poster Session Information

Poster Instructions

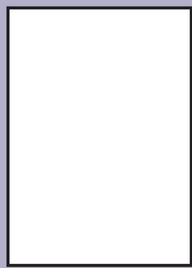
Poster sessions are scheduled for Monday, Tuesday, Wednesday and Thursday afternoons.

An ISO A0 sized poster (840x1188 mm) will fit standing on the board.

Posters must be mounted in the morning prior to the appropriate session and must be removed at the end of the session.

Mounting material will be provided.

ISO A0 sized poster
Width: 840 mm
Height: 1188 mm



Poster Rules

Since no contributions are accepted for publication only, any paper not presented at the conference will be excluded from the proceedings. Furthermore, the Scientific Program Committee reserves the right to reject publication of papers that were not properly presented in the poster sessions.

Manuscripts of contributions to the proceedings (or large printouts of them) are not considered as posters and papers presented in this way will not be accepted for publication.

There will be a designated “poster police” to verify that posters have been displayed during the relevant poster session and posters should be manned for approximately one hour at least, allowing time for delegates to visit other posters.

Papers for posters that are not displayed for the full poster session will not be published in the proceedings.

Conference Proceedings

Paper Submission

Authors will be kept updated on the status of their uploaded papers either by checking the status screen at the Conference or by logging in to their FEL10 SPMS account. Colour codes will be used to indicate the current editor status of papers. Note that, before the paper is completely ready to be published in the Proceedings, the author must have a green indication by an Editor, and an OK by a Referee. If the paper is being presented as a poster, it must also be additionally approved by the 'poster police'.

Editors:

(As on the status screen)

The paper has adhered to the template and format guidance, and is ready to be published in the Proceedings.

Changes have been made to the paper. The author must contact the proceedings office at the Conference so that the modified version can be proof-read.

There is a major problem with the paper, such as one of the source files being corrupt. The author must contact the proceedings office to arrange to see an Editor to correct this.

Referees:

The referee work will be done within the FEL10 SPMS. When your paper has received a green code from the editors it will be passed on to a referee. The referee will feed back her comments via the FEL10 SPMS. Please log on to your account to check the status and respond to referee statements if necessary. Often this means uploading a new version of the manuscript. When the referee has accepted the paper it will be ready for the Proceedings

Lund Visit

Travel Instructions

On August 27 as a part of the conference there will be a scientific excursion to MAX-lab, the Lund Laser Center and to the city of Lund. Lund has a rich culture and history which offers the possibility to an interesting visit to some of its famous sights as for example Lund Cathedral and “Kulturen” a famous open-air museum.

– Buses will leave from the conference venue (Hilton Malmö City) at intervals.
(as we can not accomodate everybody at the same time at MAX-lab).

– There will be a tour of the MAX-lab facilities.

– From MAX-lab you will walk at your own pace and choice to the Lund Laser Center (Department of Atomic Physics), the Museum “Kulturen” and the Cathedral in Lund. Guides will be provided at all places.

– From the Cathedral it is a short stroll to the Lund Station where there are trains to Malmö 3-5 times an hour (travel time 12-15 minutes). Tickets will be provided by the organisers.

MAX-lab

MAX-lab is a national laboratory operated operated jointly by the Swedish Research Council (VR) and Lund University.
The accelerators at MAX-lab consist of three electron storage rings – MAX I, MAX II and MAX III – and one 400 MeV linac (the MAX injector). The storage rings are utilized to produce synchrotron light used for experiments and measurements in a wide range of disciplines and technologies. The MAX I ring is also used as an electrons source for experiments in nuclear physics.

In total a dozen beamlines are in operation. The linac is used for injection into the storage rings but also as the driver for the test FEL facility. The tour will show the laboratory, beamlines, accelerators, the test FEL and its drive lasers. The exact focus of the tour is depending on the actual machine operating schedule.

Lund Laser Centre – LLC

Lund Laser Centre is established at Lund University, Sweden, as an organisation for coordination of research and teaching in lasers, optics and spectroscopy at Lund University. The Lund Laser Centre has the status of a European Major Research Infrastructure. Units from the Technical, Natural Sciences and Medical Faculties participate. The visit to the center will focus on the main laser laboratory, including the high power laser facility, at the Department of Physics.

The Centre is characterised by a very strong exchange of ideas, expertise and resources between different projects, where advanced electro-optics form a common denominator. Members in the Centre are the Research Divisions of Atomic Physics, Atomic Astrophysics, Chemical Physics and Combustion Physics, MAX-lab, as well as the Lund University Medical Laser Centre.

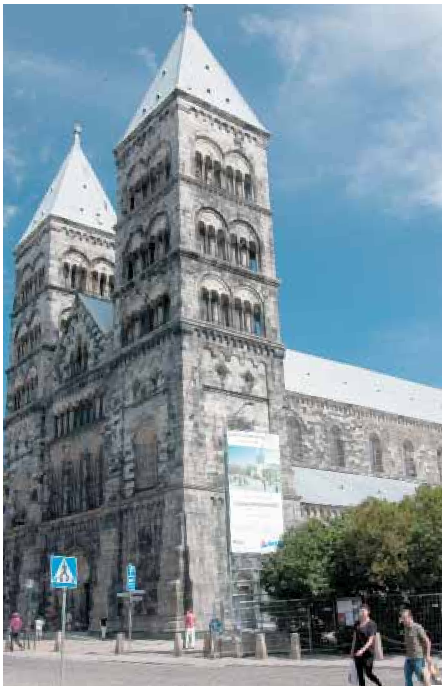
MAX IV Site

The completely new laboratory MAX IV is funded, the design is being finalized, first equipment being ordered and the building contracted. MAX IV will consist of a 3 GeV storage ring with 525 m circumference and a full energy 3 GeV linac injector. The project is financed by: The Swedish Research Council (VR), the Swedish Governmental Agency for Innovation Systems (VINNOVA), Region Skåne and Lund University. The construction site, which will be shared with the planned ESS (European Spallation Source), is just outside of Lund, 1.5 km from the current MAX-lab. The bus from Malmö will pass the site where the construction work will start later during 2010.

The Museum “Kulturen”

Kulturen is the second oldest open-air museum in the world. The museum was founded in 1892 by Georg Karlin.
The main display are the around 30 houses which show Swedish daily life through the history. In addition there are several changing exhibitions of folklore and culture, both regional and in relation to other countries and historical events.

The Cathedral In Lund



The Cathedral of Lund is around 850 years old and the largest Roman style building in the Nordic Countries.
In its first years it was the seat of the Nordic Arch bishop, when Lund still belonged to Denmark. One of the most outstanding pieces in the church is the Astronomical clock: Horologium Mirabile Lundense, which was constructed around 1424. The clock will play on week-days at 12h and 15h

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08:30 | 11:00	**Opening, New Lasing, FEL Lecture** **Chair:** A. Meseck, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, BESSY II (Berlin)

MOOAI1 **FEL Prize Lecture: The Limits of Beam Brightness from Photocathode RF Guns**

D. Dowell (SLAC)

Electron source and gun technology by its nature is a multi-disciplined endeavor requiring knowledge of beam dynamics with RF fields, static fields and space charge forces as well as the chemistry and surface science related to electron emission and ultra-high vacuum. The need for a broad range of disciplines results because the electrons undergo a sequence of processes involving emission, acceleration and optical matching. This talk describes the physical process of each step with the goal of estimating its lowest possible contribution to the total emittance. The physics of electron emission, space charge forces, and the electron optics of the RF and magnetic fields will be developed and the emittance growth assessed for the gun and low energy portion of the injector. The thermal emittance and other properties of metal and semi-conductor cathodes are briefly reviewed, and the affect these properties have upon the limiting emittance and the gun design will be summarized. And finally, the space charge emittance compensation technique and the Ferrario matching criteria for the booster linac are discussed and critiqued for their emittance limits.

MOOAI2 **FEL Prize Lecture: Emittance Growth Mechanisms in Linac-Based Free-Electron Lasers**

P. Emma (SLAC)

Prize lecture by the winner of the FEL prize 2009 for a significant contribution to the advancement of the field of Free-Electron Laser.

MOOAI3 **First Lasing at FLASH with 4.45 nm**

S. Schreiber (DESY)

Recently the free-electron laser facility FLASH at DESY, Germany has been upgraded. An important feature of the update is the increase in electron beam energy from 1 to 1.2 GeV by adding a 7th superconducting accelerating module. Recently, FLASH met the upgrade goal and accelerated the beam just above 1.2 GeV. Shortly after, for the first time, lasing at 4.45 nm with a remarkably improved performance was obtained.

MOOAI4 **SPARC Operation in Seeded and Chirped Mode**

L. Giannessi (ENEA C.R. Frascati)

SPARC is a single pass free electron laser test facility realized in collaboration between the main Italian research institutions and devoted to experiments of light amplification in different beam conditions. We have reached full saturation at 540nm by operating the FEL with a compressed beam obtained with "velocity bunching". The strongly chirped longitudinal phase space resulting from the compression process has been compensated by accordingly tapering the undulator gaps. Spectra with and without taper have been collected and an increase of about a factor 5 of the pulse energy in combination with spectra with a single coherence region have been detected in presence of the taper. The FEL has been operated as an amplifier and as a two stages cascade seeded with the second harmonic of the Ti:Sa driver laser generated in a crystal and with higher order harmonics generated in a gas cell. In seeded mode the cascade has been operated in saturated conditions with the observation of the third harmonic in the radiator at 67nm. High order harmonics up to th 11th at 37 nm have been observed from the seeded amplifier in deeply saturated conditions.

MOOAI5 **MAX-Lab Test FEL**

S. Werin (MAX-lab)

The MAX-lab test FEL at MAX-lab, Lund, Sweden has during 2010 been commissioned and first results in Seeded Coherent Harmonic Generation up to the 6th harmonic (42 nm) in linear polarization and 4th harmonic (66 nm) in circular polarization of the 263 nm Ti:Sapphire seed laser achieved. The test FEL is a collaboration between MAX-lab and the Helmholtz Zentrum Berlin utilizing the 400 MeV linac injector at MAX-lab and an undulator set-up provided by HZB.

MOOAI6 **FEL Prize Lecture: Electron Beam Diagnostics For High Current FEL Drivers**

P. Evtushenko (JLAB)

The application of high current SRF CW accelerators to drive FELs provides dramatic increase in the average photon beam brightness compared to FELs driven by pulsed NC accelerators. At the same time, use of energy recovery allows significant reductions in the required RF power. The JLab IR-Demo and IR-Upgrade demonstrated it in the IR wavelength range. Currently the options to extend this approach to soft X-ray region are under consideration [1]. As high current ERLs give the advantages of running high current and maintaining the linac beam quality they also present the challenges of measuring and understanding the beam dynamics of non-equilibrium beams combined with the requirement to keep average beam losses below the 10^{-7}

level. Operation of the IR-Upgrade provides demonstration of these challenges. In this talk we share our experience with the machine operation and beam measurements and present our outlook at the possible strategies for beam measurements and tuning in such machines. We argue that the solution to this problem might be to have diagnostics and machine models to measure and understand the phase space distribution with dynamic range of 10^6 or larger.

11:00 | 12:00 **Status Reports**
Chair: S. Werin, MAX-lab (Lund)

MOOBI1 **Progress in SDUV-FEL and Development of X-Ray FELs in Shanghai**

Z.T. Zhao (SINAP)

As the solid development steps towards constructing a hard X-Ray FEL in China, the SDUV-FEL was integrated at SINAP to test the FEL key technologies, and the Shanghai Soft X-ray FEL test facility (SXFEL) was proposed and will be constructed to generate 9nm FEL radiation with two-stage cascaded HGHG scheme. Recently a design study on a compact hard X-ray FEL was initiated aiming at constructing this XFEL facility within the SSRF campus. In this paper, the progress in SDUV-FEL, including the recent results of SASE, HGHG and ECHO experiments, is presented and the preliminary design of the SXFEL test facility and the design consideration of a compact X-Ray FEL based on a C-band linac are described.

MOOBI2 **XFEL/SPring-8 Construction and SCSS Operation Status**

T. Shintake (RIKEN/SPring-8)

XFEL/SPring-8 construction was started in 2006, aiming at generating X-ray laser at 1 Angstrom. The building construction was completed in April 2009, followed by installation of accelerator components. In March 2010, we completed all accelerating structure installation. The klystron modulator and LLRF systems are under installation. We use 19 undulator of in-vacuum type (5 m each). At this moment 10 undulators have been installed and careful qualification of undulator field is carried out. We will start high power processing in this October, and we will send the first electron beam into beam dump before April 2011, followed by beam commissioning for X-ray lasing.

MOOB3 **Status of the PSI X-ray Free Electron Laser "SwissFEL"**

T. Garvey (PSI)

The Paul Scherrer Institut is planning to construct a free electron laser covering the wavelength range of 1-70 Å. This project, ``SwissFEL" will use a C-band radio-frequency linac of variable energy, 2.1 GeV to 5.8 GeV. The laser will be equipped with two undulator lines. A short period (15 mm) in-vacuum undulator, `Aramis' will provide hard X-ray radiation in the range 1 Å to 7 Å. A 40 mm period APPLE-type undulator `Athos' will provide wavelengths from 7 Å to 7 nm. The accelerator will employ an S-band RF photogun and an S-band injector providing a low normalized slice emittance (~ 0.3 mm-mrad @ 200 pC) beam of 450 MeV. The initial photo-current of 22 Amperes is increased to 2.7 kA through the use of two magnetic chicane bunch compressors. Acceleration to full energy is provided by twenty-six C-band RF ``modules" each consisting of four, 2 m long, C-band structures. We will describe the status of the project and in particular the design of the accelerator. The beam dynamics simulations which have led us to our base-line design will be discussed and a description of the basic RF module will be given. A schedule for the project realization will also be presented.

MOOB4 **The EuroFEL Consortium of Free Electron Lasers in Europe**

J. Feldhaus (DESY)

In Europe, several national FEL projects are in progress, the seeded FEL FERMI@Elettra at Sincrotrone Trieste is expecting first lasing by the end of 2010, and the capacity of the FLASH facility at DESY in Hamburg will be doubled by adding a second, seeded FEL in the next few years. These national FEL centres in Europe are currently preparing the foundation of a consortium called EuroFEL in order to be more efficient and to better coordinate their activities in research and development, training and other areas. This contribution will present the main ideas of EuroFEL and the current status of its preparatory phase.

August 23

13:30 | 15:00 **Poster: Status reports**

MOPA01 FLASH II Status and Design

B. Faatz, V. Ayvazyan, N. Baboi, W. Decking, S. Düsterer, H.-J. Eckoldt, J. Feldhaus, M. Koerfer, T. Laarmann, A. Leuschner, L. Lilje, T. Limberg, D. Noelle, F. Obier, A. Petrov, K. Rehlich, H. Schlarb, B. Schmidt, M. Schmitz, S. Schreiber, H. Schulte-Schrepping, J. Spengler, M. Staack, F. Tavella, K.I. Tiedtke, M. Tischer, R. Treusch, A. Willner (DESY) J. Bahrdt, R. Follath, M. Gensch, K. Holldack, A. Meseck, R. Mitzner (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Elektronen-Speicherring BESSY II) V. Miltchev, J. Rossbach, J. Rönsch-Schulenburg (Uni HH)

After 5 years of successful operation of FLASH as a user facility, it has become clear that the request for beam time by users exceeds by far the available time. In addition, some experiments would benefit from an improved timing and spectral stability, which is not offered by the SASE operation. Both issues are addressed by FLASH II, which will double the amount of user stations and will deliver seeded radiation. After several years for the conceptual design, the project now enters its technical design stage before construction starts in 2011. We will present the parameter range at which FLASH II is planned to operate simultaneously to the present FLASH operation and what seeding schemes are proposed. Furthermore, the possible switching schemes between the two undulator lines at different wavelengths are presented.

MOPA02 Recent Commissioning Experience on the FERMI@Elettra First Bunch Compressor Area: Investigations of Beam Dynamics, Modeling and Control Software.

S. Di Mitri (ELETTRA)

Some experiences have recently been collected from the FERMI@elettra Free Electron Laser first bunch compressor area. This includes a magnetic compressor, diagnostics for the characterization of the longitudinal and transverse phase space and suitable optics for matching to the downstream part of the linac. We report on the beam dynamics investigations in comparison with the modeling as well as the high level software control that has allowed this experience.

MOPA04 NPS BPL and FEL Facility Update

K.L. Ferguson, C.W. Bennett, W.B. Colson, J.R. Harris, J.W. Lewellen, S.P. Niles, B. Rusnak, R. Swent (NPS) T.I. Smith (Stanford University)

The new experimental facilities for the Naval Postgraduate School Beam Physics Lab are at the 95% completion level for exterior construction, and work has begun on the internal lab spaces. A general timeline for the commencement of first experiments is presented, along with an overview of the experimental path forward. The NPS-BPL is rated for considerably higher average powers (40 kW) than most university accelerator facilities, which presents unique challenges in both the physical and administrative realms. Design considerations, radiation approval processes and other ``lessons learned'' in a non-U.S. Department of Energy government facility are discussed.

MOPA05 **Free Electron Lasers in 2010**

W.B. Colson, Y.H. Bae, J. Blau, K.J. Cohn (NPS)

Thirty-four years after the first operation of the short wavelength free electron laser (FEL) at Stanford University, there continue to be many important experiments, proposed experiments, and user facilities around the world. Properties of FELs in the infrared, visible, UV, and x-ray wavelength regimes are tabulated and discussed.

MOPA06 **Design Studies for a Next Generation Light Source Facility at LBNL**

J.N. Corlett, K.M. Baptiste, J.M. Byrd, P. Denes, R.W. Falcone, D. Filippetto, J. Kirz, D. Li, H.A. Padmore, C. F. Papadopoulos, G.C. Pappas, G. Penn, J. Qiang, M. Reinsch, F. Sannibale, R.W. Schoenlein, J.W. Staples, T. Vecchione, M. Venturini, W. Wan, R.P. Wells, R.B. Wilcox, J.S. Wurtele (LBNL) A.E. Charman, E. Kur (UCB) A. Zholents (ANL)

The Next Generation Light Source (NGLS) is a design concept, under development at LBNL, for a 10 - beamline soft x - ray FEL array powered by a 2.4 GeV superconducting linear accelerator, operating with a 1 MHz bunch repetition rate. The CW superconducting linear accelerator is supplied by a high-brightness, high-repetition-rate photocathode electron gun. Beam is distributed from the linac to the array of independently configurable FEL beamlines with nominal bunch rates up to 100 kHz, with even pulse spacing. Individual FELs may be configured for EEHG, HGHG, SASE, or oscillator mode of operation, and will produce high peak and average brightness x-rays with a flexible pulse format ranging from sub-femtoseconds to hundreds of femtoseconds.

MOPA08 **Status of the ALICE IR-FEL**

J.A. Clarke, D.J. Dunning, S. Leonard, N. Thompson (STFC/DL/ASTeC) M. Surman (STFC/DL/SRD)

An infra-red oscillator FEL was installed into the accelerator test facility, ALICE, at Daresbury Laboratory at the end of 2009. The FEL will be used to study energy recovery performance with a disrupted, large energy spread, beam and also to test novel FEL concepts. This paper will describe the installed hardware, the pre-alignment techniques that have been employed, the diagnostics that are being used to detect the infra-red output, and the progress with commissioning of the FEL itself.

MOPA09 **The Fritz Haber Institute THz FEL Status**

H. Bluem, V. Christina, D. Dowell, J.H. Park, J. Rathke, A.M.M. Todd, L.M. Young (AES) D. Douglas (Douglas Consulting) S. Gewinner, H. Junkes, G. Meijer, W. Schöllkopf, W.Q. Zhang, G. von Helden (FHI) S.C. Gottschalk, R.N. Kelly (STI) K. Jordan (Kevin Jordan PE) U. Lehnert, P. Michel, W. Seidel, R. Wuensch (FZD)

The Fritz Haber Institute of the Max Planck Society in Berlin, Germany will celebrate its Centennial in 2011. Coincident with this event, they will christen a THz Free Electron Laser (FEL) that will operate from 3 to 300 microns. A linac with a gridded thermionic gun is required to operate from 15 to 50 MeV at 200 pC while delivering a transverse rms emittance of 20 mm-mrad in a 1 psec rms, 50 keV rms energy spread bunch at the wigglers. Mid-IR and far-IR wigglers enable this electron beam to deliver the required radiation spectrum. In addition to the longitudinal emittance, a key design requirement is the minimization of the micropulse and macropulse jitter to ensure radiation wavelength stability and timing consistency for pump probe experiments. We present the completed physics and engineering design that delivers the required performance for this device. Shipment is scheduled for the end of the calendar year and the status of fabrication will be summarized.

MOPA10 **The Status of Turkish Accelerator Center, SASE-FEL Project**

H. Duran Yildiz (Dumlupinar University, Faculty of Science and Arts) P. Arikan (Gazi University, Faculty of Arts and Sciences) B. Ketenoglu, O. Yavas (Ankara University, Faculty of Engineering) I. Tapan (UU) I. Yildiz (Metu, Central Laboratory)

The status and projections of Turkish Accelerator Center (TAC), SASE-FEL Project is presented. It is planned that TAC will include a fourth generation light source, SASE-FEL facility. Technical design report is aimed to be completed in 2013. TAC SASE-FEL Collaboration is an inter-university collaboration of six Turkish Universities under the coordination of Ankara University. In this study, optimized beam parameters, SASE-FEL parameters, undulator selections and optimized parameters of undulator are discussed with some results from design and construction studies.

MOPA11 **The Status of TAC SASE FEL Facility Proposal**

P. Arikan (Gazi University, Faculty of Arts and Sciences) H. Duran Yildiz (Dumlupinar University, Faculty of Science and Arts) Ö. Karsli, B. Ketenoglu, M. Tural, O. Yavas (Ankara University, Faculty of Engineering) S. Ozkorucuklu (SDU) O. Sahin, I. Tapan (UU)

A SASE FEL facility was proposed to cover UV to soft X-rays range of the spectrum on the scope of the TAC Project. In addition, TAC SASE FEL facility will give opportunity for Turkish scientists & users to become an expert in atom, molecule and cluster physics, plasma physics, condensed matter physics, chemistry, materials science and life sciences. It was first planned to drive 1 GeV electron linac of TAC Charm Factory for SASE operation on the maintenance months of the collider. But a more promising option, namely ``ERL on Ring Collider'', is arising for Charm Factory proposal of the TAC Project nowadays. Therefore, electron linac required for SASE FEL facility is modified and based on 1 GeV electron ERL. On the other hand, various optimization studies were completed on different types of undulator configurations. For now, hybrid with iron planar undulator choice seems more convenient. Therefore, laser and undulator optimization is based on this option. Finally, electron ERL, undulator and laser optimization results are discussed and parameter sets are given.

13:30 | 15:00 **Poster: FEL Theory**

MOPB01 **Fully Electromagnetic FEL Simulation via Lorentz-Boosted Frame Transformation**

W.M. Fawley, J.-L. Vay (LBNL)

Numerical electromagnetic simulation of some systems containing charged particles with highly relativistic directed motion can by sped up by orders of magnitude by choice of the proper Lorentz-boosted frame*. A particularly good application for boosted frame calculation is short wavelength FEL simulation. In the optimal boost frame (i.e., the ponderomotive rest frame), the red-shifted FEL radiation and blue-shifted undulator

field have identical wavelengths and the number of required time-steps for fully electromagnetic simulation (relative to the laboratory frame) decreases by a factor of gamma squared. We have adapted the WARP code** to apply this method to several FEL problems including coherent spontaneous emission from prebunched e-beams, strong exponential gain in a single pass amplifier configuration, and FEL emission from e^- beams in undulators with multiple harmonic components. We discuss our results and compare with those obtained using the "standard" FEL simulation approach which applies the eikonal and wiggler-period-averaging approximations.

MOPB02 **A 3-Dimensional Theory of Free Electron Lasers**

S.D. Webb, V. Litvinenko, G. Wang (BNL)

In this paper, we present an analytical three-dimensional theory of free electron lasers. Under several assumptions, we arrive at an integral equation similar to earlier work carried out by Ching, Kim and Xie, but using a formulation better suited for the initial value problem of Coherent Electron Cooling. We use this model in later papers to obtain analytical results for gain guiding, as well as to develop a complete model of Coherent Electron Cooling.

MOPB03 **Dispersion Relations for 1D High-Gain FELs**

S.D. Webb, V. Litvinenko (BNL)

We present analytical results for the one-dimensional dispersion relation for high-gain FELs. Using kappa-n distributions, we obtain analytical relations between the dispersion relations for various order kappa distributions. Since an exact solution exists for the kappa-1 (Lorentzian) distribution, this provides some insight into the number of modes on the way to the Gaussian distribution.

MOPB04 **The Physics of FEL in an Infinite Electron Beam**

G. Wang, V. Litvinenko (BNL) S.D. Webb (Stony Brook University)

Under the paraxial approximation, we solve linearized Vlasov-Maxwell equations for an infinite electron beam with kappa-2 energy distributions passing through a helical wiggler. For various initial perturbations, we obtain closed form solutions and the effects of optical guiding, space charge and energy spread are investigated.

MOPB05 **Extremely High Gain FEL Amplifiers**

V. Litvinenko, V. Yakimenko (BNL)

In traditional scheme of a high gain FEL amplifier the maximum value of its gain is limited by presence of initial shot noise in the electron beam. In practice it limits FEL applications in low noise/narrow bandwidth regime -- for example in amplifying weak seeds. We present a concept of an FEL where this noise is suppressed and the FEL gain can be increase by few orders of magnitude. We also discuss possible proof-of-principle experiment at Accelerator Test Facility at BNL.

MOPB06 **Three-Dimensional Simulation of Free-Electron Laser With Helical Wiggler and Ion-Channel Guiding**

F. Jafari Bahman, B. Maraghechi (AUT)

Three-Dimensional simulation of Free-Electron Laser amplifiers at the presence of helical wiggler and ion-channel has been reported. The electromagnetic field is assumed to express in terms of the TE modes of a cylindrical waveguide in the absence of the electron beam. The final form of dynamical equations for the evolution of the slowly varying amplitude and wavenumber of TE mode is obtained by substitution of the vector potentials in to Maxwell's equations. A cold, uniform, axisymmetric electron beam with a flat-top density profile has been considered for modeling the initial injection of the electron beam. The three-dimensional Lorentz force equation in the presence of a realistic helical magnetostatic wiggler, ion-channel electrostatic field and electromagnetic fields describes the electron dynamics. A set of coupled nonlinear first order differential equations is derived and solved numerically by Runge-Kutta method. The 10th-order Gussian quaderature technique is used for calculation of averages in the field equations. Finally, evolution of the radiation power and growth rate of the TE11 mode is shown.

MOPB10 **Fluctuations of Free Electron Oscillator (FEO) Parameters Due to an Electron Beam Spontaneous Noise**

S.G. Oganesyan (RAU) Y. Hovhannisyan (RC) G.S. Oganesyan (LT CSC)

Employing the set of semiclassical equations [1] we have studied the influence of the spontaneous noise upon the phase and frequency of the FEO. The device includes a long undulator, a Fabry-Perot resonator and the space-uniform e-beam. It was adopted that oscillator operates in a steady-state single mode regime. For simplicity the contribution of the thermal noise has been omitted. We have derived equations both for fluctuations of the electron beam density matrix and for fluctuations of the phase and amplitude of laser radiation. It is shown, that the dispersion of frequency is directly proportional to the dispersion of the nondiagonal elements of the fluctuation density matrix. Applying the method of correlation functions and using the second quantization technique we have calculated the spectral densities of the mentioned dispersions. The effect of the phase diffusion has been studied as well. It is shown, that both the absolute value of the frequency fluctuations and the phase diffusion coefficient are directly proportional to the relative energetic spread of the e-beam.

MOPB11 **Theoretical Description of an Electron Beam Spontaneous Noise in an Undulator Free Electron Oscillator (FEO)**

S.G. Oganesyan (RAU) Y. Hovhannisyan (RC) G.S. Oganesyan (LT CSC)

We have considered the problem of theoretical analysis of FEO operation that takes into account the spontaneous noise of the free electrons in the undulator field. In the framework of a semiclassical approach the device operation is described both by an exact density matrix of the second order for the e-beam and a nonlinear equation (of the Van Der Pol type) for the electric field strength. Employing the average density matrix we have studied the oscillator ope absolute value of the ration in a nonlinear steady-state regime [1, 2]. Fluctuations of the density matrix lead to fluctuations of laser parameters due to the spontaneous noise of the electron beam. Using the approach and applying a Klein-Gordon equation we have derived two sets of equations: a) for the average matrix and b) for the fluctuation matrix. In turn the Maxwell equations have been reduced to a Van Der Pol equation that contains a source of spontaneous noise. To clarify the spectral density of the dispersion of the fluctuation matrix we have used a method of correlation functions [3]. It is demonstrated that the density depends only on the undulator field strength.

MOPB12 FEL-IFEL, a Crossed Field Wiggler Scheme for Energy Transfer Between Two Electromagnetic Waves

A. Raghavi (PnUM)

A combination of two planar magnetic wigglers with orthogonal fields and a shared electron beam is proposed for energy transfer between two different electromagnetic waves. It is shown that one of the wigglers can acts as an IFEL accelerator by extracting energy from a seed wave while simultaneously another wiggler works as a FEL and amplifies its corresponding resonant frequency. The equation of motion in the small signal gain (SSG) regime for this FEL-IFEL structure is studied. It is shown that the bunching process occurs for the electron beam in two different scales, corresponding to two different ponderomotive waves. It is concluded finally that, in principle, it is possible to use a FEL-IFEL scheme for energy exchange between two electromagnetic waves and retain an electron beam in resonance with two different electromagnetic waves simultaneously.

MOPB13 Analysis and Optimization of FELs With Irregular Waveguides

V.A. Goryashko (NASU/IRE)

Using a time-dependent approach the analysis and optimization of a planar FEL-amplifier with an axial magnetic field and an irregular waveguide is performed. By applying methods of nonlinear dynamics three-dimensional equations of motion and the excitation equation are partly integrated in an analytical way. As a result, a self-consistent reduced model of the FEL is built in special phase space. The reduced model is the generalization of the Colson-Bonifacio model and takes into account the electrons' intricate dynamics and intramode scattering. The reduced model and concepts of evolutionary computation are used to find optimal waveguide profiles. The numerical simulation of the original non-simplified model is performed to check the effectiveness of found optimal profiles. The FEL parameters are chosen to be close to the parameters of the experiment*, in which a sheet electron beam with the moderate thickness interacts with the TE01 mode of a rectangular waveguide. The results strongly indicate that one can improve the efficiency by a factor of five or six if the FEL operates in the magnetoresonance regime and if the irregular waveguide with the optimized profile is used.

MOPB14 Microbunching Instability and Shot-to-Shot Fluctuation of Single Spike SASE FEL Operation

H.X. Deng, J. Yan, M. Zhang (SINAP)

A self-consistent ``start-to-end'' free electron laser (FEL) simulation approach is proposed*, in which all macroparticles are directly tracked from the surface of the photocathode to the exit of the undulator. It is expected to be helpful for understanding of self amplified spontaneous emission (SASE) start-up, microbunching instability, shot-to-shot fluctuation and noise propagation. Using the well benchmarked codes ASTRA, ELEGANT and GENESIS, the principle was illustrated in the simulation of 1pC low charge, single spike operation of SASE FEL. In this paper, the principles and the numerical results of the simulation are presented.

MOPB15 Interaction of Own Radiation With Particle Itself

Zh.B. Seksembayev (ENU)

In a classical FEL electrons move on serpentine path-trajectory. Suspecting that periodic parameters of undulator are constant we observe radiation and its interaction with electrons from the point of view of classical electrodynamics. There is a situation of interaction between radiation (Cherenkov effect) and particles that radiated given one. It is called self-interaction. It means that electrons sometimes can shake themselves without action from outer. Situation for such process and calculation of probabilities were made. Degrees of generation related on parameters of system are viewed.

MOPB16 Energy Phase Correlation and FEL Efficiency

G. Dattoli, L. Giannessi (ENEA C.R. Frascati) P.L. Ottaviani, S. Pagnutti (ENEA-Bologna) E. Sabia (ENEA Portici)

We analyze the dynamics of Free Electron Laser (FEL) devices, operating with a bunched beam exhibiting a longitudinal phase space correlation. We show that the presence of an energy-position correlation term is responsible for very interesting effects like an enhancement of the peak output power, a shortening of the laser pulses and an increase of the non linearly generated harmonic intensities. We conjecture that the effect is due to a kind of energy tapering effect, associated with the correlation. We discuss the difference of the dynamics with respect to an ordinary undulator tapering and discuss the relative advantages.

MOPB17 Slices and Ellipse Geometry

G. Dattoli, M. Del Franco, A. Petralia (ENEA C.R. Frascati) E. Sabia (ENEA Portici)

We reconsider the problem of slice emittance in FEL SASE device and develop a method accounting for the relevant interplay with the laser power growth. We introduce new criteria for the slice beam transport and matching by introducing the concept of radical emittance, which is complementary to that of projected emittance, and show that the optimization with respect to this new quantity may significantly enhance the FEL SASE performances.

MOPB18 The Dynamics of the Electrons in a Free-Electron Laser Whit a Coaxial Wiggler

R. Ghahremaninezhad (GSI) A.A. Kordbacheh (IPM)

In this research, the dynamics of the electrons, in a free-electron laser whit a coaxial wiggler field and a static guiding magnetic field is analysed. The equations of motion are solved to get the orbital velocity components. And the trajectories of the single-electron when the first, third and fifth spatial harmonic components of the coaxial wiggler field are present and the higher orders are neglected, are determined. The injected electrons into the wiggler at , where radial component of the wiggler field is minimum, with a good approximation remain around their initial radius, and experience the minimum changes in their radius. This wouldn't be happened for the electrons injected at the other. The third and fifth spatial harmonics of the wiggler field give rise to group III and group IV respectively and can be specified by a strong negative mass regime.

MOPB19 One-Dimensional Model of Superradiance of Short Electron Bunch Moving in Undulator Field

N.S. Ginzburg, A. Malkin, A. Sergeev (IAP/RAS)

In the paper we investigate the process of superradiance from short (with typical size of several wavelengths) electron bunch within an averaged one-dimensional model. We consider the radiation process in the co-moving reference frame in which the electrons oscillate in an undulator field. Using the Lagrange approach, an electron bunch can

be represented as a gas of macroparticles with ponderomotive and Coulomb interactions. The ponderomotive force at small in the wavelength scale interparticle distances is attractive, that is, directed oppositely to the Coulomb force. The conditions of formation of SR pulses are defined. The possibility of 2D generalization of the model is discussed. The developed model is used to simulate superradiance from intense picosecond bunches generated by photoinjectors.

MOPB20 **Analysis of the Effects of a Laser Pulse on the Phase Space of a Beam Extracted From a Cathode**

V. Petrillo (Universita' degli Studi di Milano) A. Bacci, A.R. Rossi (Istituto Nazionale di Fisica Nucleare) M. Ferrario (INFN/LNF)

We study both analytically and numerically the effects of a laser pulse on the phase space of an electron beam in the stage of extraction from the cathode.

MOPB21 **One-Dimensional FEL Equations Without SVEA**

V. Petrillo, C. Maroli (Universita' degli Studi di Milano) L. Giannessi (ENEA C.R. Frascati)

We have written and numerically solved a set of 1-d FEL equations for electrons and radiation without the need of the slowly varying envelope approximation (SVEA). The equations, which take into account both forward and backward waves, have been applied to the case of a very short beam, as long as few wavelenghts, and to the case of long beams with short density modulations.

MOPB22 **Circularly-Polarized Harmonic Emission in FELs**

E. Allaria (ELETTRA) G. De Ninno (University of Nova Gorica) G. Geloni (European XFEL GmbH)

Harmonic emission can be used for extending the tuning range of undulators in synchrotron and FEL beamlines. However, in FEL's relying on helical undulators, coherent emission at the harmonics is concentrated out-of-axis, and it has been predicted to be very low compared to the fundamental. Quantitative measurements on the Elettra SR-FEL operated in harmonic generation scheme show a good agreement with theoretical predictions, and suggest that alternatives schemes should be explored to allow an efficient emission of circularly polarized harmonic radiation. In view of the future need for FERMI@Elettra to use the harmonic emission to extend his tuning range toward the 1nm spectral range, we investigated the possibility to generate on-axis harmonic emission with partial circular polarization from an elliptic undulator.

MOPB23 **Three-Dimensional Modes of a Lamellar Grating for Smith-Purcell Experiments**

J.T. Donohue (CENBG) J. Gardelle (CESTA)

Several years ago Andrews and Brau * presented a two-dimensional (2-D) theory for the production of coherent Smith-Purcell radiation by an initially continuous beam. An essential component of their analysis was the dispersion relation for a lamellar grating (i.e., rectangular profile) relating frequency and axial wave number k. Both simulations and an experiment performed at CESTA ** using a wide beam have confirmed the validity of their approach. However, all gratings are three-dimensional objects, and one may ask what modifications of the theory might be necessary. We present here our solution to the problem, which assumes a progressive wave in the direction of the grooves, with wave

number q. A surprisingly simple modification of the Andrews and Brau 2-D dispersion relation is found. We have extensively tested our theory, both with simulations using the 3-D PIC code "MAGIC", and with measurements of the properties of the surface wave on the CESTA grating made using a network analyzer. Extremely good agreement is found, both with and without sidewalls on the grating.

MOPB24 **Relativistic Growth Rate of Free-Electron Laser in a Partially Waveguide**

B. Farokhi, A. Abdykian (Arak University)

A relativistic free-electron laser with a 1D helical wiggler field and axial guide field is presented. The configuration consists of a cylindrical metallic with arbitrary ratio of electron beam radius to waveguide inner radius . A relativistic nonlinear wave equation is derived. Relativistic equation that permits calculation of the dispersion curves for four families of electromagnetic and electrostatics modes are derived. It is shown that the dispersion curves dependent on (the Lorentz factor) which is ignored in previous work. Finally, a relativistic nonlinear wave equation for three-wave interaction is derived and employed to obtain a formula for spatial growth rate of excited oscillations in the wiggler field destroyed the cyclotron resonance which appears in the non-relativistic case. Numerical analysis is conducted to study the growth rate, radiation wavelength and required relativistic factor as function of axial magnetic field . In drawn figures, it is shown that difference between relativistic and non-relativistic cases.

MOPB25 **Fully Relativistic Growth Rate Free-Electron Laser in Completely Filled Waveguide**

B. Farokhi, A. Abdykian (Arak University)

A free-electron laser with a helical wiggler field, cylindrical metallic waveguide, and axial guide field operating in the collective regime infinitesimally above cutoff a transverse magnetic ( ) mode is considered. The waveguide is completely filled with a relativistic electron beam. Parametric decay of the wiggler pump wave in the beam frame, into a space-charge wave and an electron-magnetic ( ) wave guide is analyzed in 3-dimensions. A nonlinear wave equation for 3-wave interaction is derived and employed to obtain a formula for spatial growth rate of excited oscillations in the wiggler field destroyed the cyclotron resonance which appears in the non-relativistic case. Numerical analysis is conducted to study the growth rate, radiation wavelength and required relativistic factor as function of axial magnetic field.

MOPB26 **The Effects of Self-Fields on the Electron Trajectory and Gain in Two-Stream Electromagnetically Pumped Free-Electron Laser With Ion Channel Guiding.**

S. saviz (PPRC)

A theory of two-stream free-electron laser in a combined electromagnetic wiggler (EMW) and ion channel guiding is developed. In the analysis, the effects of self-fields have been taken in account. The electron trajectories and the small signal gain are derived. The characteristics of the linear-gain and the normalized maximum gain are studied numerically. The results show that there are seven groups of orbits in the presence of self-fields similar to seven groups reported in the absence of self-fields. It was also shown that the normalized gains of 2 groups are decreasing and for the rest of them are increasing by growing . Furthermore, it was found that the two-stream instability and the self-field lead to a decrease in maximum gain, in comparison to with out self, except for group 4.

MOPB27 **The Imperfectness of Electron Bunch Initial Longitudinal Phase Space on a Seeded Free Electron Laser Performance**

J. Wu, J.J. Welch (SLAC) R.A. Bosch (UW-Madison/SRC) A.A. Lutman (DEEI)

A single-pass high-gain x-ray free electron laser (FEL) calls for a high quality electron bunch. In particular, for a seeded FEL amplifier and for a harmonic generation FEL, the electron bunch initial energy profile uniformity and peak current uniformity are crucial for generating an FEL with a narrow bandwidth. After the acceleration, compression, and transportation, the electron bunch energy profile entering the undulator can acquire temporal non-uniformity both in energy and local density. We study the effects of the electron bunch initial energy profile non-uniformity and local density variation on the FEL performance. Intrinsically, for a harmonic generation FEL, the harmonic generation starts with an electron bunch having energy modulation as well as density bunching at the previous stage FEL wavelength and its harmonics. Its effect on the harmonic generation FEL in the radiator is then studied.

MOPB28 **Three-Dimensional Analysis of Frequency-Chirped FELs**

Z. Huang, Y.T. Ding, J. Wu (SLAC)

Frequency-chirped FELs are useful to generate a large photon bandwidth or a shorter x-ray pulse duration. In this paper, we present a three-dimensional analysis of a high-gain FEL driven by the energy-chirped electron beam. We show that the FEL eigenmode equation is the same for a frequency-chirped FEL as for an undulator-tapered FEL. We study the transverse effects of such FELs including mode properties and transverse coherence. Comparison with numerical simulations are also discussed.

MOPB29 **Soft X-Ray Superradiation in Crystals with Electron Beams of Relativistic Targets**

H.K. Avetissian, G.F. Mkrtchian (YSU)

As a small-setup X-Ray FEL with electron beams of relatively low energies (10-50 MeV) the channeling radiation and coherent bremsstrahlung in the crystals have earlier been considered in the works*. The realization of these schemes requires either initially modulated electron beams or extremely high current densities, at which the destruction of the crystal may occur. However, at the ultrashort electron pulses, when the propagation time trough the crystal is less than all characteristic times of interaction process reducing to the crystal destruction (electron-phonon energy transfer period, which is about several hundred femtoseconds), one can expect significant superradiation of high density electron beams in these coherent processes. Due to the recent achievements of laser technology with the ultrathin relativistic-targets/plasma-layers providing ultrashort electron beams of solid-state densities**, the considering schemes may appear quite realistic for realization of powerful x-ray sources. In the present work the superradiation of such dense beams at the arbitrary incident angle in a crystal is investigated, which correspond either to channeling or coherent bremsstrahlung.

MOPB30 **An Unaveraged Computational Model of a Variably Polarised Undulator FEL**

L.T. Campbell, B.W.J. McNeil (USTRAT/SUPA)

An unaveraged 3D model of the FEL has been developed which can model variably polarised undulators. The radiation field polarisation is self-consistently driven by the electron dynamics and is completely variable. This paper describes both physical model and computational code.

MOPB31 **Four-Dimensional Simulations of FEL Amplifiers**

J. Blau, K.J. Cohn, W.B. Colson (NPS)

A four-dimensional simulation in (x,y,z,t) has been developed for studying the combined effects of transverse and longitudinal optical modes in Free Electron Laser (FEL) amplifiers. The parallelized program runs on cluster computers, with each node following a slice along the optical pulse. The slower-moving electrons are periodically transferred to successive nodes. The simulation includes betatron motion of the electrons. The electron beam is characterized by current density, pulse length, emittance, and energy spread. The seed laser is characterized by peak amplitude, waist radius and position, and pulse length and shape. The undulator can have focusing in one or both planes, and either a linear or step taper. The optical and electron beams can be tilted or shifted off-axis to study misalignment effects. The simulation has recently been modified to allow input of particles from codes such as Parmela. This allows us to study electron beams with arbitrary phase space distributions and correlations. The program can also output the particles after the FEL interaction, to enable start-to-end simulations of energy recovery linac (ERL) FELs.

MOPB32 **Beam Quality and Transport Stability Simulations in Echo Enabled Harmonic Generation**

J. Henderson, B.W.J. McNeil (USTRAT/SUPA) D.J. Dunning (STFC/DL/ASTeC)

The method of Echo Enabled Harmonic Generation is a possible method of achieving coherent short wavelengths in an FEL amplifier. In this paper the effects of noise variations is some of the important parameters affecting the stability of the final harmonic bunching of the electron beam are investigated numerically.

MOPB33 **The SASE FEL Two-Time Correlation Function**

O.A. Shevchenko, N. Vinokurov (BINP SB RAS)

The new approach for the SASE radiation properties calculation was proposed recently. It is based on the use of BBGKY chain of equations, adapted for FEL. In fact, it is the only known logically correct way to describe the SASE phenomenon. The two-time correlation function is necessary for calculation of averaged SASE spectrum. The solution of the correlation function equation for linear stage of SASE process is obtained.

MOPB34 **Diffraction Superradiation of Electron Beams on Metallic Screen at Arbitrary Geometry**

Kh.V. Sedrakian (YSU)

We present the exact theory of coherent diffraction radiation -- superradiation of a relativistic electron beam passing above an ideally conducting screen for the general geometry, for potential source of coherent intense terahertz radiation. On the base of obtained exact analytical formulas for arbitrary incident angles of a beam over the screen surface (for a single particle spontaneous radiation, see Ref.*), and taking also into account the energetic and angular spreads of the actual beams we have analyzed the influence of the space sizes, angular, and momentum divergences of a particle beam on the spectral-angular distributions of the diffraction superradiation. It is expected that these exact results may be applied to nondestructive beam diagnostics for more precise definition of the beam parameters, in particular, to determine the beam bunch lengths (that on the base of the approximate solution for diffraction radiation in Kirchhoff approximation has been proposed in Ref.**) with a possibly high degree of accuracy, as well as to measure the beams densities and angular divergences via considering exact formulas of diffraction superradiation in terahertz domain of the spectrum.

MOPB36 Analysis of Shot Noise Suppression for Electron Beams

D.F. Ratner (Stanford University) Z. Huang, G.V. Stupakov (SLAC)

Shot noise can affect the performance of free electron lasers (FELs) by driving instabilities (e.g. the microbunching instability) or by competing with seeded density modulations. Recent papers have proposed suppressing shot noise to enhance FEL performance. In this paper we calculate the change in the bunching factor from an energy modulation (e.g. electron interactions from space charge or undulator radiation) followed by a dispersive section. We show that for a broad class of interactions, selecting the correct dispersive strength suppresses shot noise across a wide range of wavelengths. The final noise level depends on the beam's energy spread and the properties of the interaction potential. We also consider the experimental feasibility of suppressing shot noise.

MOPB37 Investigation of the Spherical Raman-Nath Equation (SRNE) With the Presence Ion-Channel Guiding on the Free Electron Laser

M. Alimohamadi, H. Mehdian (TMU)

The spherical Raman-Nath equation played an important role in the quantum description of a helical wiggler free electron lasers. We discussed the exact solution of the Raman- Nath differential equation with ion-channel guiding and helical wiggler. The solution for this differential difference equation is obtained using the Lie algebraic method in the small electron-recoil and weak-coupling limits.

MOPB38 Beam Temperature Effects on the Growth Rate of a Two-Stream Free Electron Laser

N. Mahdizadeh (Islamic Azad University, Sabzevar Branch) F.M. Aghamir (University of Tehran) S. Saviz (PPRC)

The effects of temperature on the growth rate of a two-stream free electron laser (TS-FEL) with planar wiggler magnetic pump have been investigated. The dispersion equation has been derived through the use of continuity, momentum transfer, and Maxwell's equations. In the analysis, only the longitudinal component of the pressure tensor is considered in the electron equation of motion. The characteristics of the dispersion relation along with the growth rate are analyzed numerically. The results show that the growth rate in this system (TSFEL) is relatively higher than the conventional FEL; finally, we compare our results with other cases, like without beam temperature, and conventional FEL.

MOPB39 **Transverse Coherence of the Odd Harmonics of the Radiation From SASE FEL With a Planar Undulator**

E. Schneidmiller, M.V. Yurkov (DESY)

We present a comprehensive analysis of coherence properties of the odd harmonics radiated from a SASE FEL with a planar undulator. The transverse correlation function and the degree of transverse coherence is calculated by means of numerical simulations with the code FAST. Similarity techniques are used to derive general coherence properties of the radiation in the saturation regime.

13:30 | 15:00 **Poster: X-Ray and Short Wavelength FELs**

MOPC01 **Stability and Mode Evolution in an X-Ray Cavity for an X-Ray FEL Oscillator**

G.-T. Park (University of Chicago) K.-J. Kim, R.R. Lindberg (ANL)

We study the performance of the proposed configurations of an x-ray cavity for an x-ray FEL oscillator (XFELO)*,**. The cavity stability and tolerances of the optical elements are determined by the matrix method of particle optics. We also study how the roughness of the grazing incidence, curved mirrors affects the evolution of the x-ray modes.

MOPC02 **Beam Optics and Parameter Design of the XFEL/SPring-8 Accelerator**

T. Hara, H. Tanaka, K. Togawa (RIKEN/SPring-8)

The commissioning of the XFEL/SPring-8 facility is scheduled in the spring of 2011. Since the accelerator of XFEL/SPring-8 uses a thermionic gun with an 1 A initial beam current, the total bunch compression ratio reaches about 3000, which is one order higher than a photocathode system. For nonlinearity compensation in the bunch compression, two correction cavities are installed, which are operated at the same frequency as the linac and not at its higher-harmonic. A large compression ratio, particularly at the velocity bunching, results in larger projected parameters of the electron bunch compared to its slice values. The transverse optics of the accelerator is designed for the projected parameters using newly introduced linear formulation of the beam envelope including acceleration effects. The beam optics of the main linac and undulator sections are based on a FODO-like lattice and additional quadrupole magnets are installed at each chicane for dispersion correction. In this presentation, the XFEL/SPring-8 accelerator layout and its expected beam parameters are shown to achieve the 0.1 nm X-ray FEL.

MOPC03 **Beam Dynamics and Performance of the X-Ray Free-Electron Laser Oscillator with Crystal Cavity**

R.R. Lindberg, K.-J. Kim, Yu. Shvyd'ko (ANL) W.M. Fawley (LBNL)

We discuss the physics of the x-ray free-electron laser (FEL) oscillator taking into account the frequency and angular acceptance of the Bragg crystals and the transverse radiation dynamics/stability in the oscillator cavity. A combination of analytic and simulation methods are used to determine the tolerances and FEL performances. We present simulation results for a two-crystal cavity and realistic FEL parameters that indicate $\sim 10^9$ photons in a nearly Fourier-limited, ps pulse. Compressing the electron beam to 100 A

and 100 fs results in comparable x-ray characteristics for relaxed beam emittance, energy spread, and/or undulator parameters, albeit in a larger radiation bandwidth. Finally, preliminary results indicate that the four-crystal FEL cavity can in principle be tuned in energy over a range of a few percent.

MOPC04 **Options of FLASH Extension for Generation of Circularly Polarized Radiation in the Wavelength Range Down to 1.2 nm**

E. Schneidmiller, M.V. Yurkov (DESY)

With the present undulator (planar, period 2.73 cm, peak field 0.486 T) the minimum wavelength of 4.5 nm at FLASH is determined by the maximum electron beam energy of approximately 1.2 GeV. On the other hand, many perspective user applications require shorter wavelength radiation and circular polarization. In this paper we perform analysis of a helical afterburner for generation of short wavelength, helically polarized radiation. We consider two options, operation of the afterburner at the second (frequency doubler), and the fourth (frequency quadrupler) harmonics. Since even harmonic of the SASE FEL radiation are suppressed, there is no linearly polarized background radiation from the main undulator. Our simulations show that relatively high level of the radiation power can be achieved in the afterburner, about 60 MW in the frequency doubler, and about 5 MW in the frequency quadrupler.

MOPC05 **Expected Properties of the Radiation From the European XFEL Operating at the Energy of 14 GeV**

E. Schneidmiller, M.V. Yurkov (DESY)

This report deals with the analysis of the parameter space of the European XFEL. An impact of two potential changes is analyzed: consequences of the operation with low-emittance beams, and decrease of the driving energy of the accelerator from 17.5 to 14 GeV.

MOPC06 **An Option of Frequency Doubler at the European XFEL for Generation of Circularly Polarized Radiation in the Wavelength Range Down to 1 - 2.5 nm**

E. Schneidmiller, M.V. Yurkov (DESY)

Wavelength range of high scientific interest refers to K- and L- absorption edges of magnetic elements which spans from 2.5 nm to 1.4 nm (500 - 900 eV). This wavelength range can be partially covered by SASE3 at the European XFEL, from 1.6 nm and down when operating at the nominal energy of 17.5 GeV. Operation at the reduced energy would allow to cover complete wavelength range of interest. Currently SASE3 is a planar device producing linearly polarized radiation. On the other hand, it is important to have circular polarization for experiments with magnetic samples. Solution of the problem of polarization is installation of an afterburner generating circularly polarized radiation. This can be helical afterburner or crossed-planar afterburner operating at the fundamental or double frequency. Here we present the results for a helical afterburner operating at the double frequency.

MOPC07 **Betatron Switcher for a Multi-Color Operation of an X-Ray FEL**

R. Brinkmann, E. Schneidmiller, M.V. Yurkov (DESY)

With bright electron beams the full length of gap-tunable X-ray FEL undulators can be efficiently used to generate multiple x-ray beams with different independent wavelengths for simultaneous multi-user operation. We propose a betatron switcher and show that one only needs to install a compact fast kicker in front of an undulator without any modifications of the undulator itself. Different groups of bunches get different angular kicks, and for every group a kick is compensated statically (by corrections coils or moving quadrupoles) in a part of the undulator, tuned to the wavelength designated to the given group. As a generalization of the method of the betatron switcher, we briefly describe a scheme for pump-probe experiments.

MOPC08 Measurement of Sliced-Bunch Parameters at FLASH

C. Behrens, C. Gerth (DESY)

The capability of the free-electron laser (FEL) user facility FLASH at DESY was expanded by several upgrades during the shutdown in 2009/2010. A key extension is the installation of a third-harmonic (3.9 GHz) RF system for the linearization of the longitudinal phase space in front of the bunch compressors. In order to control the bunch compression and make full use of the third-harmonic RF system, a new diagnostic section for the measurements of sliced bunch parameters directly in front of the undulators was designed and commissioned. In this paper, we describe the beam imaging systems and their optical performance. The achievable resolution of both time and energy is shown and compared to the design values. First measurements of the linearized longitudinal phase space with high resolution are presented.

MOPC09 Upgrade of the FEL User Facility Flash

S. Schreiber, B. Faatz, J. Feldhaus, K. Honkavaara, R. Treusch (DESY) J. Rossbach (Uni HH)

The free-electron laser facility FLASH at DESY, Germany finished its very successful 2nd user period late summer 2009. Recently FLASH has been upgraded, and is now in the commissioning phase. The 3rd user period is scheduled to start late summer 2010. In many aspects the upgraded FLASH is an FEL with a new quality of performance. It can provide thousands of FEL pulses per second with wavelengths approaching the carbon 1s absorption edge and the water window. The extension of the photon wavelength range is realized by increasing the electron beam energy up to 1.2 GeV by adding a 7th superconducting accelerating module. The dynamics behavior of the electron beam is improved by installing 3rd harmonic superconducting RF cavities. In addition, an experiment for seeded FEL radiation, sFLASH, is integrated to the FLASH linac. This report summarizes the ongoing commissioning and the expected performance as a free electron laser user facility.

MOPC10 Ytterbium Fibre Laser Based Electro-Optic Measurements of the Longitudinal Charge Distribution of Electron Bunches at FLASH

L.-G. Wissmann, J. Breunlin (Uni HH) B. Schmidt, B. Steffen (DESY)

The Free Electron Laser FLASH has been upgraded during winter 2009/10. Amongst other components, a third harmonic module operating at 3.9 GHz (ACC39) has been installed. Together with the energy chirp induced by off-crest operation, it allows for a linearisation of the longitudinal phase space, leading to a uniform compression of the electron bunch with final bunch lengths of 150 μm rms. In contrast to the old non-linear compression scheme, peak current and bunch length are extremely sensitive to the phases of ACC39 and ACC1 and have to be monitored continuously. The foreseen bunch length is within the resolution of electro-optic spectral decoding methods. An ytterbium fibre laser system in combination with a 175 μm thick GaP crystal is used to achieve a good match between the electric field phase velocity and the laser pulse group velocity in the electro-optic crystal. This ensures a large modulation of the polarisation of the chirped laser pulse in the EO crystal. The information on the electron bunch length carried by the laser pulse is decoded in a spectrometer and read out with an InGaAs line scan camera.

MOPC11 **Commissioning of an Electro-Optic Electron Bunch Length Monitor at FLASH**

J. Breunlin, L.-G. Wissmann (Uni HH) B. Schmidt, B. Steffen (DESY)

The free electron laser in Hamburg (FLASH) underwent major modifications during a 6 months shutdown like the installation of a 3rd harmonic module, a seeding experiment (sFLASH) and a 7th accelerating module. Also instrumentation has been improved. A new compact electro-optic (EO) bunch length monitor has been installed downstream the first bunch compressor. At this position, the bunches are expected to have a length of about 1 ps, well suited for the resolution of an EO bunch length monitor with spectral decoding of the time (EO-SD). The setup uses a commercial ytterbium fiber laser, a compact optics inside the beam pipe designed at PSI (Switzerland) and a spectrometer with fast InGaAs line scan camera. These components, together with RF synchronisation unit and readout electronics, will be installed in the accelerator tunnel. Reliability, robustness and high uptime are key features as the EO monitor is meant to serve as permanent beam diagnostics. Here we report on the commissioning of the components and first experiments with the complete system.

MOPC12 **XFEL Photon Diagnostics -- Overview of Cornerstone Methods**

J. Grünert (European XFEL GmbH)

We present considerations for photon diagnostics devices for the European XFEL in view of the FEL beam parameters. The presentation is based on the discussions at a workshop(*) dedicated to x-ray photon diagnostics in Ryn/Poland in February 2010. The methods are grouped under the three main photon beam characteristics - spectral, temporal and spatial properties, where the latter contains also wavefront and coherence properties.

MOPC13 **Considerations on Fermilab's Superconducting Test Linac for an EUV-Soft X-ray SASE FEL**

A.H. Lumpkin, M.D. Church, H.T. Edwards, S. Nagaitsev, M. Wendt (Fermilab)

A superconducting (SC) RF Test Accelerator at the New Muon Lab (NML) is currently under construction at Fermilab. Its design goals include the replication of the pulse train proscribed for the International Linear Collider (ILC) and operations with the prototypic beam of the base RF unit. At 3 nC per micropulse and with 3000 micropulses per macropulse at a 5-Hz rate and at 750 MeV, a 40-kW beam would be generated. An RF photoelectric gun based on the PITZ-Zeuthen design will generate the beam which has a lower emittance of about 1-2 pi mm mrad when run at 1 nC or less per micropulse based on tests at Zeuthen. This beam quality is sufficient, when properly bunch compressed, to provide the driving beam for an extreme ultraviolet (EUV) and soft x-ray (SXR) self-amplified spontaneous emission (SASE) free-electron laser (FEL) or seeded FEL. Estimates for the gain length and output power have been calculated for wavelengths from 80 to 12 nm (at 1.5 GeV) using the simple scaling formula of M. Xie. This wavelength regime with 200-fs bunch lengths would complement the hard x-ray SASE FEL project at SLAC in the USA.

MOPC14 LCIS X-Ray Pulse Duration Measurement Using the Statistical Fluctuation Method

J. Wu, P. Emma, Z. Huang (SLAC) E. Schneidmiller, M.V. Yurkov (DESY)

For a SASE-FEL, the FEL pulse energy fluctuates from shot to shot, because the lasing process starts up from shot noise. When operating in the exponential growth regime, the radiation exhibits the properties of completely chaotic polarized light. Hence, the probability distribution of the FEL pulse energy follows a gamma distribution. Based on the measurement of such a distribution function, one can calculate the average number of `degrees of freedom' or `modes' in the radiation pulse. Thus, one can measure the FEL pulse temporal duration. In this paper, we report experimental results at LCLS. Measurements are conducted for both nominal charge (250 pC) and low charge (20 pC) cases. For both cases, results are obtained for different undulator lengths and various electron peak current settings.

MOPC16 Transverse-Coherence Properties of the FEL at the LCLS

Y.T. Ding, Z. Huang (SLAC) S.A. Ocko (MIT)

The Linac Coherent Light Source has achieved stable operation at x-ray wavelengths of 20-1.2 Angstrom with peak brightness many orders of magnitude beyond conventional synchrotron sources. Understanding transverse coherence properties of such a SASE source is of great practical importance for user experiments. Based on a fast Monte Carlo algorithm, we present numerical analysis of the LCLS coherence properties for the simulated radiation fields at different wavelengths and bunch charges.

MOPC17 Beam Parameters and Tolerances for a Low-Charge Option in a PAL-XFEL

E.-S. Kim (KNU) I. Hwang (PAL) J.G. Hwang (Kyungpook National University) M. Yoon (POSTECH)

We investigated beam dynamics in a 10-GeV linear accelerator for SASE (Self-Amplified Spontaneous Emission) Free-Electron Laser (FEL) at PAL. The linac is designed to provide the optimal beams to generate radiation of the wavelength of 1-Å in the undulator. An optimum choice of beam parameters with low-charge option is performed to reduce the correlated energy spread after final beam compression and to make accelerator system insensitive to rf jitters. The bunch compressors are designed such that the effects of nonlinearities due to wakefields, rf curvature and second order momentum compaction become as small as possible in the linear accelerator. The tracking simulations in the linear accelerator include longitudinal and transverse wakefields, and the effects of errors such as rf gun timing, rf phase and rf voltage. In result, through these design studies, we could get beam parameters and accelerator parameters to be able to provide the radiation power of 10 GW. Results on the microbunching instability are also shown.

MOPC19 X-Ray Free Electron Laser Project of Pohang Accelerator Laboratory

H.-S. Kang, S.H. Nam (PAL)

Pohang Accelerator Laboratory (PAL) is proposing an X-ray free-electron laser facility that is designed to generate 0.1-nm wavelength coherent X-ray by using self-amplified spontaneous emission mechanism. A 10-GeV electron linear accelerator is required to generate high brightness electron beam with 0.2 nC charge, normalized emittance of 0.5 um-rad, and peak current of over 2.66 kA in order to reduce the required length of undulator for saturation below 60 meters. The radiation that is coherent and a few tens of femto-second long will cover the hard X-ray (0.1 ~ 1 nm) and the soft X-ray in the ranges of 2~ 5 nm. Advanced X-ray free-electron laser concepts are also being considered in the design: the self-seeded operation for narrow band spectrum as well as the attosecond X-ray pulse generation using the energy modulation of electron beam by optical laser beam. The baseline design of femtosecond X-ray generation for PAL-XFEL as well as challenges toward attosecond X-ray pulse generation will be presented.

MOPC20 Coherence Properties of SwissFEL

S. Reiche (PSI)

The proposed SwissFEL project is an X-ray Free-Electron Laser, which operates down to a wavelength of 1 Ångstrom. In comparison to other XFELs (LCLS, SCSS and European XFEL) SwissFEL has the lowest beam energy of 5.8 GeV. Therefore a short period in vacuum undulator (15 mm) and a low beam emittance is required for maximum overlap between the electron beam and the fundamental FEL mode and a sufficient degree of transverse coherence at the saturation point. We present the numerical analysis of the radiation field properties along the undulator with an emphasis on the degree of coherence at saturation and undulator exit.

MOPC21 A Two-Beam Soft X-Ray FEL

W.K. Lau, A.P. Lee (NSRRC) N.Y. Huang (NTHU)

We proposed to use a 30 GHz microwave undulator to produce coherent soft X-ray by collective backscattering of the microwave off from a 350 MeV high brightness beam. However, high power microwave of few hundered MW is required to setup undulating field that is strong enough for our purpose. The possibility of using a wake-field microwave source which is driven by another GHz-repetition-rate ultrashort relativistic beam as the power source for the 30 GHz undulator is being investigated.

MOPC22 ZFEL: A Compact, Soft X-ray FEL in the Netherlands

J.P.M. Beijers, S. Brandenburg, K. Eikema, R. Hoekstra, K. Jungmann, T. Schlathoelter (KVI) B. Noheda, P. Rudolf, P.H.M. van Loosdrecht (RUG)

We outline our plans to construct a soft X-ray FEL facility at KVI, University of Groningen, The Netherlands. This new facility will be based on a 2.6 GeV normal-conducting electron linac followed by an undulator and will produce X-ray laser light with wavelengths downto 0.5 nm. The electron linac will be driven by a RF photo-injector and X-band acceleration structures based on CLIC developments with an acceleration gradient of 100 MeV/m. Various techniques will be implemented to also establish longitudinal coherence. The entire length of the FEL will be on the order of 100 meters. The facility is meant as a international user facility with a strong contribution of local AMO, material science and biochemistry groups. The design and construction will be a collaborative effort with contributions from different (inter)national research groups.

August 23

15:30 | 17:00	**FEL Theory** **Chair:** W.M. Fawley, LBNL (Berkeley, California)

MOOCI1 **FEL Simulations: History, Status and Outlook**

S. Reiche (PSI)

The coupled system of radiation interacting with a co-propagating electron beam within an undulator of an FEL exhibits many degrees of freedom. Only in an idealized and simplified model can the FEL equations be solved analytically and a more complete description requires numerical methods. Therefore numerical codes have been developed along with the advances in FEL theory, starting from a simple 1 D model to today's fully time-dependent 3D simulations, utilizing large scale parallel computers. This presentation gives a brief history of FEL simulation and addresses the remaining challenges in FEL modeling which we hope to solve in the near future.

MOOCI2 **Coherence Properties of the Radiation From X-Ray FELs**

E. Schneidmiller, M.V. Yurkov (DESY)

Start-up of the amplification process in x-ray FELs from the shot noise in the electron beam defines a specific behavior of longitudinal and transverse coherence properties of the radiation. Particularly important is the case of an x-ray FEL optimized for maximum gain of the fundamental radiation mode. Applying similarity techniques to the results of numerical simulations allowed us to find universal scaling relations for the main characteristics of an optimized X-ray FEL operating in the saturation regime: efficiency, coherence time and degree of transverse coherence. We find that with an appropriate normalization of these quantities, they are functions of only the ratio of the geometrical emittance of the electron beam to the radiation wavelength. Statistical and coherence properties of the higher harmonics of the radiation are highlighted as well.

MOOC3 **Spontaneous Emission Sub-Radiance and Coherence Limits of FEL**

A. Gover (University of Tel-Aviv, Faculty of Engineering)

The cooperative spontaneous emission from a bunch of particulate dipole radiators (e.g. excited atoms) can be enhanced (super-radiance) or suppressed (sub-radiance) by proper phasing of the radiators[1] Analysis and 3-D simulation of collective interaction microdynamics in a drifting e-beam, reveal a process of homogenization of the particles distribution and suppression of the beam current shot-noise[2]. Consequently, such a beam would exhibit Dicke's kind of spontaneous emission sub-radiance when injected into a FEL. With present state of the art technology, suppression and control of FEL SASE power can be attained at optical frequencies up to the UV. A theory will be presented on the implications of this beam noise control on the attainable coherence level of seed injected FELs. It is shown that when the beam current shot-noise is suppressed, the coherence of the FEL is limited by the beam energy spread. The fundamental theoretical limit of FEL coherence, analogously to conventional lasers[3], is found to be, the quantum noise limit. This would be attainable only if the beam energy spread can be reduced below the level of the photon emission energy.

MOOC4 **The Effect of Undulator Harmonics Field on Free-Electron Laser Harmonic Generation**

Q.K. Jia (USTC/NSRL)

The harmonics field effect of planar undulator on Free-Electron Laser (FEL) harmonic generation has been analyzed. For both the linear and the nonlinear harmonic generation, the harmonic generation fraction can be charactered by the coupling coefficients. The modification of coupling coefficients is given when third harmonics field component exist, thus the enhancement of the harmonic radiation can be predicted. With the third harmonics magnet field being 30 percent of the fundament, for both the small signal gain and the nonlinear harmonic generation in high gain, the intensity of third-harmonic radiation can maximally be doubled.

17:15 | 18:15 **Tutorial**

Chair: A. Meseck, BESSY GmbH (Berlin)

MOTUI1 **How an FEL Works**

B.W.J. McNeil (USTRAT/SUPA)

This tutorial will give an introduction to the physics of how FELs work and will be targeted at a 1st/2nd year post-graduate level audience. I will try to give the audience a conceptual understanding of the basic electron-field interactions that allow the electrons to bunch and emit coherently. Some of the physics that tends to inhibit the FEL interaction will also be described.

08:30 | 10:00 **Storage Rings and ERL FELs**
Chair: S.V. Benson, JLAB (Newport News, Virginia)

TUOAI1 **Radiation from laser-modulated and laser-sliced electron bunches in UVSOR-II**

M. Katoh (UVSOR)

Coherent synchrotron radiation (CSR) has been intensively investigated because of its potential ultrahigh power in the terahertz (THz) region. CSR is emitted not only from short electron bunches but also from bunches with longitudinal microstructure of radiation wavelength scale. Laser slicing is a technique for creating sub-mm dip structure on electron bunches circulating in a storage ring. Such a bunch emits broadband CSR of sub-ps duration. More generally, in principle, one can produce arbitrary density structures by the laser electron interaction. As a useful example, periodic density structures can be produced by using amplitude-modulated laser pulses. The period of the structure can be varied by changing the period of the amplitude modulation. The first successful demonstration was conducted at UVSOR-II. The electron bunch with the periodic density modulation emitted monochromatic and tunable THz-CSR in a bending magnet. In this talk, some latest results from the THz CSR experiments with laser modulation technique at UVSOR-II will be presented, including the direct measurement of the CSR electric field and beam dynamics of the micro-density structures on electron bunches.

TUOAI2 **The Elettra Storage-Ring Free-Electron Laser: a Source for FEL Studies and User Experiments**

G. De Ninno, E. Allaria, M.B. Danailov, E. Karantzoulis, C. Spezzani, M. Trovo (ELETTRA) M. Coreno (CNR - IMIP) G. De Ninno (University of Nova Gorica) E. Ferrari (Università degli Studi di Trieste) G. Geloni (European XFEL GmbH)

The paper will report about the last achievements of the Elettra storage-ring FEL. The latter include: a) a noticeable improvement of the source performance (generation of coherent radiation at 87 nm, attainment of a very good shot-to-shot stability); b) general FEL studies, relevant to single-pass devices (characterization of the angular distribution of harmonic emission, analysis of the frequency pulling effect), and c) first user experiments (pump-probe on gas phase and solid-state samples).

TUOA3 **Feasibility Study of Short-Wavelength and High-Gain EFLs in an Ultimate Storage Ring**

K. Tsumaki (JASRI/SPring-8)

In recent years ultimate storage ring has been studied aiming at ultra-small emittances and ultra-bright synchrotron radiation. Z. Hung et al.* studied an FEL in the EUV and soft x-ray regions in one of such rings as PEPX 4.5 GeV storage ring and showed that the three orders of magnitude improvement in the average brightness is possible at these radiation wavelengths. We studied an ultimate storage ring that has 0.034 nm-rad natural emittance and 5.4 MeV energy spread at 6 GeV**. The normalized emittance is 0.2 μm-rad with full coupling and the relative energy spread is 0.089 %. As smaller beam emittances and higher beam energy have possibilities of shorter wavelength FELs, we studied the feasibility of high-gain FELs in the range of x-ray regions as well as soft x-ray regions. In this paper we present the results of analysis and simulation of high-gain FEL in the ultimate storage ring.

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TUOA4 **Use Of Multipass Recirculation And Energy Recovery In CW SRF X-FEL Driver Accelerators**

D. Douglas, W. Akers, S.V. Benson, G.H. Biallas, K. Blackburn, J.R. Boyce, D.B. Bullard, J.L. Coleman, C. Dickover, F.K. Ellingsworth, P. Evtushenko, S. Fisk, C.W. Gould, J.G. Gubeli, F.E. Hannon, C. Hernandez-Garcia, K. Jordan, J.M. Klopf, R. Li, M. Marchlik, S.W. Moore, G. Neil, T. Powers, D.W. Sexton, I. Shin, M.D. Shinn, C. Tennant, R.L. Walker, G.P. Williams, F.G. Wilson, S. Zhang (JLAB) B. Terzic (Thomas Jefferson National Accelerator Facility (JLAB))

We discuss the use of multipass recirculation and energy recovery in CW SRF drivers for short wavelength FELs. Benefits include cost management (reduced system footprint, RF and SRF hardware, and associated infrastructure such as cryogenic systems), ease in radiation control (low exhaust drive beam energy), ability to accelerate and deliver multiple beams of differing energy to multiple FELs, and opportunity for seamless integration of multistage bunch length compression into the longitudinal matching scenario. Issues include those associated with ERLs, compounded by the challenge of generating and preserving the CW electron beam brightness required by short wavelength FELs. We thus consider the impact of space charge, BBU and other environmental wakes and impedances, ISR and CSR, potential for microbunching, intra-beam and beam-residual gas scattering, ion effects, RF transients, and halo, as well as the effect of traditional design, fabrication, installation and operational errors (lattice aberations, alignment, powering, field quality). Context for the discussion is provided by JLAMP, the proposed VUV/X-ray upgrade to the existing Jefferson Lab FEL.

10:30 | 12:30 **X-Ray and Short Wavelength FELs**
Chair: Z. Huang, SLAC (Menlo Park, California)

TUOBI1 **LCLS-II: An Upgrade for the Linac Coherent Light Source**

J. Wu (SLAC)

The success of LCLS [1] generates strong motivation and solid technical basis to extend its capabilities. The upgrade will extend x-rays wavelength range down to 0.06 nm. A new soft x - ray adjustable - gap undulator line will produce FEL with wavelengths up to 6 nm. To allow full electron beam rate and independent electron beam parameters in each line, a new injector and pair of bunch compressors will be added to the second kilometer of SLAC linac. The electron from this linac part will bypass the LCLS accelerator into the soft x - ray undulators which can provide two FEL pulses with variable delay and photon energy and may be configured for narrow bandwidth pulse via self - seeding. External seeding with the echo - enabled harmonic generation can improve temporal coherence. The new bypass line can add multiple electron bunches within each RF pulse. LCLS - II will provide polarization control and can incorporate the low - charge, few - femtosecond pulse duration operating mode. A THz radiation source will be included to provide x - ray/THz pump - probe capabilities. The schemes and parameters are based on measurements and experience at LCLS.

TUOBI2 **FLASH Upgrade and First Results**

S. Schreiber (DESY)

The free-electron laser facility FLASH at DESY, Germany finished its very successful 2nd user period late summer 2009. Recently FLASH has been upgraded. The 3rd user

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period is scheduled to start late summer 2010. In many aspects the upgraded FLASH is an FEL with a new quality of performance. It can provide thousands of FEL pulses per second with wavelengths approaching the carbon 1s absorption edge and the water window. The extension of the photon wavelength range is realized by increasing the electron beam energy up to 1.2 GeV by adding a 7th superconducting accelerating module. The dynamics behavior of the electron beam is improved by installing 3rd harmonic superconducting RF cavities. In addition, an experiment for seeded FEL radiation, sFLASH, is integrated to the FLASH linac. Recently, FLASH achieved a beam energy above 1.2 GeV and lasing below 5 nm with a remarkably improved performance.

TUOB3 **A Comparison Study of High Harmonic Characterizations in EEHG Operation of SDUV-FEL**

H.X. Deng, J.H. Chen, C. Feng, D.G. Li, D. Wang (SINAP)

The echo-enabled harmonic generation (EEHG) scheme has remarkable efficiency for generating high harmonic microbunching with a relatively small energy modulation. A proof of principle experiment of EEHG scheme is under commissioning at Shanghai deep ultraviolet (SDUV) free electron laser (FEL) facility, where the third harmonic of the 1047nm seed laser is expected to be amplified in the 9m long radiator. Recently, to explore the advantage of EEHG scheme, higher order harmonics are under consideration seriously in SDUV-FEL. In this paper, several methods for measuring 9~15th order harmonic microbunching are comparatively analyzed. Study shows that, in comparison with the coherent transition radiation (CTR) and coherent synchrotron radiation (CSR) based diagnostics, the coherent harmonic radiation (CHR) of the radiator undulator would be a more feasible way to characterize the high order harmonic microbunching in EEHG operation of SDUV-FEL.

TUOB4 **Second and Third Harmonic Measurements at the Linac Coherent Light Source**

D.F. Ratner, F.-J. Decker, Y.T. Ding, P. Emma, J.C. Frisch, Z. Huang, R.H. Iverson, H. Loos, M. Messerschmidt, H.-D. Nuhn, T.J. Smith, J.L. Turner, J.J. Welch, J. Wu (SLAC) R.M. Bionta (LLNL)

The Linac Coherent Light Source (LCLS) is a Free Electron Laser (FEL) operating with a fundamental wavelength ranging from 1.5-0.15 nm. Characterization of the higher harmonics present in the beam is important to users, for whom harder X-rays can either extend the useful operating wavelength range or represent a background to measurements. We present here measurements of the power in both the second and third harmonics.

13:30 | 15:00 **Poster: Storage ring & ERL / FEL oscillator & Long Wavelength**

TUPA02 **A Laser-Activated Plasma Switch for Extraction of Single FELBE Radiation Pulses**

W. Seidel, S. Winnerl (FZD)

In order to decrease the average radiation power of the Rossendorf free-electron laser FELBE, as required for certain experiments (high pulse energies but moderate or low average power), the FEL repetition rate can be reduced from 13 MHz to 1 kHz. To this end, plasma switching of FEL radiation pulses was demonstrated for cw operation.

The plasma switch is based on the principle of photo-induced reflectivity by an optically excited electron-hole plasma. Germanium or silicon serves as semiconductor material for the switch. The semiconductor was illuminated by a Nd:YAG laser amplifier system (1 kHz, wavelength 1064 nm, pulse duration16 ps, 1Watt), generating an electron-hole plasma on the front surface of the semiconductor. To integrate this plasma-switch into the existing experimental set-up we build an additional by-pass to the Germanium or Silicon slab which is under Brewster's angle. To get a high contrast in the switched beam we adjust the polarization plane of the incoming beam to the right direction by using an additional polarization rotator. We will report on first results at different wavelength. Submitted as a poster to the FEL 2010 conference.

TUPA03 A Tapered-Undulator Experiment at the ELBE FIR Oscillator FEL

V. Asgekar (University of Pune) U. Lehnert, P. Michel (FZD)

A tapered undulator experiment was carried out at the Forschungszentrum Dresden-Rossendorf (ELBE) far-infrared FEL. The main motivation was to see whether the presence of a dispersive medium due to the partially waveguided resonator has any effect on the outcome. The FEL saturated power and the wavelength shifts have been measured as a function of both positive as well as negative undulator field amplitude tapering. In contrast to the typical high-gain FELs where positive tapering (i.e. a decrease of undulator field amplitude over the beam path) proves beneficial for the output power we observe an improvement of performance at negative taper. During the same experiments we studied the characteristics of the detuning curves. The width of the curves indicates a maximum small-signal gain for zero taper while the output peak power is highest for negative taper. Whereas the saturated power output and the detuning curve characteristics agree with the known theoretical predictions, the wavelength shifts showed deviations from the expected values. Details of the experiment are presented.

TUPA04 Control of Instability Induced by a Detuning in FEL Oscillator

C. Evain, M.-E. Couprie (SOLEIL) S. Bielawski, C. Szwaj (PhLAM/CERCLA) M. Hosaka (Nagoya University) M. Katoh (UVSOR) A. Mochihashi (JASRI/SPring-8)

In FEL oscillator, a desynchronisation between the electron-bunch passage frequency and the repetition rate of the laser can lead to instability, characterised by erratic longitudinal shape of the emitted light pulses. We show that this instability can be controlled using a simple feedback system which consist in re-injecting in the cavity a part of the emitted light. Analytical, numerical and experimental studies on the UVSOR-II storage ring have been performed, and show that the energy needed to achieved the control can be extremely weak, in practical higher than the noise level[1]. We also show that another important parameter is the phase of the re-injected signal with respect to the light in the cavity. Depending of the value of this phase, we can observe a shift of the emitted light wavelength, which can go with a modulation of the laser pulse envelop. Both of this two phenomenas are quantitatively analysed.

TUPA05 Mode-Stability in FEL Oscillators

S. Krishnagopal, S.A. Samant (BARC)

Mode stability can restrict the tuning range of FEL oscillators. We investigate the stability of FEL oscillators as a function of wavelength as well as size of the coupling hole. We show that concentric configurations are preferred to confocal ones. We study

mode-stability using multi-particle simulations, for both, symmetric as well as asymmetric modes.

TUPA06 A High Power CW mm-THz Wave Source Based on Electrostatic Accelerator FEL

F. Wang, J. Wu (SLAC) Q.K. Jia, A.L. Wu (USTC/NSRL)

Lots of applications with mm wave need very high power (from tens of kW to MW), such as surface processing of metals and ceramics, heating magnetically confined plasma in thermonuclear fusion reactors, isotope separation and so on. Recently developed gyrotrons can provide up to 1 MW CW mm-wave source, however there are a number of limitations, needs of supper conducting magnet, cathode lifetime degradation because of very high current, almost approaching the upper limit of their power and frequency capabilities, and so on. It is thought that the electrostatic accelerator FEL (EA-FEL) will be a promising high power IR-mm source, because of its high average power generation, high-energy conversion efficiency and high spectral purity. The property of an EA as a high quality e-beam source for a FEL is crucial for attaining high brightness spontaneous emission radiation. The unique features of EA-FELs make them naturally fitting for a variety of applications in the present and in the near future. And few high power mm-IR EA FEL facilities have been successfully built around world. Here an EA of 3 MeV with beam current of 2 A is studied for a high average power (kWs) mm-THz source

TUPA07 Dependence of Gain on Current in the Coherent Smith-Purcell Experiment at Cesta

J.T. Donohue (CENBG) J. Gardelle, P. Modin (CESTA)

At FEL 2009, we presented experimental results on coherent Smith-Purcell obtained at CESTA in the microwave frequency domain * . Those results strongly supported the two-dimensional theory proposed by Andrews and Brau some years ago ** , and were consistent with simulations performed with the PIC code "

MAGIC". That experiment used a large current, 200 A, for a grating of width 10 cm. In a follow-up experiment, emittance slits were used to reduce the current to as low as 2 A, with a quite thin, flat, and wide beam. The gain as a function of current and also of vertical beam position was measured in detail. In particular, the start current for our set-up was found. In parallel, 2-D simulations of the experiment with "MAGIC" were extensively compared with the experimental results. Very good agreement between simulations and experiment is obtained. This lends confidence that simulations of a scaled-down version of our experiment will be a reliable guide for Terahertz frequency coherent Smith Purcell experiments. Such simulations suggest that radiation in the range 100-200GHz should be feasible.

TUPA08 Ultra-Compact Smith-Purcell Free-Electron Laser

J.D. Jarvis, C.A. Brau, J.L. Davidson, B.L. Ivanov (Vanderbilt University) H.L. Andrews (LANL)

Recently, the theory of the Smith-Purcell free-electron laser has been confirmed by the experiments of Andrews, et al. [1], and of Gardelle, et al. [2] In addition, high-brightness cathodes have been developed using field-emission from arrays of diamond pyramids [3]. By combining these developments we have designed an ultracompact (``shirt-pocket'') free-electron laser and we have begun constructing the device. The electron beam comprises an array of 2-micron diamond-pyramid field emitters that overfills an einzel lens 200-microns wide and 1-mm long, fabricated using ps-laser machining. The beam is accelerated to 10 keV and focused in the short dimension over a lamellar metal grating with a period of 150 microns and a length of 10 mm. The predicted start current at a wavelength of 1084 microns is 11 mA, which corresponds to 9 A/cm^2 at the cathode, before focusing. We have tested cathodes at 30 A/cm^2 and 600 mA total current; higher current density should be possible.

TUPA09 Power Enhancement of the Low Frequency Branch in a Short Pulse Waveguided FEL

V. Zhaunerchyk, R.T. Jongma, W.J. van der Zande (Radboud University) Yu. Lurie, Y. Pinhasi (Ariel University Center of Samaria, Faculty of Engineering)

The long-wavelength FELs demand the use of a waveguide. Due to the waveguide dispersion, such FELs support two frequency branches. When the low frequency resonant value is far from the cut-off frequency, the conventional FEL gain is significantly larger for the high frequency branch, therefore usually generation of only this radiation is feasible. However, if the electron bunch shortens, short pulse effects start to play an essential role in the FEL operation. When the FELs employ electron bunches much shorter than the resonant wavelength, their behavior is similar to the prebunched FELs, where light amplification can also occur due to stimulated superradiance [*]. In this contribution we present a mechanism for selective amplification of the low frequency branch which enables an extension of the FEL spectral range towards significantly longer wavelengths. It is concluded that the observed power enhancement is due to the stimulated superradiance. The data reported here were obtained with a wideband interaction FEL code [**].

TUPA10 Stabilization of the Bunch Repetition Rate for a Compact Terahertz Fel Driven by a Microtron

G.M. Kazakevich, V.M. Pavlov (BINP SB RAS) Y.D. Chernousov (ICKC) Y.U. Jeong, B.C. Lee, S. H. Park (KAERI) I.V. Shebolaev (ICKC SB RAS)

The compact FEL driven by a classical S-band microtron fed by a magnetron generates terahertz radiation tunable in wide range. The FEL provides output power of ~ 50 W in the terahertz range at the macro-pulse duration of 2-4 μs. The FEL parameters are available due to stabilization of the accelerated beam current and the magnetron frequency. The last one is stabilized using the frequency pulling in the magnetron. This limits deviations of the magnetron frequency within a range of 200-250 kHz through a signal, reflected from the microtron accelerating cavity which also serves as an external stabilizing resonator for the magnetron. A concept based on employment of an external magnetron driver for stabilization of the magnetron frequency is proposed to upgrade the FEL. The driver will concurrently increase the FEL macro-pulse energy

in 1.5-2 times decreasing the FEL optical resonator intrapulse detuning. The concept considered in this work is compared with the existing frequency stabilization.

TUPA11 **THz Free-Electron Laser Optical Design and Simulations**

A.A. Zimmer, J. Blau, W.B. Colson (NPS)

The Free Electron Laser (FEL) provides a versatile method for producing laser light. Traditionally, FELs are complicated in design and occupy large research facilities. The primary goal of this research effort is to investigate a particular FEL design that is small in size and operates in the terahertz (THz) frequency regime. The optics materials requirements are explored for power levels ranging from mW to kW. Additionally, as part of a simpler design and in spite of the large amount of diffraction present at THz wavelengths, a waveguide will not be utilized as others have done previously. Laser beam clipping, which is defined as the absorption of the laser beam at the outer edges of the diffracted mode, and a shortened undulator are investigated as methods to support the elimination of the waveguide.

TUPA12 **XFEL Oscillator Simulation Including Angle-Dependent Crystal Reflectivity**

W.M. Fawley (LBNL) K.-J. Kim, R.R. Lindberg, Yu. Shvyd'ko (ANL)

The oscillator package within the GINGER FEL simulation code has now been extended to include angle-dependent reflectivity properties of Bragg crystals. Previously, the package was modified to include frequency-dependent reflectivity in order to model x-ray FEL oscillators[*] from start up from shot noise to saturation. We will present a summary of the algorithms used for modeling the crystal reflectivity and radiation propagation outside the undulator, discussing various numerical issues relevant to the domain of high Fresnel number and efficient Hankel transforms. We give some sample XFEL-O simulation results obtained with the angle-dependent reflectivity model, with particular attention directed to the longitudinal and transverse coherence of the radiation output.

TUPA14 **Terahertz Band Free Electron Lasers With Hybrid Bragg Reflectors**

A. Malkin, N.S. Ginzburg, N.Yu. Peskov, A. Sergeev, V.Yu. Zaslavsky (IAP/RAS)

Periodical Bragg structures can be considered as an effective way of controlling the electromagnetic energy fluxes and provision of spatial coherence of radiation in the electron devices with oversized interaction space. Advance of FEL with 2D distributed feedback [*] into the terahertz waveband can be achieved basing on a two-mirror hybrid scheme in which a new modification of Bragg reflector exploiting the coupling between the two counter-propagating waves and a cutoff mode is used as an upstream mirror. This reflector provides effective mode selection over the "narrow" transverse coordinate directed between the plates forming planar waveguide. Synchronization of radiation from a sheet electron beam over the "wide" coordinate can be obtained by 2D Bragg structures providing 2D distributed feedback used as a downstream mirror. Both upstream and downstream Bragg reflectors are compatible with intense beam transport. Thus the advantage of suggested scheme against traditional THz band FEL [**] is the possibility of realization of long-pulse (microsecond) generation regimes with high (mulimegawatt) output power level.

TUPA15 Conceptual Design of a Table-Top THz Free-Electron Laser for Security Inspection

Y.U. Jeong, B.H. Cha, H.K. Cha, Y. Cha, K.H. Jang, K. N. Kim, B.C. Lee, J.Y. Lee, K. Lee, Y.W. Lee, J. Mun, S. H. Park, J.H. Sunwoo (KAERI) G.M. Kazakevich (BINP SB RAS) D.H. Kim (HNU)

A high-power table-top terahertz (THz) free electron laser (FEL) has been designed conceptually. The main application of the FEL is considered to be security inspection. The target wavelength and average power of the system are 200-600 micriometers and 1 W. A compact 4-5 MeV microtron accelerator and corresponding beam optics are under design for obtaining optimal electron-beam condition for FEL lasing. We have designed a superconducting helical undulator having a period of 24 mm, on-axis maximum field strength of 0.7 T, and total length of 600 mm. Preliminary idea of a low-loss and high-gain waveguide oscillator including mirrors has been studied by using 2-D and 3-D codes.

TUPA16 THz Free-Electron Laser Based on FEL Oscillator Scheme

A.L. Wu (USTC/NSRL)

In recent years, THz source is studied by more and more laboratories. An external injecting ICT-RF gun has been designed in National Synchrotron Radiation Laboratory. In this paper, it will use the electron that produced by ICT-RF gun and a new type of terahertz (THz) radiation source using free electron laser oscillator(FELO) is discussed. The conceptual design and numerical simulation are presented.

TUPA17 Present Status of the TAC IR-FEL Facility & Experimental Stations

S. Ozkorucuklu (SDU) A. Aksoy, Ö. Karsli, B. Ketenoglu, M. Tural, O. Yavas (Ankara University, Faculty of Engineering) P. Arikan (Gazi University, Faculty of Arts and Sciences) H. Duran Yildiz (Dumlupinar University, Faculty of Science and Arts) I. Tapan (UU)

The TAC IR-FEL project has been carried out by joint Turkish inter-university working group since 2006 and will start user operation in 2013. This facility will be based on a superconducting electron linac with 15-40 MeV energy range to obtain FEL in oscillator mode covering 2-250 microns of the spectrum. In addition, this study will highlight recently and ongoing promising R&D applications of FELs in Turkey. An extensive scientific programme will be established in eight experimental stations like semiconductors, materials science, surface science, non-linear optics, photochemistry, biology and nanotechnology. On the other hand, principal trends of modern applied techniques such as IR Spectroscopy, FTIR Spectroscopy, Sum Frequency Generation (SFG), Pump-Probe, THz Spectroscopy, Near Field Optical Microscopy, FEL-PAS and MALDI MS are proposed. Finally, this facility will give opportunity for R&D and training to scientists and researchers in our region.

TUPA18 Analysis of the Start-up Phase of an FEL With a Partial Waveguide Resonator

D. Oepts, A.F.G. van der Meer (FOM Rijnhuizen)

Several of the short-pulse FELs that are operated above 100 microns make use of a partial waveguide in the resonator, in particular inside the undulator, and a central hole in one of the mirrors for outcoupling. Experimentally, it was found that these FELs suffer from one or a number of tuning 'gaps': narrow wavelength windows within the tuning range

where the output is strongly reduced or where the laser even does not turn on. Recently, Prazeres et al.[1] noted that the periodicity of the tuning gaps seemed to be related to increments in the phase shifts between the fundamental waveguide mode and the transverse higher order modes being multiples of 2π. Using a computer model they were able to reproduce some of the main features of the experimental observations and showed that the cavity outcoupling and losses change abruptly across the tuning gap. A detailed explanation for why this happens was still lacking though. In this contribution we will discuss a relatively simple model that we used to simulate the start-up phase. Based on this, we will provide an explanation for the failure of the FELIX long-wavelength laser to start up around 39 microns.

TUPA19 **Improvement of a Smith-Purcell Free-electron Laser**

D. Li, K. Imasaki (ILT) M.R. Asakawa (Kansai University) Z. Shi, Z. Yang (UESTC) Y. Tsunawaki (OSU)

A two-section grating system for Smith-Purcell free-electron lasers is investigated. The system is composed of two open gratings, which are with different geometrical parameters. It is expected that the original continuous electron beam is bunched in the first section by interaction with evanescent wave near the grating surface, and enhanced radiation can be extracted at the second section with the form of super-radiant radiation at a required angle. With the help of particle-in-cell simulation, the electron beam bunching and directed output of the fundamental radiation and higher order harmonics are demonstrated.

TUPA20 **Study on a Compact Smith-Purcell Free-electron Laser**

D. Li, K. Imasaki (ILT) M.R. Asakawa (Kansai University) Y. Tsunawaki (OSU)

Compact terahertz radiation sources are necessary in many applications such as biophysics, material science and industrial imaging. We are trying to develop a terahertz radiation source based on a Smith-Purcell radiation device, which is driven by a moderate energy electron beam. The electron beam is generated from Spindt cathode. The Spindt cathode used in our research contains 10,000 pairs of ultrasmall needles and gate electrodes in a 1mm diameter aria. A tiny cathode, i.e., each pair of needle and electrode, generates an electron beamlet with a diameter around 1μm, and these tiny cathodes are arrayed with a spacing of 10μm. The electron beam can be readily generated by applying a gate voltage of 70V because of the high electric field on the emission needle. Electron beam emitted from the Spindt cathode are then accelerated toward the collector electrode, which is followed by the double slab type resonator. The maximum acceleration voltage is 100kV. In this paper, we report the latest results of this research.

TUPA21 **CSR Shielding Experiment**

M.G. Fedurin, A.V. Fedotov, A. Kayran, V. Litvinenko, V. Yakimenko (BNL) P. Muggli (USC)

It is well known that the emission of coherent synchrotron radiation is dipole magnets leads to increase in beam energy spread and emittance. At the Brookhaven National Laboratory Accelerator Test Facility (ATF) we study the suppression of CSR emission and of its effects when generated in the exit dipole magnet of the beam line dogleg by the single bunch with varied beam peak current and bunch length. Horizontal conducting plates with variable spacing (0-14mm) are placed in the vacuum chamber of the dipole magnet. With the plates fully open, an energy spread comparable to the bunch separa-

tion (~50kV) is observed. Preliminary experimental results show that closing the plates change beam energy losses and beam energy spread. Combination of Coherent Synchrotron Radiation, Resistive Wall energy loss and Collimator Step Wake Field effects can be observed at different electron beam parameters.

TUPA22 FEL Potential of eRHIC

V. Litvinenko, I. Ben-Zvi, C.C. Kao, J.B. Murphy (BNL)

BNL plan to build 5-to-30 GeV energy recovery linac for its future electron-ion collider, eRHIC. In past few months the laboratory turned its attention to FEL potential of this unique machine, which was initially assessed in our early paper [1]. In this talk we present current vision of a possible FEL farm and narrow-band FEL-oscillators driven by this accelerator.

TUPA23 Femtosecond Coherent Synchrotron Radiation at SOLEIL, Using a Two Laser-Electron Interaction Scheme

C. Evain, M.-E. Couprie, J.-M. Filhol, A. Loulergue, A. Nadji (SOLEIL) A. Zholents (ANL)

Harmonic generation on storage ring Free Electron Laser has provided so far coherent radiation in the V-UV spectral range. However, the available straight section limits the application of such schemes to the X-ray range. We propose here a scheme to produce CSR in storage ring, using a double laser-electron interactions in two tuned undulators. The first interaction enables to get femtosecond radiation from a picosecond electron bunch, like in the slicing scheme. A second interaction enables to modulate the longitudinal charge distribution of the electron bunch at a harmonic of the laser wavelength, like in the EEHG scheme proposed recently for FEL. Application of this scheme on the SOLEIL case shows that fs CSR can be produced in the TEMPO beamline.

TUPA25 Steady State Microbunching in a Storage Ring to Produce Coherent Radiation

D.F. Ratner (Stanford University) A. Chao (SLAC)

Synchrotrons and storage rings deliver radiation across the electromagnetic spectrum at high repetition rates, and free electron lasers (FELs) produce radiation pulses with high peak brightness. However, at present few light sources can generate both high repetition rate and high brightness outside the optical range. We propose to create steady state microbunching (SSMB) in a storage ring to produce high average power coherent radiation. In this paper we consider the parameters required for SSMB at both short wavelength (EUV lithography) and long wavelength (sub-millimeter) sources. We also consider the feasibility of a proof-of-principle experiment in current storage rings, for example to produce two pulses with variable spacing for pump-probe experiments.

TUPA26 Characteristics of Inverse Compton X-Rays Generated Inside the NIJI-IV Free Electron Laser Oscillators

H. Ogawa, N. Sei, K. Yamada (AIST)

Inverse Compton X-rays were obtained during lasing of the NIJI-IV free electron laser (FEL) in the infrared range. The position of the Compton collisions between electron bunches and laser pulses inside the FEL oscillator strongly influenced the energy spectrum of the Compton X-rays. Collisions outside the undulator magnetic field led to a sharp and clear Compton edge, while collisions inside the undulator magnetic field made it quite obscure. The position of collisions can be determined by changing the bunch-filling pattern on the 16 RF successive buckets. In this experiment two or three bunches selectively remained in suitable RF buckets. The maximum X-ray energies were 0.7-2.1 MeV for the laser wavelengths of 2.6 μm - 0.88 μm with a fixed e-beam energy of 310 MeV. Relative energy width of the 1.2 MeV Compton X-rays was observed to be 11 % with a lead collimator of 10 mm in diameter. The maximum X-ray yield was of the order of 10^6 photons/sec in a three-bunch operation mode. The energy spectra and X-ray yields were investigated under various Compton collision conditions. The results will be discussed in the conference.

TUPA27 Preliminary Studies for the Implementation of Femto-Slicing at the Elettra Storage Ring

S. Spampinati, G. De Ninno (University of Nova Gorica) E. Allaria, C. Spezzani (ELETTRA) E. Ferrari (Università degli Studi di Trieste)

Femto-slicing is almost routinely used at several synchrotron light sources like ALS, BESSY and SLS to obtain sub-picosecond x-ray pulses. In this paper we study the possibility to implement this technique at the Elettra storage ring, by taking advantage of the setup currently used to generate free-electron laser radiation.

TUPA28 13.5-nm Free-Electron Laser for EUV Lithography

Y. Socol (Falcon Analytics) G.N. Kulipanov, O.A. Shevchenko, N. Vinokurov (BINP SB RAS) A.N. Matveenko (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Elektronen-Speicherring BESSY II)

Lithography over the last years has been actively used to produce more compact and powerful computers. The dimensions of the microchips still require shorter wavelengths of light to enhance future `nano' scale production. It is envisaged that 193 nm lithography is beginning to reach its limit. Extreme Ultraviolet (EUV) lithography of 13.5 nm wavelength could provide a solution for the next step of miniaturization, however presently no light source exists with sufficient average power. We report here results of a study, showing the feasibility of a FEL EUV source driven by a multi-turn superconducting energy-recovery linac (ERL). The proposed 40x20 m^2 facility will be located underground for radiation safety purposes. With MW-scale consumption from the power grid it is estimated to provide 5 kW of average EUV power. We elaborate in some detail the SASE option, which is presently technically feasible, however regenerative-amplifier option should be also kept in mind. The proposed design is based on a short-period (2-3 cm) undulator. The corresponding electron beam energy is about 0.6-0.8 GeV. The proposed accelerator consists of photoinjector, booster, and a multi-turn ERL.

TUPA29 Design of a Multi-Turn ERL for Hybrid K-Edge Densitometer

R. Hajima, R. Nagai, N. Nishimori, M. Sawamura (JAEA/ERL) T. Hayakawa, M. Seya, T. Shizuma (JAEA)

Hybrid K-edge densitometer (HKED) is used for concentration measurement of U, Pu and minor actinides in liquid solution samples. In the HKED, the concentration of the most-abundant element is determined by K-edge densitometer and concentrations of other elements are derived from XRF signals. We propose a multi-turn small-size energy-recovery linac (ERL) to produce laser-Compton scattered X-rays for the HKED. The X-rays with good monochromaticity and energy tunability allow measurement of actinides with much better resolution than the existing HKED systems based on X-ray

tubes. The ERL energy is 85 MeV to produce 130-keV X-rays. In the present design, we adopt a racetrack configuration, in which electrons are accelerated six times by L-band superconducting linac and decelerated six times for the energy recovery. Design and expected performance of the ERL-HKED are presented.

13:30 | 15:00 **Poster: Seeding and Seeded FELs**

TUPB01 **Noise and Coherence Propagation in Multi-Stage FELs: Application to Echo-Enhanced Harmonic Generation**

R.R. Lindberg, K.-J. Kim (ANL)

We discuss noise propagation in echo-enhanced harmonic generation (EEHG)*. We follow the noise sources due to initial beam shot and energy noise and laser amplitude and phase noise through the EEHG scheme, calculating the final signal-to-noise ratio in terms of the input laser power, beam, and undulator parameters. We show that the signal-to-noise ratio at the Nth harmonic is degraded by the factor $(N+1)^2$, that depends on the second undulator pair only. This has a simple physical explanation which relates the calculation to previous similar studies**. We discuss the implications on coherence for future sources based on EEHG.

TUPB02 **A Simple Method for Controlling the Line Width of SASE X-Ray FELs**

G. Geloni (European XFEL GmbH) V. Kocharyan, E. Saldin (DESY)

We describe a novel single-bunch self-seeding scheme to obtain highly monochromatic X-rays from a baseline XFEL undulator. For a single-bunch self-seeding scheme a long electron beam bypass is required, implying modifications of the baseline undulator configuration. We avoid such requirement exploiting a single crystal in the transmission direction. The method can be realized using a temporal windowing technique, requiring a magnetic delay for the electron bunch only. The proposed setup is extremely simple and composed of as few as two simple elements: the crystal and the short magnetic chicane, which accomplishes three tasks by itself. It creates an offset for crystal installation, removes the electron micro-bunching from the first undulator, and acts as a delay line for temporal windowing. Using a single crystal installed within a short magnetic chicane in the baseline undulator, it is possible to decrease the bandwidth of the radiation well beyond the XFEL design down to 10^{-5}. The installation of the magnetic chicane does not perturb the undulator focusing system and does not interfere with the baseline mode of operation.

TUPB03 **Experiments on the Tuning of Seeded FELs Through Frequency Pulling**

E. Allaria, C. Spezzani (ELETTRA) G. De Ninno (University of Nova Gorica)

In seeded FELs, the final wavelength of the produced coherent radiation is imposed by the seed wavelength. This gives to seeded FELs the advantage of producing more stable and clean pulses with respect to a SASE FEL, but also sets some limitation on tunability. The latter normally relies on the tunability of the seed source. As a way to overcome this limitation, it has been suggested to use the relatively large bandwidth of short seed pulses. This opportunity has been recently theoretically and numerically explored, showing that such a method is of limited utility. In this work we provide the experimental evidence of frequency pulling in FEL's, confirming theoretical predictions. The experiment has been done on the Elettra storage ring FEL operated in the harmonic generation configuration.

TUPB04 High Harmonic Sources for Seeding of FERMI@Elettra

P.J.M. van der Slot, H.M.J. Bastiaens, K.-J. Boller (Mesa+) S. Biedron, M.B. Danailov, S.V. Milton (ELETTRA) J.L. Herek (UT-MESA+ OS)

FERMI@Elettra is a free electron laser user facility currently under construction at Sincrotrone Trieste S.C.p.A. Its goals are to produce high-brightness, ultra-short pulses with wavelengths ranging from 100 - 20 nm (FEL1) and 40 - 4 nm (FEL2) and deliver these pulses to a wide range of user experiments. Currently, FERMI uses the HGHG technique to improve both the stability and the longitudinal and spectral coherence of the output of the laser. Direct seeding of FEL1 using a High Harmonic (HH) source is also foreseen and allows a direct comparison between the two seeding methods. For an HH source, we will use neutral atoms in a hollow waveguide in combination with coherent control of the drive laser pulse to provide wavelength tuning as well as selective enhancement of the harmonic orders. For direct seeding of FEL 2 we propose HH generation from ions in a modulated plasma waveguide. The ions allow generation of shorter wavelengths, while the modulated plasma waveguide provides a long interaction length as well as quasi-phase matching for boosting the output energy of the source. In this paper, we will present the HH source for FEL1 as well as a concept for HH seeding of FEL2.

TUPB05 Simulation Studies for the EEHG Experiments at the SDUV-FEL

J.H. Chen, C. Feng, D. Wang (SINAP)

The experiments to demonstrate the echo-enabled harmonic generation (EEHG)principle have been carried out at the Shanghai Deep Ultraviolet Free-electron Laser (SDUV-FEL) test facility. Some imperfection and diffusion effects, which may deteriorate the EEHG performance, are studied in this paper.

TUPB06 Some Experimental Results of EEHG(Echo Enabled Harmonic Generation) at SINAP

D. Wang (SINAP)

EEHG(Echo Enabled Harmonic Generation) is a new seeded FEL scheme proposed by G. Stupakov in 2008. It is particularly efficient for producing high harmonic bunching which is very useful in short wavelength seeded FELs. This paper will describe some latest experimental results of EEHG(Echo Enabled Harmonic Generation) operation at Shanghai Inst of Applied Physics, Chinese Academy of Sciences.

TUPB07 Numerical Investigations of Laser-Beam Interaction in an Undulator

H.X. Deng, J.H. Chen, C. Feng, B. Liu, D. Wang, J. Yan (SINAP) T.Y. Lin (East China Normal University)

Laser-beam interaction in an undulator is commonly suggested in the development of free electron laser schemes. In this paper, a three-dimensional algorithm is developed for serving the laser-beam interactions in arbitrary magnetic field, which is built on the fundamental of the electrodynamics, i.e. the electron's behavior is determined by the magnetic field and the laser electric field in time domain. And several interested issues,

i.e. the detuning effects in laser-heater, the carrier envelope phase effects of the few-cycle laser in attosecond x-ray FEL scheme, and the tuning ability of the output wavelength in standard high gain harmonic generation FEL scheme are numerically discussed.

TUPB08 Staged Self-Seeding Scheme for Narrow Bandwidth, Ultra-Short X-ray Harmonic Generation Free Electron Laser at LINAC Coherent Light Source

J. Wu, P. Emma, J.B. Hastings (SLAC) C. Pellegrini (UCLA)

Success of the world's first x-ray (0.15-1.5 nm) free electron laser (FEL) - LCLS - at SLAC opens the gate for new science. In this paper, we study the FEL performance for a two-stage self-seeding scheme by introducing a photon monochromator and an electron by-pass in the undulator system. The FEL generated in the first part of the undulator system is purified in spectrum, recombines with the electron bunch, and is amplified in the second part of the undulator system to saturation. Such modifications will improve the FEL longitudinal coherence, reducing the FEL band-width by two-orders of magnitude, but with similar peak power; hence improving the peak brightness by two-orders of magnitude. Such a self-seeding scheme is studied for both soft x-ray (200 eV to 2 keV) and hard x-ray (800 eV to 8 keV) cases with single electron bunch. The photon monochromator system is configurated as variable line spacing gratings for soft x-ray and single crystal for hard x-ray. Harmonic Generation and Chirped FEL are also considered aiming at reaching even shorter wavelength x-ray photons and at generating FEL pulse with even shorter temporal duration, respectively.

TUPB10 Optics for Self-Seeding Soft X-ray FEL Undulators

Y. Feng, J.B. Hastings, J. Krzywinski, M. Rowen, J. Wu (SLAC) P.A. Heimann (LBNL)

A complete optical system including grating monochromator and mirrors was designed to provide self-seeding of the soft X-ray undulators to be possibly built as part of the LCLS-II project. The grating monochromator consisted of a cylindrical horizontally focusing mirror, a plane vertically deflecting pre-mirror, a variable-line-spacing plane vertically deflecting grating, a horizontal exit slits, and a spherical vertically collimating mirror. The grating monochromator was designed to operate in the fixed-focus mode and tuning of the energy was designed to be achieved by rotations of only the pre-mirror and the grating. Only one ruling of 2200 l/mm was needed to cover the energy range from 200 to 2000 eV with an almost constant resolving power of greater than 22700. The monochromator would produce fully transform-limited pulses of 12 fs (rms) long at 2000 eV or 120 fs (rms) long at 200 eV with sufficient power to allow seeding. The optical system produced a slightly energy-dependent time delay of about 10 ps. The transverse size of the input beam was preserved in the horizontal direction, but was reduced in the vertical direction depending on the tuning energy.

TUPB11 Noise Amplification in HGHG Seeding

G.V. Stupakov (SLAC)

It is well known that harmonic generation in HGHG amplifies the shot noise in the beam. In this work, we introduce a framework for theoretical description of the noise dynamics in such a device consisting from un undulator-modulator and a chicane. We propose to consider the interaction of particles in the modulator-undulator through the radiation field as a source which modifies the noise level in the beam. The coherent part

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of this interaction is responsible for the FEL process while the random part introduces correlations in the particle's positions and modifies the noise properties of the beam. We develop a 1D version of the method and apply it to the HGHG seeding mechanism.

TUPB12 **Noise Amplification in Echo-Enabled Harmonic Generation (EEHG)**

G.V. Stupakov, Z. Huang, D.F. Ratner (SLAC)

It is generally accepted that harmonic-generation seeding in FELs amplifies the noise in the beam and enhances the spontaneous component of the FEL radiation. In this paper we analyze the noise dynamics caused by particle interaction in the undulators of the EEHG seeding mechanism. We develop a 1D model of the noise evolution through the system and calculate the amplification factor as a function of frequency. Our results are applied to a typical soft x-ray EEHG FEL.

TUPB13 **Echo-Seeding Options for LCLS-II**

D. Xiang, G.V. Stupakov (SLAC)

The success of LCLS has opened up a new era of x-ray sciences. An upgrade to LCLS is currently being planned to enhance its capabilities. In this paper we study the feasibility of using the echo-enabled harmonic generation (EEHG) technique to generate narrow bandwidth soft x-ray radiation in the proposed LCLS-II soft x-ray beam line. We focus on the conceptual design, the technical implementation and the expected performances of the echo-seeding scheme. We will also show how the echo-seeding scheme allows one to generate two color x-ray pulses with the higher energy photons leading the lower energy ones as is favored by the x-ray pump-probe experiments.

TUPB15 **Metrology of High Order Harmonics for FEL Seeding**

E. Mansten, C. Erny, M. Gisselbrecht, X. He, A. L'Huillier, R. Rakowski, J. Schwenke (Lund University, Division of Atomic Physics) M.B. Gaarde (LSU) S. Werin (MAX-lab)

High order harmonic generation (HHG) is planned or considered to be used as a seed source in several free electron laser (FEL) facilities. The feasibility of this scheme relies on the performance and stability of the HHG source. We have performed a complete metrology study on high order harmonic generation (HHG) in argon. We were able to measure the pulse energy of individual harmonics and perform an energy jitter analysis. Our result showed harmonic pulse energies up to 34 nJ, with an energy jitter of 5 to 10%. We also measured divergence and pointing stability of the HHG source. The experimental results are complemented with one-dimensional seeding calculations. In particular, the calculations illustrate the selection of one harmonic from the comb of harmonics present in an HHG source. The stability measurements of single harmonics are highly relevant for the development of HHG seeded FELs.

TUPB16 **Numerical Study on Coherent Harmonic Generation Free Electron Laser Seeded by Chirped External Laser**

H. Zen, M. Adachi, M. Katoh (UVSOR) M. Hosaka, Y. Taira, N. Yamamoto (Nagoya University) T. Tanikawa (Sokendai - Okazaki)

Coherent Harmonic Generation Free Electron Laser (CHG-FEL)* ** is a short pulse and coherent radiation source in vacuum ultra-violet regime. A measurement of CHG-FEL spectrum*** has been done and sidebands in spectrum were observed under an over-bunching condition. The measurement was done with chirped seed laser to avoid strong over-bunching of electron beam and to obtain larger pulse energy for high signal to noise ratio. In the paper ***, however, the seed laser chirping was not taken into account in the numerical analysis and the numerical results qualitatively agreed with experimental results but quantitatively not. We consider that the discrepancy was caused by the chirping property of the seed laser, and thus we have developed a time dependent simulation code which can deal the effect of seed laser chirping. Results of the code qualitatively agreed well with the shape of measured spectrum, not only bandwidth but also the sideband structure. And the code was used to evaluate the temporal and spectral property of CHG-FEL seeded by a chirped laser. The code revealed the spectral widening and chirped property of CHG-FEL pulse when the CHG-FEL is driven by a chirped seed laser.

TUPB17

Generation of Atto-Second Water Window Coherent X-Ray Radiation Through Modulation Compression

J. Qiang (LBNL) J. Wu (SLAC)

In this paper, we propose a scheme to generate atto-second to femto-second tunable water window (~2-4 nm) coherent X-ray radiation for future light source applications. This scheme improves the previously proposed modulation compression method [1] by using a 10 pC, 100 μm electron beam at 2 GeV energy, a 200 nm seeding laser, an X-band linac, two opposite sign bunch compressors, and a long wavelength laser to generate a prebunched, kilo-Amper current beam with a modulation wavelength within the water window. Such a beam will be sent into an undulator to generate a short pulse transverse and temporal coherent soft X-ray radiation. The requirement of initial seeding laser power is small. The electron beam at the entrance of undulator can have sub micron normalized emittance.

TUPB18

FEL Experiments at SPARC

L. Giannessi, F. Ciocci, G. Dattoli, M. Del Franco, A. Petralia, M. Quattromini, C. Ronsivalle, E. Sabia, I.P. Spassovsky, V. Surrenti (ENEA C.R. Frascati) D. Alesini, M. Bellaveglia, M. Castellano, E. Chiadroni, L. Cultrera, G. Di Pirro, M. Ferrario, L. Ficcadenti, D. Filippetto, A. Gallo, G. Gatti, E. Pace, B. Spataro, C. Vaccarezza, C. Vicario (INFN/LNF) A. Bacci, V. Petrillo, A.R. Rossi, L. Serafini (Istituto Nazionale di Fisica Nucleare) M. Bougeard, B. Carré (CEA) F. Briquez, M.-E. Couprie, M. Labat (SOLEIL) A. Cianchi (Università di Roma II Tor Vergata) F. Frassetto, L. P. Poletto (LUXOR) G. Lambert (LOA) G. Marcus, J.B. Rosenzweig (UCLA) M. Moreno, M. Serluca (INFN-Roma) A. Mostacci (Rome University La Sapienza) J.V. Rau, V. Rossi Albertini (ISM-CNR)

SPARC is a single pass free electron laser test facility realized in collaboration between the main Italian research institutions and devoted to experiments of light amplification in different beam conditions. While the laser was commissioned in self amplified spontaneous emission (SASE) mode during the last year, the operation in seeded mode has been recently demonstrated. The amplifier has been seeded with the second harmonic of the Ti:Sa driver laser generated in a crystal and with higher order VUV harmonics generated in a gas cell. The comparison between seeded and unseeded FEL emission will be discussed. The laser has been also operated in a new SASE configuration with a strongly chirped longitudinal e-beam phase space resulting from the RF compression. The chirp has been compensated by accordingly tapering the undulator gaps. Spectra

with and without taper have been collected. An increase of about a factor 5 of the pulse energy in combination with spectra with a single longitudinal coherence region have been detected in presence of the taper. The combination of the chirp with the input seed is under study.

TUPB19 **Generation of High Harmonics in Elliptical Polarization**

G. Lambert, J. Gautier, A. Sardinha, S. Sebban, F. Tissandier, C. Valentin, B. Vodungbo, P. Zeitoun (LOA) M. Fajardo (GoLP)

FEL have been recently evolving very fast in the EUV to soft X-ray region. Once seeded with high harmonics (HH) generated in gas, these light sources deliver amplified emissions with properties which are, for most of them, directly linked to the injected HH beam, e.g. the ultrashort pulse duration for FEL and the high temporal and spatial degree of coherence. One of the limitations of the HH radiation is the polarization. Indeed, until now only harmonics with linear polarization can be obtained as the efficiency of harmonic generation decreases very fast with the ellipticity of the driving laser. Here we present two different techniques which allow achieving high harmonics with elliptical polarization. The first one is based on a system of four mirrors either in gold or molybdenum material to shift the phases of the s and p components of the linearly polarized harmonics. The second one is the generation of harmonics in cross polarized w and 2w beams. Controlling the 2w energy allows managing the polarization state. This technique has recently shown great perspectives for the seeding of FEL at short wavelength.

TUPB20 **Present Status and Commissioning Results of sFLASH**

V. Miltchev, A. Azima, J. Boedewadt, F. Curbis, H. Delsim-Hashemi, M. Drescher, Th. Maltezopoulos, M. Mittenzwey, J. Rossbach, J. Rönsch-Schulenburg, R. Tarkeshian, M. Wieland (Uni HH) K. Honkavaara, T. Laarmann, H. Schlarb (DESY) R. Ischebeck (PSI) S. Khan (DELTA) A. Meseck (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Elektronen-Speicherring BESSY II)

The free-electron laser in Hamburg (FLASH) was previously being operated in the self-amplified spontaneous emission (SASE) mode, producing photons in the XUV wavelength range. Due to the start-up from noise the SASE-radiation consists of a number of uncorrelated modes. One option to increase the coherence and to improve the synchronisation between the FEL-pulse and an external laser is to operate FLASH as an amplifier of a seed produced using high harmonics generation (HHG). An experimental set-up, named 'sFLASH', has been installed to test this concept for the wavelengths below 40 nm. The sFLASH installation took place during the planed FLASH shutdown in the winter of 2009/2010. The technical commissioning, which began in March 2010, will be followed by seeded-FEL commissioning in the summer of 2010. In this contribution the present status and the sFLASH commissioning results will be discussed.

TUPB21 **Characterization of Seeded FEL Pulses at FLASH: Status, Challenges and Opportunities**

T. Laarmann (DESY)

Since 2004, the free-electron laser FLASH at DESY has operated in the Self-Amplified Stimulated Emission mode (SASE), delivering gigawatt pulses with wavelengths between 6.5 nm and 40 nm in the femtosecond domain. In 2009, DESY installed an additional radiofrequency module for controlling the phase space of the electron bunches that gives the possibility to generate bunches with high peak currents (~kA), but ten times larger pulse durations (~250 fs) compared to the previous configuration. The relaxed timing requirements of the new configuration make it possible to externally seed FLASH with high-order harmonics of an optical laser below 40nm generated in a gas target (sFLASH). Because in this case amplification is triggered within the seed pulse length instead of starting from shot-noise as in the SASE process, spikes in the temporal/spectral pulse profiles should be absent and the temporal jitter should be eliminated. In this contribution the present status of the sFLASH photon diagnostics including first commissioning will be discussed.

TUPB22 **The XUV Injection Beam Line for Direct Seeding at sFLASH**

J. Boedewadt, A. Azima, F. Curbis, H. Delsim-Hashemi, M. Drescher, Th. Maltezopoulos, V. Miltchev, M. Mittenzwey, M. Rehders, J. Rossbach, J. Rönsch-Schulenburg, R. Tarkeshian, M. Wieland (Uni HH) S. Bajt, S. Düsterer, J. Feldhaus, T. Laarmann, H. Schlarb (DESY) R. Ischebeck (PSI) S. Khan (DELTA)

A direct seeding scheme at the free-electron laser facility FLASH in Hamburg is currently commissioned. High-harmonics from 800 nm laser pulses are generated in a noble gas (HHG). In the first phase the FEL will be seeded with the 21st harmonic at 38 nm. To transport the XUV pulses from the HHG source into the variable gap undulators a dedicated beam line was designed and installed, giving the possibility to steer and focus the beam within the undulator to achieve the transverse overlap of the XUV seed beam with the electron beam. Several diagnostics are installed to measure XUV beam position and size along the beam line. In this contribution the characteristics and first results of the commissioning will be presented.

TUPB23 **Experimental Demonstration of Wideband Tunability of an Ultrafast Laser Seeded Free-Electron Laser**

X. Yang, Y. Hidaka, J.B. Murphy, B. Podobedov, S. Seletskiy, Y. Shen, X.J. Wang (BNL)

We report the first experimental characterization of the wideband tunability of an ultrafast laser seeded FEL using a short seed laser pulse (140 fs in FWHM) and a variable energy electron beam. The experiments were conducted at the NSLS SDL and the FEL output spectrum and pulse energy were measured versus the electron beam energy. A significant spectral tuning range (8%) was observed. The experiment is in good agreement with predictions using the Perseo simulation code.

TUPB24 **Fluctuation Study of Polarization Degree With Crossed Undulator**

H. Geng (USTC/NSRL)

The crossed-planar undulator has been shown to be a promising scheme for full polarization control in x-ray FELs. For SASE FELs, it has been shown a maximum average degree of circular polarization of about 80% is achievable at fundamental wavelength just before saturation. In SASE FELs, the radiation has an intrisic fluctuation due to its shot noise startup. In this paper, we study the fluctuation of circular polarization degree with a crossed undulator for a SASE x-ray FEL. The fluctuation of circular polarization degree for both the fundamental and the harmonic radiation will be considered.

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TUPB25 **Saturation Phenomena of VUV Coherent Harmonic Generation at UVSOR-II**

T. Tanikawa (Sokendai - Okazaki) M. Adachi, M. Katoh, J. Yamazaki, H. Zen (UVSOR) M. Hosaka, Y. Taira, N. Yamamoto (Nagoya University)

Light source technologies based on laser seeding are under development at the UVSOR-II electron storage ring. In the last FEL conference (FEL2009), we reported spectral measurements of coherent harmonic generation (CHG) seeded by the fundamental of Ti: Sapphire laser, in the region of vacuum-ultra violet (VUV). In this conference, we will report some systematic measurements such as the undulator gap dependence and seed laser power dependence. In the laser power dependence, we have observed a saturation of CHG intensity. The result will be compared with simulations. A seeding light source based on high harmonic generation (HHG) in rare gas is under development. The status will be reported.

TUPB26 **Past and Future of the DELTA Free-Electron Laser**

H. Huck, R. Burek, S. Khan, A. Schick, G. Schmidt, K. Wille (DELTA)

The storage-ring FEL at DELTA has been successfully operated with different filling patterns and temporal structures following the installation of new mirror chambers three years ago. The modulation depth of the optical-klystron spectrum was used to measure the electron energy spread. The measured FEL output power at high beam currents strongly exceeded the predictions of the low-gain model. This could be explained by the microwave instability being damped significantly by the onset of the FEL interaction. In the near future, the optical klystron will be seeded by external ultrashort laser pulses in order to produce highly coherent, intense and ultrashort VUV pulses by coherent harmonic generation (CHG). Additionally, coherent ultrashort THz pulses will be generated several meters downstream of the optical klystron by the laser-induced gap in the electron bunch.

TUPB27 **Seeding Strategy for the SwissFEL**

S. Reiche (PSI)

The soft X-ray beamline of SwissFEL foresees seeding to improve the longitudinal coherence and FEL stability down to a wavelength of 1 nm. Most promising seeding strategies are echo-enabled harmonic generation (EE-HG) and high harmonic generation (HHG), though both have enormous technical difficulties to reach short wavelength below 10 nm. However the requirements on the seeding sources are reduced when both seeding methods are combined by using a HHG seed for the second stage of the EE-HG. The advantages are a longer target wavelength of the HHG source at around 50 nm and the significantly reduced strength of the first dispersion in the seeding beam line. The results of the numerical studies, applied to the SwissFEL soft X-ray beamline, as well as the difficulties and the benefits of this operation mode are presented here.

TUPB28 **Influence Of Chirp In FEL Sources Seeded By High Order Harmonics Generated In Gas**

F. Briquez, M.-E. Couprie, C. Evain, M. Labat (SOLEIL) L. Giannessi (ENEA C.R. Frascati)

ARC-EN-CIEL project consists of three High Gain Harmonic Generation Free Electron Laser sources seeded by High order Harmonics generated in Gas. FEL1 (resp. 2) covers the 200-1.5 (resp. 10-0.6) nm range. Both sources are based on a 1 GeV electron beam with a 5 mm.mrad emittance and a 0.1% RMS energy spread, and of a 26 mm period in vacuum modulator. FEL 1 employs a 30 mm period APPLE-2 type radiator, allowing obtaining helical polarization, whereas FEL 2 uses an 18 mm period in vacuum type undulator to reach higher energies. Studies on how the chirp affects the central wavelength and the bandwidth of the FEL radiation are carried out. Simulations are performed with PERSEO code. Different cases of chirp are investigated, in particular those occurring with the High order Harmonics generated in Gas.

15:30 | 17:00 **FEL Oscillator and Long Wavelength FELs**
Chair: S. Khan, DELTA (Dortmund)

TUOCI1 **The THz-FEL FELBE at the Radiation Source ELBE**

W. Seidel (FZD)

Two free-electron lasers (FELBE; 4-21 μm and 18-250 μm, respectively) have been in routine user operation for a wide range of IR experiments at the radiation source ELBE in the Forschungszentrum Dresden-Rossendorf for several years. The lasers are driven by a superconducting RF linac that permits the generation of a cw-beam with a repetition rate of 13 MHz and a high average beam power. In addition, operation in a macropulse modus (pulse duration >100 μs, repetition rate ≤ 25 Hz) is possible. A few important experiments using the cw-operation are discussed. Furthermore, an outlook is given on the experiments which use the beam of FELBE in the High Magnetic Field Laboratory Dresden (HLD). The HLD provides pulsed magnetic fields up to 60 T. It operates as a user facility since 2007.

TUOCI2 **Tunable Soft X-Ray FEL Oscillator**

J.S. Wurtele, G. Penn, M. Reinsch (LBNL) P.R. Gandhi, X.W. Gu, J.S. Wurtele (UCB) K.-J. Kim, R.R. Lindberg, A. Zholents (ANL)

A concept for a tunable soft x-ray free electron laser (FEL) oscillator is proposed and studied numerically. It is based on the idea of echo enabled harmonic generation [1] and takes advantage of the oscillator's ability to start up from spontaneous emission, thereby eliminating the need for optical lasers. In the proposed concept, harmonic tunability is accomplished through beam manipulations using magnetic chicanes and a tunable radiator while two FEL oscillators remain at a fixed frequency. An additional advantage of the proposed technique is the possibility to utilize multilayer x-ray mirrors with a high backward reflectivity of the order of 70%, allowing the initial beam manipulation to be accomplished at a short wavelength, close to the final soft x-ray output. The high repetition rate soft x-ray output is expected to have longitudinal coherence and a narrow bandwidth.

TUOC3 **Modeling and Operation of an Edge-Outcoupled Free-Electron Laser**

M.D. Shinn, S.V. Benson, G. Neil, A.M. Watson (JLAB) R. Lalezari (ATF) P.J.M. van der Slot (Mesa+)

We report on the design, and broadly tunable operation, of a high average power free-electron laser using edge-outcoupling. For this type of outcoupling, the cavity mode has a larger area than the mirror diameter, and the mode `spills" around it. While used in positive branch unstable resonators, in this case, the resonator was in a stable configuration. Using an edge-outcoupler composed of an aluminum-coated sapphire substrate, the IR Upgrade FEL at Jefferson Lab achieved a maximum power of 260W at 3.87 microns, with an output power of 20 W or higher from 0.8 to 4.2 microns. Measurements of gain, loss, and output mode are compared with our models.

TUOC4 **Radiation Characteristics of the Long-Wavelength FEL at FELIX in the Vicinity of a Tuning Gap.**

A.F.G. van der Meer, D. Oepts (FOM Rijnhuizen)

Several of the short-pulse FELs that are operated in a wavelength range starting well below and ending well above 100 microns make use of a partial waveguide in the resonator and a central hole in one of the mirrors for outcoupling. The purpose of the waveguide is to confine the optical mode, in particular within the gap of the undulator. Experimentally, it was found that these FELs suffer from one or a number of tuning 'gaps': narrow wavelength windows within the tuning range where the output is strongly reduced or where the laser even does not turn on. Recently, Prazeres et al.[1] , using a simulation model, were able to reproduce some of the main features of the tuning curve and showed that the cavity outcoupling and losses change abruptly across a tuning gap. In this contribution we will present experimental results for the gain, cavity loss, saturated power and spectral intensity across one of the most prominent gaps in the tuning curve of the FELIX long-wavelength FEL. Both for the normal case and for the case where a slit is used to limit the optical mode extent on the free-space mirror.

17:15 | 18:15 **Tutorial**
Chair: A. Meseck, BESSY GmbH (Berlin)

TUTUI1 **Generation and Properties of HHG Radiation**

A. L'Huillier (Lund University, Division of Atomic Physics)

When an intense laser field interacts with an atomic gas, nonlinear processes take place, leading to the emission of high-order harmonics of the laser radiation. In the spectral domain, a comb of odd-order harmonics is obtained,while in the temporal domain, the emission consists of a sequence of extremely short pulses of light, in the attosecond range. This talk will review the basic physics of high- order harmonic generation, the performances that can be obtained as well as some of the applications.

08:30 | 10:00 **Seeding and Seeded FELs**
Chair: D. Garzella, CEA (Gif-sur-Yvette)

WEOAI1 **Pulse-Splitting in Short Wavelength Seeded Free Electron Laser**

M. Labat, M.-E. Couprie (SOLEIL) S. Bielawski, C. Szwaj (PhLAM/CERCLA) C. Bruni (LAL) N. Joly (University of Erlangen-Nuremberg)

We investigate a dynamical behaviors occurring in single-pass free electron lasers (FELs), depending on the electron beam, undulator and seed laser parameters. We put in evidence a complex spatiotemporal deformation of the amplified pulse, leading ultimately to a pulse splitting effect with two sub-pulses. This phenomenon has been first observed in PERSEO simulations in the case of ARC-EN-CIEL project studies, and then been analyzed more in details with the Colson-Bonifacio FEL equations. This studies reveal that slippage length as well as the seed laser pulse wings are the main ingredients of this dynamics [1]. We show that the splitting results from the nonhomogeneous saturation of the gain by the optical field copropagating with the electron beam.

WEOAI2 **sFLASH - First results of a direkt seeding at FLASH**

J. Boedewadt, A. Azima, F. Curbis, H. Delsim-Hashemi, M. Drescher, Th. Maltezopoulos, V. Miltchev, M. Mittenzwey, M. Rehders, J. Rossbach, R. Tarkeshian, M. Wieland (Uni HH) S. Bajt, S. Düsterer, J. Feldhaus, T. Laarmann, H. Schlarb (DESY) R. Ischebeck (PSI) S. Khan (DELTA)

The free-electron laser facility FLASH at DESY (Hamburg) was upgraded during a five month shutdown in winter 2009. Part of this upgrade was the installation of a direct seeding experiment in the XUV spectral range. Beside all components for transport and diagnostics of the photon beam in and out of the accelerator environment, a new 10m long variable gap undulator was installed upstream of the existing FLASH undulator system. The seed pulses are generated within a noble gas jet by focusing 40 fs long Ti:Sa laser pulses into it resulting a comb of higher harmonics. In the first phase of the experiment the 21st harmonic of the 800nm drive laser will be used to seed the FEL process. The commissioning of the experiment has started in April and the first results are expected after the FLASH commissioning period mid of summer 2010. The experimental setup and the commissioning procedures as well as first result will be presented.

WEOA3 **Commissioning the Echo-Seeding Experiment ECHO-7 at SLAC**

D. Xiang, E.R. Colby, M.P. Dunning, A. Gilevich, C. Hast, R.K. Jobe, D.J. McCormick, J. Nelson, T.O. Raubenheimer, K. Soong, G.V. Stupakov, Z.M. Szalata, D.R. Walz, S.P. Weathersby, M. Woodley (SLAC) P.L. Pernet (EPFL)

ECHO-7 is a proof-of-principle echo-enabled harmonic generation FEL experiment in the Next Linear Collider Test Accelerator (NLCTA) at SLAC. The experiment aims to generate coherent radiation at 318 nm and 227 nm, which are the 5th and 7th harmonic of the infrared seed laser. In this paper we present the experimental results from the commissioning run of the completed experimental setup which started in April 2010.

WEOA4 **First Results of Coherent Harmonic Generation at the MAX-Lab Test Fel**

S. Werin, N. Cutic, F. Lindau, S. Thorin (MAX-lab) J. Bahrdt, K. Holldack (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Elektronen-Speicherring BESSY II) C. Erny, A. L'Huillier, E. Mansten (Lund University, Division of Atomic Physics)

The first generation of coherent harmonic radiation from the MAX-lab test FEL have recently been achieved. The 380 MeV electron beam has been seeded by a 263 nm Ti:Sapphire laser and coherent radiation in the harmonics 1 to 4 (263 -- 66 nm) has been produced both in linear and circular polarization mode. The facility consists of a photo cathode RF gun, the MAX injector (two 95 MeV linacs placed in a recirculator), beam transport including compression optics and the two undulators (modulator and radiator) separated by a four magnet chicane for bunching control. The radiator undulator is of Apple type providing tunable polarization. The basic characterization of the source with dynamic studies of laser energy, undulator gap and chicane influence on the coherent harmonic signal will be reported.

10:30 | 12:00 **Short Pulse Length FELs**
Chair: D. Wang, SINAP (Shanghai)

WEOBI1 **The Push Towards Short X-Ray Pulse Generation Using Free Electron Lasers**

A. Zholents (ANL)

X-ray free electron lasers (FELs) are well suited to pursue a long-standing goal of studying matter in a transient state that is far from equilibrium. This state often determines the functions of materials and, thus, holds a key to understanding how to control them. The natural time scale for most of the dynamic processes involving atoms is of the order of 100 femtoseconds, and existing x-ray FELs have already surpassed this mark. The natural time scale for dynamic processes driven by electrons is of the order of 100 attoseconds, and this is the next Rubicon for FELs. In this talk I will review the state of the art in generation of femtosecond x-ray pulses using FELs and will discuss a number of new ideas en route to sub-femtosecond x-ray pulses.

WEOBI2 **Ultra-Short Low Charge Operation at FLASH and the European XFEL**

I. Zagorodnov (DESY)

The Free Electron Laser in Hamburg (FLASH) is a SASE FEL user facility and in addition serves as a prototype for the European XFEL. The recent upgrade of FLASH with a higher harmonic RF module opens a new possibility for ultra-short low charge operation. The advantage of small transverse emittance at low charges can be used only with strong, linearized bunch compression. At this report we consider simulations of the beam dynamics at low charges and estimate the expected properties of the radiation at FLASH and the European XFEL. We present first experimental results at FLASH.

WEOB3 **A Single-Shot Method for Measuring Femtosecond Bunch Length in Linac-Based Free-Electron Lasers**

Z. Huang, K.L.F. Bane, Y.T. Ding, P. Emma (SLAC)

There is a growing interest in the generation and characterization of femtosecond and sub-femtosecond pulses from linac-based free-electron lasers (FELs). In this paper we study a simple longitudinal transformation* for measuring a very short electron bunch. We show that this method can be applied in a straightforward manner at x-ray FEL facilities such as the Linac Coherent Light Source by slightly adjusting the second bunch compressor followed by running the bunch on an rf zero-crossing phase of the final linac. After taking into account the linac wakefield, we find the condition under which the final beam energy spread corresponds directly to the compressed bunch length. When used in conjunction with a high-resolution electron spectrometer, this method potentially reveals temporal information of femtosecond and sub-femtosecond electron bunches used by such FELs.

WEOB4 **ECHO Enhanced Harmonic Emission in FERMI**

E. Allaria (ELETTRA) G. De Ninno (University of Nova Gorica)

FERMI@Elettra will have two different seeded FELs for covering the spectral range between 80 and 4nm. The shorter wavelength FEL, namely FEL-2, will cover the spectral range between 20 and 4 nm, and will be based on a double cascade high gain harmonic generation scheme. Moreover, the system has been designed to allow the implementation of other seeding schemes, like seeding with high-order harmonics generated in gas and echo-enhanced harmonic generation (EEG). In this work, we present the studies on the possible implementation on FERMI of the EEHG, reporting about the expected performance. The number of photons per pulse and the FEL bandwidth are calculated by means of time dependent start-to- end simulations.

13:30 | 15:00 **Poster: Short Pulse Length FELs**

WEPA01 **Short Pulse Radiation from an Energy-Chirped Electron Bunch in a Soft-X-Ray FEL**

I.P.S. Martin (Diamond) R. Bartolini, I.P.S. Martin (JAI)

The production of short pulse radiation of 1fs or below would open up many new areas of research. Saldin et al recently proposed a scheme to generate such pulses, in which a laser pulse consisting of only a few optical cycles is used to give a short energy chirp to the electron bunch and uses a tapered undulator to compensate the chirped region. In this paper we study the application of this scheme to a soft x-ray free electron laser, including the results of fully start to end simulations and an assessment of the sensitivity to jitter.

WEPA02 **SASE FEL at SDUV-FEL**

D.G. Li, J.H. Chen, H.X. Deng, Q. Gu, B. Liu, D. Wang (SINAP)

A SASE experiment has been done at SDUV-FEL(SINAP), the spontaneous radiation and exponential growth regime are observed. The results are compared with the SASE theory.

WEPA03 An Analysis of EEHG-Assisted Attosecond X-Ray Free Electron Laser Schemes

H.X. Deng, Z.M. Dai, D. Wang, J. Yan (SINAP)

Based on the principle of echo-enabled harmonic generation (EEHG), two kinds of free electron laser (FEL) schemes serving for pump-probe experiments (i.e. the one using a femtosecond infrared pulse [*] and an attosecond soft x-ray pulse and the other using two attosecond soft x-ray pulses [**]) were proposed. In this paper, brief analytical model and three-dimensional simulations are developed to assessment the performance of EEHG-assisted attosecond x-ray FEL schemes. Moreover, on the basis of the results, a more compact, robust and easier to be operated scheme is proposed for two color attosecond pulse generation.

WEPA04 Femtosecond Electron Bunch Generation Using Photocathode RF Gun

K. Kan, T. Kondoh, T. Kozawa, K. Norizawa, A. Ogata, J. Yang, Y. Yoshida (ISIR)

Femtosecond electron beam, which is essential for pump-probe measurement, was generated with a 1.6-cell S-band photocathode rf gun. The rf gun was driven by femtosecond UV laser pulse (266 nm), which was generated with third-harmonic-generation (THG) of Ti:Sapphire femtosecond laser (800 nm). The longitudinal and transverse dynamics of the electron bunch generated by the UV laser was investigated. The bunch length was measured with the dependence of energy spread on acceleration phase in a linac, which was set at the downstream of the rf gun. Transverse emittance at the linac exit was also measured with Q-scan method.

WEPA06 Coherent Diffraction Radiation as a Tool for Longitudinal Profile Measurements of Short Electron Beams.

K. Lekomtsev, R. Ainsworth, G.A. Blair, G.E. Boorman, V. Karataev, M. Micheler (JAI) R. Corsini, T. Lefevre (CERN)

Electron beam profile monitoring is vital for the installations of the next generation light sources such as a Linear Collider and an X-ray Free Electron Laser (XFEL). In linear colliders a short beam is required for better luminosity. In XFELs a short bunch is required by users to perform time resolved experiments. Therefore a robust, non-invasive and simple in use method for the longitudinal bunch length monitoring is essential for optimal accelerator performance. Coherent diffraction radiation(CDR) is a promising phenomenon for the beam profile measurements. A setup for investigation of CDR from the targets with various configurations as a tool for non-invasive longitudinal diagnostics has been installed in a CRM line of the CLIC Test Facility 3(CERN)[1, 2]. In this report we present the status of the experiment and results on interferometric measurements of CDR from a single target configuration. Studies on downstream background contribution in the CRM line have been performed. Recently we have upgraded the system by installing a second target. In this report we shall also demonstrate the results on simulations of CDR spatial distribution from the two target configuration.

WEPA07 Variable Gap Undulator for 1.5-48 keV Free Electron Laser at LINAC Coherent Light Source

C. Pellegrini (UCLA) J. Wu (SLAC)

Success in commissioning the world's first x-ray (0.15-1.5 nm) free electron laser (FEL) - the LINAC Coherent Light Source (LCLS) - at SLAC National Accelerator Laboratory opens the gate for new science. Further improving the FEL spectrum bandwidth, shortening the FEL pulse temporal duration, and generating even higher energy x-ray photons are urged by various potential users. In this paper, we study the possibility of generating femtosecond duration X-ray pulses with a variable photon energy from 1.5 to 48 keV, using an electron beam with the same characteristics of the LCLS beam, and a planar undulator with additional focusing. We assume that the beam energy can be changed, and the undulator has a variable gap, allowing the undulator parameter to be changed from zero to a maximum value. It is assumed to be operated in an ultra-low charge and ultra-short pulse regime.

WEPA09 **A Compact Electro Optical Bunch Length Monitoring System - First Results at PSI**

F. Mueller, P. Peier, V. Schlott (PSI) B. Steffen (DESY)

Electro Optical (EO) sampling is a promising non-destructive method for measuring ultra short (sub picosecond) electron bunches. A prototype of a compact EO bunch length monitor system for the future SwissFEL facility was designed and built at PSI. Its core components are an optical setup including the electro optically active crystal and an Ytterbium fiber laser system which emits broadband pulses at 1050nm. The new monitoring system is described in detail and first experimental results from the SLS injector are presented.

WEPA10 **Electro Optical Measurement of Coherent Synchrotron Radiation for Picosecond Electron Bunches With Few pC**

B. Steffen (DESY) F. Mueller, P. Peier, V. Schlott (PSI)

Electro Optical (EO) sampling is a promising non-destructive method for measuring ultra short (sub-ps) electron bunches. The FEMTO slicing experiment at the Swiss Light Source modulates about 3 pC of the 5 nC electron bunch longitudinally. The coherent synchrotron radiation (CSR) emitted by this substructure was measured in a single shot EO technique in gallium phosphide (GaP) using pulses from an Yb fiber laser. The arrival time jitter and the broadening of this ps long structure over several turns of the synchrotron could be measured with sub-ps resolution.

WEPA11 **The MAX IV Injector as a Soft X-Ray FEL Driver**

S. Werin, N. Cutic, M. Eriksson, F. Lindau, S. Thorin (MAX-lab)

The MAX IV injector is funded and under construction. It is designed to drive a Short Pulse Facility generating spontaneous incoherent photon pulses in the keV range with pulse lengths below 100 fs in the first phase of the project. This source will with minor modifications be able to drive a Free Electron Laser down into the soft X-ray region and with an extended energy a full X-ray FEL at 1-2 Å. The key feature of the system is the availability of a 3-3.5 GeV linac, a low emittance photo cathode RF-gun and two bunch compressors including sextupoles for linearization. By extracting pulses of 0.1-0.2 nC charge, normalized emittances below 1 mm mRad and peak currents above 3 kA can be achieved. Such pulses are very well suited for a FEL facility. We describe the MAX IV injector system and discuss the options and perspectives for an X-ray FEL at the MAX IV facility.

WEPA13 **Experiment of Terahertz Coherent Transition Radiation Generated from Ultrashort Bunching Beam**

W. Liu, Y.-C. Du, Hua,,J.F. Hua, W.-H. Huang, C.-X. Tang, D. Wu, L.X. Yan (TUB)

In this paper, we will report the experiment of THz coherent transition radiation generated from the ultrashort buching beam produced by the photocathode RF gun. In this experiment, the THz radiation power and frequency are measured by the compact device by hand -made. On the same time, the bunch length is measured by the CTR. On the other hand, the bunching beam compressed by velocity bunching is realized in this experiment. As the bunch length is sensitive the mircowave phase of accelerator tube, for obtaining the strong THz radiation, its radiation intensity versus bunch length and input phase are studied.

WEPA14 **Ultrafast X-Ray Pulse Measurement Method**

G. Geloni (European XFEL GmbH) V. Kocharyan, E. Saldin (DESY)

In this paper we describe a measurement technique capable of resolving femtosecond X-ray pulses from XFEL facilities. Since these ultrashort pulses are themselves the shortest event available, our measurement strategy is to let the X-ray pulse sample itself. Our method relies on the application of a "fresh" bunch technique, which allows for the production of a seeded X-ray pulse with a variable delay between seed and electron bunch. The shot-to-shot averaged energy per pulse is recorded. It turns out that one actually measures the autocorrelation function of the X-ray pulse, which is related in a simple way to the actual pulse width. For implementation of the proposed technique, it is sufficient to substitute a single undulator segment with a short magnetic chicane. The focusing system of the undulator remains untouched, and the installation does not perturb the baseline mode of operation. We present a feasibility study and we make exemplifications with typical parameters of an X-ray FEL.

15:30 | 17:00 **Poster: FEL Technology I (Injector and Linac)**

WEPB01 **Upgrades of Beam Diagnostics in Support of Emittance-Exchange Experiments at the Fermilab A0 Photoinjector**

A.H. Lumpkin, H.T. Edwards, A.S. Johnson, J. Ruan, J.K. Santucci, Y.-E. Sun, R. Thurman-Keup (Fermilab)

It is recognized that beam manipulations such as a flat beam transformation followed by an emittance exchange (EEX) could support a high gain free-electron laser (FEL) push for shorter wavelengths. An ongoing program on demonstrating the exchange of transverse horizontal and longitudinal emittances at the Fermilab A0 photoinjector (A0PI) has benefited recently from the upgrade of several of the key diagnostics stations. The use of an array of 50-micron wide slits to sample the phase spaces to measure divergences of less than 100 microradians resulted in 20 times smaller images with positions distributed over several mm. Improvements in the screen resolution term and reduction of the system depth-of-focus impact by using YAG:Ce single crystals normal to the beam direction will be described. On the longitudinal side, the requirements to measure small energy spreads (<10 keV) in the spectrometer and bunch lengths less than 500 fs dictated specifications. Upgrades to the Hamamatsu C5680 streak camera and the addition of the Martin-Puplett interferometer addressed the short bunch lengths. An example of the EEX tables will be presented.

WEPB02 **Overview and Prospect of Laser Systems for Future X-Ray Free-Electron-Laser Light Sources**

S. Zhang (JLAB) W.E. White (SLAC)

The recent success of the X-ray laser machines at FLASH and LCLS has demonstrated the unrivaled capability of free-electron-lasers for scientific research that demands both extremely short pulses and high photon energy. With the rapid progress in the performance of the existing machines and many proposed facilities, the technical requirements on the conventional lasers such as drive lasers, X-ray seed lasers and diagnostic lasers has reached an new level which goes well beyond the present capability of any commercially available lasers or even lasers that are still under development in research labs. This paper will present a brief overview of the status of the recent development of the high energy and high repetition-rate short pulse laser, in particular those used in high-brightness X-ray FELs. We will discuss the challenges facing the state-of-the-art laser technologies and the near future prospect to meet the requirements set by the FEL machines. In addition, the need and techniques for temporal and spatial shaping will be addressed along with our experimental experience.

WEPB03 **Investigation and Evaluation on Pulse Stackers for Temporal Shaping of Laser Pulses**

S. Zhang, S.V. Benson, J.G. Gubeli, G. Neil, F.G. Wilson (JLAB)

A sophisticated research device such as an advanced photo-cathode injector for a high energy accelerator-based X-ray light source requires drive lasers with a flat-top shape both in time and space in order to generate high-quality short electron beam bunches. There are a number of different ways to spatially shape laser beams, but the practical methods for temporal shaping, in particular in the picosecond or femtosecond regime, are quite limited. One simple way to shape laser pulses is pulse stacking by birefringent crystals. This method has been adopted for several applications. While the method itself has the great advantage of simplicity, the overall performance depends on many factors. In this paper, we will present both analysis and a recent experimental study about important pulse shaping characteristics that, to our knowledge, have not been adequately explored before. Evaluation on the pros and cons of the method and how to improve the overall performance will be discussed.

WEPB04 **Design Considerations for JLAMP Injector**

P. Evtushenko, F.E. Hannon, C. Hernandez-Garcia (JLAB)

The Jefferson Lab FEL facility is considering an upgrade of the existing ERL driven FEL. The main objective of the upgrade is to extend the wavelength reach into the 10 to 100nm range. The upgrade is envisioned to operate a CW electron beam with a repetition rate up to 4.678 MHz and bunch charge of 200 pC. The upgrade requires increasing the maximum electron beam energy to 600 MeV. New 300 MeV CW Linac and two-pass acceleration and energy recovery will be used to reach such a beam energy. A beam with transverse emittance of 1 um and longitudinal emittance of 50 keV-ps is required at the wiggler. The JLAMP injector must generate beam with brightness somewhat better than this to allow for some degradation during acceleration and delivery of the beam to the wiggler. While such beams are generated in pulsed high gradient normal conducting guns it will be one of the main challenges of JLAMP to generate such a beam in a CW system. Compared to the existing JLab FEL injector the beam brightness needs to be increased by a factor of 20. Our considerations and modeling indicate that this is possible. In this contribution we present the current status of the design of such a CW injector.

WEPB05 Conditioning of a New Gun at PITZ Equipped with an Upgraded RF Measurement System

M. Otevrel, G. Asova, J.W. Baehr, M. Hänel, Ye. Ivanisenko, M. Krasilnikov, M. Mahgoub, D.A. Malyutin, A. Oppelt, S. Rimjaem, F. Stephan, M. Tanha, G. Vashchenko, X.H. Wang (DESY Zeuthen) K. Floettmann, D. Reschke (DESY) M.A. Khojoyan (YerPhI) J. Saisut (Chiang Mai University)

A new photocathode electron gun is about to be characterized at PITZ*. It is an L-band normal conducting 1.6 copper cell cavity with improved cooling system. It has the same design as the previously installed gun, characterized at PITZ during the run period 2008/9**. Due to the particle-free surface cleaning method utilizing dry ice, a significant reduction of the dark current was achieved in case of the previously tested cavity. This effect is also expected for the new gun. To improve the accuracy of the RF power measurement and control, a new in-vacuum directional coupler was installed between the T-combiner combining the two 5 MW arms of the RF source and the input coaxial coupler. The new in-vacuum coupler will provide much more accurate information about the RF power in the gun and will allow applying appropriate control feedback. Consequently improved stability of the gun operation is expected. Tuning and conditioning results of this new gun cavity will be presented as well as the results of the measurements of the gradient and the gun phase measurements using this new coupler.

WEPB06 Measurement and Simulation Studies of Emittance for Short Gaussian Pulses at PITZ

M.A. Khojoyan, G. Asova, J.W. Baehr, H.-J. Grabosch, L. Hakobyan, M. Hänel, Ye. Ivanisenko, M. Krasilnikov, M. Mahgoub, M. Otevrel, B. Petrosyan, S. Rimjaem, A. Shapovalov, R. Spesyvtsev, L. Staykov, F. Stephan, G. Vashchenko (DESY Zeuthen) G. Klemz (MBI) S. Lederer (DESY) B.D. O'Shea (UCLA) R. Richter (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH) J. Rönsch-Schulenburg (Uni HH)

The Photo Injector Test facility at DESY, Zeuthen site (PITZ), develops and optimizes electron sources for Free Electron Lasers (FEL's) such as FLASH and European XFEL. The electrons are generated by the photo effect using a cesium telluride (Cs2Te) cathode and are accelerated in an 1.6-cell L-band RF-gun cavity with about 60MV/m maximum accelerating field at the cathode. The upgraded laser system at PITZ produces flat-top and Gaussian laser pulses of different time durations. Emittance measurements have been done for short Gaussian laser temporal profile ~2ps FWHM and for 6.6 MeV electron beam energy. The transverse projected emittance has been measured for various transverse laser spot sizes at the cathode and different low bunch charges to find an optimum condition for thermal emittance measurements. ASTRA simulations were performed for various measurement conditions to estimate the space charge contribution to the emittance. The comparison of emittance measurement results and simulations is presented and discussed in this contribution.

WEPB07 **Investigations on the Impact of Modulations of the Transverse Laser Profile on the Transverse Emittance at PITZ**

M. Hänel, M. Krasilnikov, F. Stephan (DESY Zeuthen)

The Photoinjector Test Stand at DESY, Zeuthen site (PITZ) was established to develop and optimize electron bunch sources for linac-based free electron lasers like FLASH or the future European XFEL. The successful operation of such FELs requires electron bunches of very low normalized transverse emittance of the order of 1 mm mrad at a charge of 1 nC. One key issue for obtaining low-emittance electron bunches is the possibility to influence the electron bunch properties by varying the photocathode laser pulse characteristics. This contribution focuses on the discussion of deviations from the optimum transverse shape of a circular flat-top. Different types of modulations are added to the flat-top and the resulting change in transverse emittance will be discussed based on beam dynamics simulations.

WEPB08 **Transverse Dynamics of an Energy Chirped Electron Beam for Slice Emittance Measurements at PITZ**

Ye. Ivanisenko, F. Stephan (DESY Zeuthen)

Photo Injector Test facility in Zeuthen (PITZ) characterizes high-brightness electron sources. Up to now injector optimization was done towards projected emittance minimization and the studied photo injectors were delivered for operation of the Free electron LASer in Hamburg (FLASH). Now a slice emittance measurement setup has been commissioned at PITZ. In this approach the electron bunch is accelerated to obtain a linear correlation between the particle's momentum and its position within the bunch. A certain momentum range corresponds to a certain longitudinal slice (part) of the bunch. A momentum filtering slit after a dipole cuts out a fraction of the bunch charge . Emittance of the chosen charge portion is measured using a slit scan or a quadrupole scan. This measurement technique uses an energy chirped beam which is not a standard operation mode. It is possible to apply a transformation that corrects for the relative slice rotation in trace space due to the correlated energy spread. In this way we can analyze the beam slice transverse emittance right after the injector section. The correction method is discussed in this work.

WEPB09 **Measurements and Simulations of Emittance for Different Bunch Charges at PITZ**

S. Rimjaem, G. Asova, J.W. Baehr, H.-J. Grabosch, L. Hakobyan, M. Hänel, Ye. Ivanisenko, M.A. Khojoyan, G. Klemz, M. Krasilnikov, M. Mahgoub, M. Otevrel, B. Petrosyan, A. Shapovalov, R. Spesyvtsev, L. Staykov, F. Stephan (DESY Zeuthen) S. Lederer (DESY) M.A. Nozdrin (JINR) B.D. O'Shea (UCLA) R. Richter (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH) J. Rönsch-Schulenburg (Uni HH)

Transverse projected emittance optimization is one of the main research activities at the Photo Injector Test facility at DESY, Zeuthen site (PITZ). The emittance measurement program in the 2009 run period concentrated on projected emittance measurements using a single sit scan technique. The photocathode laser profile has been optimized yielding small emittance. The flat-top temporal profile has been used in the standard projected emittance measurements. The small emittance values down to less than 1 mm-mrad have been measured for the nominal 1 nC bunch charge. Emittance optimizations for lower bunch charges have also been conducted using the same measurement setup

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and procedure as for the case of 1 nC. Numerical simulations have been carried out to compare the results with the measurements. Measurement and simulation results of the transverse emittance for the bunch charges of 0.1, 0.25, 0.5 and 1 nC will be reported and discussed in this contribution.

WEPB10 Low-charge Simulations for Phase Space Tomography Diagnostics at the PITZ Facility

J. Saisut, G. Asova, M. Krasilnikov, S. Rimjaem, F. Stephan (DESY Zeuthen) J. Saisut (ThEP Center, Commission on Higher Education) C. Thongbai (Chiang Mai University)

The Photo-Injector Test Facility at DESY, Zeuthen site (PITZ) aims to optimize high brightness electron sources for linac-based FELs. Since the performance of an FEL strongly depends on the transverse electron beam emittance, the electron source is studied in details at PITZ by measuring the emittance with the help of the Emittance Measurement Systems (EMSYs). The EMSY employs the slit scan technique which is optimized for 1nC bunch charge and, therefore, it might not be an optimal choice for low charge bunches. To extend the ability of the facility for transverse phase space measurements, a module for phase-space tomography diagnostics and its matching section are installed in 2010. The basic components of the module are four screens separated by FODO cells. It is designed for operation with high charge and low energy beams*. This work studies the performance of the tomography module when it is operated with low charge beams. The influence of different beam parameters is evaluated according to the requirement to match the envelope to the optics of the FODO lattice. Simulation results and phase space reconstructions are presented.

WEPB11 Measurement of the Bunch Compression Characteristics by Using a CSR Monitor and a Streak Camera at the SCSS Test Accelerator

H. Maesaka, S.I. Inoue, Y. Otake (RIKEN/SPring-8) S. Matsubara, Y. Tajiri (JASRI/SPring-8)

To measure the femtosecond bunch length (10 - 1000 fs) of the XFEL facility at SPring-8, we developed a coherent synchrotron radiation (CSR) monitor and a streak camera system. A pyro-electric detector was employed to measure the CSR intensity, since the CSR frequency region is THz or far infra-red. The CSR source is a dipole magnet of a chicane section. For the streak camera, we used Hamamatsu FESCA200, which has 200 fs resolution. The temporal structure of the optical transition radiation (OTR) from a metal mirror is observed by this camera. By using these monitors, the bunch length dependence was measured as a function of the rf phase of an S-band accelerator upstream of the bunch compressor at the SCSS test accelerator. A strong correlation between the CSR intensity and the S-band phase was observed. The CSR intensity was small at a debunching phase and the intensity increased as the rf phase was shifted to the bunching direction. Finally, it decreased in the over-bunching region. The bunch length data from the streak camera also had the same tendency. Thus, the bunch compression characteristics were appropriately measured and were consistent with our simulation results.

WEPB12 Cesium Emission in Dispenser Photocathodes

E.J. Montgomery, D.W. Feldman, P.G. O'Shea (UMD) J.R. Harris, J.C. Jimenez (NPS) K. L. Jensen (NRL)

Photocathodes are a promising electron source for future high average current FELs,

with ps response, kA/cm^2 peak and A/cm^2 average current, but will require delicate cesium-based coatings to achieve requisite quantum efficiency (QE). The UMD dispenser photocathode replenishes cesium from a subsurface reservoir, extending lifetime [1]. Recesiation has been shown to reverse oxidizer-induced QE loss [2]. Optimization of pore size and spacing will enable uniform recesiation without emitting excess cesium into the cavity. We here quantify for the first time cesium emission from active dispenser photocathodes and summarize status of experimental and modeling efforts.

WEPB13 Design and Cold Test of A Thermionic Rf Gun Used for Terahertz FEL

X. Yang, W. Bai (CAEP/IAE)

To construct a compact terahertz FEL, a design scheme of a multicell thermionic rf gun with two independent microwave feed-in ports is proposed. The phase displacement between the two independent feed-in ports is adjustable. Numerical simulation results show that the power of back electron bombardment can be reduced notably, and the back electron bombardment power within one rf period is no more than 8 kW. The expected result of the cold test have been achieved, and the cold test work has been completed. Simulation and cold tested results of the gun are introduced detailly in this paper.

WEPB14 Photocathode Drive Laser for SwissFEL

C. Vicario, R. Ganter, C.P. Hauri, S. Hunziker, F. Le Pimpec, C. Ruchert, A. Trisorio (PSI)

For high brigthness photocathode RF gun, proper laser pulses should be used to generate the photocurrent. Transverse uniformity and longitudinal laser flat top profile are predicted to improve the electron beam brigthness. Moreover the laser stability and its sub-ps synchronicity respect to accelerating field are essential for stable and reliable operation. Finally the intrinsic emittance, which is the ultimate limit for the beam emittance, could be tuned by varying the laser photon energy. For this purpose, we developed a mJ frequency tripled Ti:sapphire laser, tunable within 260-283 nm range. Dependence of the intrinsic emittence and of the quantum efficiency with the photon energy has been measured and compared to theory for various metallic photocathode. In this paper the R&D activities aiming at the photocathode laser for the future SwissFEL project are reported.

WEPB15 Commissioning of The Low-Charge Resonant Stripline BPM System For The SwissFEL Test Injector

B. Keil, A. Citterio, M.M. Dehler, V. Schlott, L. Schulz, D.M. Treyer (PSI)

In addition to cavity RF beam position monitors (BPMs) with submicron resolution for undulators, Linac-based FELs often use a 2nd medium-resolution standard RF BPM type e.g. with button or stripline electrodes for locations where the position resolution and drift is less critical and the beam aperture is larger, like in the main linac and beam transfer lines. This paper introduces the architecture and first beam commissioning results of the standard BPM system for the SwissFEL test injector, a 250MeV linac that is progressively being commissioned at PSI in order to perform R&D for the "SwissFEL" 5.8GeV hard-Xray FEL facility proposed at PSI. Since the SwissFEL has a nominal bunch charge range of 10-200pC, the test injector is equipped with 500MHz resonant stripline BPMs that are optimized for high signal-to-noise ratio at low beam charge to support machine operation well below 10pC. First tests with a direct sampling electronics designed at PSI showed a single-bunch resolution of <20um RMS at 2pC. The BPMs can also be used for for charge measurement. They are insensitive to dark current and allow to measure the gun laser-induced bunch charge with <30fC RMS resolution at 2pC.

WEPB16 **Design of the SwissFEL Switchyard**

N. Milas, H.-H. Braun, C.H. Gough (PSI)

The SwissFEL facility will produce coherent, ultra-bright, and ultra-short photon pulses covering a wavelength range from 0.1 nm to 7 nm, requiring an emittance between 0.18 to 0.43 mm mrad. In order to provide electrons to the soft X-ray beam line of the SwissFEL a switchyard is necessary, which will divert the electron beam, with an energy of 3.4 GeV, after the first set of accelerating structures. This switchyard has to be design in such a way to guarantee that beam properties like low emittance, high peak charge and small bunch length will not be spoiled. In this paper we present the schematics and discuss ideas and constraints on the kicker, misalignments and charge fluctuation for the SwissFEL switchyard.

WEPB17 **Sensitivity and Tolerance Study for the SwissFEL**

B. Beutner, S. Reiche (PSI)

The SwissFEL facility will produce coherent, ultra-bright, and ultra-short photon pulses covering a wavelength range from 0.1 nm to 7 nm, requiring an emittance between 0.18 to 0.43 mm mrad. It consists of an S-band rf-gun and booster and a C-band main linac, which accelerates the beam up to 5.8 GeV. Two compression chicanes will provide the required peak current of 2.7 kA. An important issue is the stability of the photon pulses leaving the undulator toward the user stations. Arrival time and peak current stability are crucial factors for the scientific return of the user experiments. Machine stability, especially the rf jitter, will directly affect these important figures. Shot-to-shot jitter is of main interest here since long term drifts can be compensated by slow feedback systems. We present a study on stability including rf tolerances for a new optimised layout of the SwissFEL.

WEPB18 **Microtron Design Using a PIC Code for a Compact THz FEL**

K.H. Jang, Y.U. Jeong, K. Lee, J. Mun, S. H. Park (KAERI)

Electrons are accelerated in the microtron by an alternating electric field of constant frequency in a constant uniform magnetic field. In designing an electron microtron, accurate prediction of electrons trajectories from an electron source to their orbits under related conditions such as RF power and magnetic field is required not only for their stable acceleration but also for increasing the extracted amount of electrons to the FEL undulator. Using the PIC (Particle In Cell) code, specific problems concerned with the acceleration of electrons in the microtron will be treated in the presentation

WEPB19 **Particle Density Effects in the Transition Radiation Energy Spectrum: Theory and Experimental Investigation at PSI**

G.L. Orlandi, R. Ischebeck, V. Schlott (PSI) B. Steffen (DESY)

The spectral and angular distribution of the radiation intensity by a single and individually radiating electron is in principle different from what expected from a high density electron beam. For a given wavelength, the beam particle density modifies via a charge form factor the angular and spectral distributions characterizing the radiation emission by a single electron. In particular, under high energy and high particle density conditions, the Transition Radiation (TR) energy spectrum by an electron beam is expected to be affected by the electron-transverse-density that, at very short wavelength -- even in the visible, in principle - can influence the number of photons emitted at a given wavelength and their angular distribution (brightness increase with density). The investigation of such a phenomenon is relevant to beam diagnostics and to understand the bunch collective effects influencing TR emission. The status of the experimental investigation of the beam-transverse-size effects in the Optical Transition Radiation (OTR) at SLS and, in perspective, at the SwissFEL will be presented and the main formal aspects of the model predicting them will be described.

WEPB20 Novel Nondestructive Shot-by-Shot Monitor to Measure 3D Bunch Charge Distribution With a Femtosecond EO-Sampling

H. Tomizawa, H. Dewa, H. Hanaki, S. Matsubara, A. Mizuno, T. Taniuchi, K. Yanagida (JASRI/SPring-8) T. Ishikawa, N. Kumagai (RIKEN/SPring-8) K. Lee (University of Tokyo) A. Maekawa, M. Uesaka (UTNL)

We developed a single-shot and non-destructive 3D bunch charge distribution (BCD) monitor based on Electro-Optical (EO) sampling with a manner of spectral decoding for XFEL/SPring-8. For the transverse detection, eight EO-crystals (Pockels effect) surround the beam axis azimuthally, and a linear-chirped probe laser pulse with a hollow shape passes through the EO-crystal. We plan to use an amorphous material which has only an even-order field dependence (Kerr effect) in donut shape without assembling eight conventional EO-crystals. The polarization axis of the probe laser should be radially distributed as well as the Coulomb field of the electron bunches. Since the signal intensity encoded at each crystal depends on the strength of the Coulomb field at each point, we can detect the transverse BCD. In the longitudinal detection, we use a prove laser with a broadband square spectrum (> 400 nm @ 800 nm) so that the temporal resolution is < 30 fs, if the pulse width of probe laser is 500 fs. In order to achieve 30-fs temporal resolution, we use an organic EO material, DAST crystal, which is transparent up to 30 THz. We report the first experimental results of our 3D-BCD monitor.

WEPB21 Preliminary Study Results of Collective Noise-Dynamics Control in the LCLS Injector e-Beam

A. Nause, A. Gover (University of Tel-Aviv, Faculty of Engineering) J. Qiang (LBNL) J. Wu (SLAC)

Coherent OTR measurements on the LCLS injector[1] drew interest in collective interaction micro-dynamics in e-beams. Studies of micro-bunching, based on 1D analytical model and 3-D simulations, suggested that the e-beam current-noise can be controlled and suppressed by collective interaction in a drift section[2,3]. This is expected to be expressed in the intensity and radiation pattern of measured COTR. We present preliminary results of beam dynamics simulation with GPT code and IMPACT-T code, together with COTR computations corresponding to recent COTR measurements on the LCLS injector. Based on the simulations we compare the OTR radiation pattern in the case of a random distribution beam (shot-noise dominated) to the case of spatially and temporally coherent beam modulation (pre-bunching) and to the case of a partially coherent beam emerging from a collective-interaction section. We discuss the effect of betatron motion on the beam dynamics in these cases.

WEPB22 **Thermal Emittance Measurement of the Cs2Te Photocathode in FZD Superconducting RF Gun**

R. Xiang, A. Arnold, P. Michel, P. Murcek, J. Teichert (FZD)

The thermal emittance of the photocathode is an interesting physical property for the photoinjector, because it decides the minimum emittance the photoinjector can finally achieve. In this paper we will report the latest results of the thermal emittance of the Cs2Te photocathode in FZD Superconducting RF gun. The measurement is performed with solenoid scan method with very low bunch charge and relative large laser spot on cathode, in order to reduce the space charge effect as much as possible, and meanwhile to eliminate the wake fields and the effect from beam halos.

WEPB23 **Status of the SRF Gun Operation at ELBE**

J. Teichert, A. Arnold, H. Buettig, D. Janssen, M. Justus, U. Lehnert, P. Michel, P. Murcek, Ch. Schneider, R. Schurig, R. Xiang (FZD) T. Kamps, J. Rudolph, M. Schenk (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Elektronen-Speicherring BESSY II) G. Klemz, I. Will (MBI) F. Staufenbiel (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH)

The superconducting RF photo-injector (SRF gun) at FZD is the first operating electron injector of its kind. The gun with a $3\frac{1}{2}$-cell cavity and a frequency of 1.3 GHz produces an electron beam of 3 MeV with a maximum bunch charge of about 400 pC. Also the design values for the acceleration gradient could not be reached with the cavity which is in use at present the SRF gun will improve the beam quality for ELBE users. End of 2009 the beamline was installed which connects the SRF gun with the ELBE accelerator. We will report on the first test and on the progress in applying the SRF gun for user operation.

WEPB25 **Studies of CSR Effect on Beam Compression at NSLS Source Development Laboratory**

S. Seletskiy (BNL)

At BNL NSLS Source Development Laboratory (SDL) 70MeV electron beam is compressed by the bunch compressor consisting of a linac section followed by 4-magnet chicane. The Coherent Synchrotron Radiation (CSR) affects the quality of compressed beam thus limiting FEL performance. In this report we describe the measurements of CSR effect realized at SDL for a range of beam charges at various settings of the bunch compressor. The CSR measurements complemented by careful reconstruction of the longitudinal phase space of the beam allowed the benchmarking of respective numerical simulations and building reliable model of the bunch compressor, which includes collective effects.

WEPB27 **Advanced Beam Dynamics Experiments at SPARC**

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The recent successful operation of the SPARC injector in the Velocity Bunching (VB)

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mode (bunches with 1 kA current with emittance of 3 mm-mrad have been produced) has opened new perspectives to conduct advanced beam dynamics experiments with ultra-short electron pulses able to extend the THz spectrum and to drive the FEL in the SASE Single Spike mode. In particular a new technique called Laser Comb, able to generate a train of short pulses with high repetition rate, has been tested in the VB configuration. Two electron beam pulses 300 fs long separated by 1 ps have been characterized and the spectrum produced by the SASE interaction has been observed. The energy/density modulation produced by an infrared laser pulse interacting with the electron beam near the cathode has been also investigated. In this paper we report the experimental results obtained so far.

WEPB28 NPS Prototype Superconducting 500 MHz Quarter-Wave Gun Update

S.P. Niles, W.B. Colson, K.L. Ferguson, J.R. Harris, J.W. Lewellen, B. Rusnak, R. Swent (NPS) P.R. Cunningham, M.S. Curtin, D.C. Miccolis, D.J. Sox (Boeing Company) T.I. Smith (Stanford University)

The Naval Postgraduate School Beam Physics Laboratory, Niowave, Inc., and The Boeing Company have completed construction of a superconducting 500 MHz quarter-wave gun and photocathode drive laser system. This prototype gun went from conception to initial operation in just under one calendar year. Such rapid progress is due in part to the decision to develop the gun as a prototype, deliberately omitting some features, such as tuners and cathode loadlocks, desired for a linac beam source. This will enable validation of the basic concept for the gun, including high-charge bunch dynamics, as rapidly as possible, with lessons learned applied to the next generation gun. This paper presents results from initial testing of the gun, technical challenges of the prototype design, and improvements that would enhance capabilities in future versions of this novel design.

WEPB29 Simulations on Operation of the FLASH Injector in Low Charge Regime

Y.A. Kot (DESY)

The overall bunch compression in FLASH is limited on the one hand by the rf tolerances and on the other hand by linearization of the particle distribution in the longitudinal phase space. While the last one has been significantly improved after the installation of the third harmonic system during the upgrade 2009-2010, the constraint given by rf tolerances cannot be mitigated significantly. To avoid this limitation one has to operate with shorter bunches already at the injector. Since the bunch length is dominated there by the longitudinal space charge one has to go to lower bunch charges. Working points for the operation of the FLASH injector with 20-500pC bunches have been found by means of the optimization procedure based on ASTRA code. The expected bunch parameters are reported in this paper and compared with the experimental results. Further the discussion on advantages and drawbacks of the injector operation in low charge regime is given.

WEPB30 Multistage Bunch Compression

I. Zagorodnov, M. Dohlus (DESY)

The nonlinearities of the RF fields and the dispersion sections can be corrected with a higher harmonic RF module. In this paper we present an analytical solution for nonlinearity correction up to the third order in a multistage bunch compression and acceleration system without collective effects. A more general solution for a system with collective effects (space charge, wakefields, CSR effects) is found by iterative tracking procedure based on this analytical result. We apply the developed formalism to study two stage bunch compression in FLASH and three stage bunch compression in the European XFEL. Different charges are considered. Analytical estimations of RF tolerances are given.

WEPB31 Multiturn ERLs: Experience and Prospects

N. Vinokurov, E.N. Dementyev, B.A. Dovzhenko, Ya.V. Getmanov, B.A. Knyazev, E.I. Kolobanov, V.V. Kubarev, G.N. Kulipanov, L.E. Medvedev, S.V. Miginsky, L.A. Mironenko, V.K. Ovchar, B.Z. Persov, V.M. Popik, T.V. Salikova, M.A. Scheglov, S.S. Serednyakov, O.A. Shevchenko, A.N. Skrinsky, V.G. Tcheskidov, Y.F. Tokarev, M.G. Vlasenko, P. Vobly, N.S. Zaigraeva (BINP SB RAS)

Multiturn energy recovery linacs (ERL) looks very promising for making ERLs less expensive and more flexible, but have serious intrinsic problems. At this time only one multiturn ERL exists. This Novosibirsk ERL operates with two orbits and two free electron lasers now. The Novosibirsk terahertz radiation user facility provides 0.5 kW average power at 50 - 240 micron wavelength range. Two another orbits and third free electron laser are under construction. The operation experience revealed specific problems of ERLs (especially, of multiturn ones). Some solutions were proposed recently. Possible applications of multiturn ERLs, such as generation of high power and short pulse radiation and internal target operation for nuclear physics, are discussed.

WEPB32 X-band PhotoInjector Studies at SLAC

F. Zhou, C. Adolphsen, Y.T. Ding, Z. Li, A.E. Vlieks (SLAC)

An X-band rf gun at SLAC can reliably operate with 200 MV/m accelerating gradient on the cathode, which is nearly twice the 115MV/m gradient in the LCLS gun. The higher gradient should roughly balance the space charge related transverse emittance growth for the same charge but provide 3-4 times shorter bunch length. SLAC is studying the feasibility of using an X-band rf gun to produce low emittance bunches for applications such as a mono-energetic MeV gamma ray source with LLNL and a photoinjector for a compact X-band FEL. Systematic beam dynamics are being studied for a 5.5 cells X-band gun followed by two 53 cm long high gradient X-band accelerator structures. A fully 3D program, ImpactT, is used to track particles taking into account space charge forces, short-range longitudinal and transverse wakefields, and the 3D rf fields in the structures, including the quadrupole of the couplers. The effects of misalignments of the various elements, such as the drive-laser, gun, solenoid and accelerator structures, are evaluated. This paper presents these results and estimates of the expected emittance vs cathode gradient, and effects of mode mixing between major and parasitic modes.

WEPB33 Investigating Multi-Bunch Operation for the LCLS

F.-J. Decker, R. Akre, A. Brachmann, Y.T. Ding, D. Dowell, P. Emma, J.C. Frisch, P. Hering, Z. Huang, R.H. Iverson, H. Loos, H.-D. Nuhn, D.F. Ratner, T.J. Smith, J.L. Turner, J.J. Welch, W.E. White, J. Wu (SLAC)

The Linac Coherent Light Source at SLAC is a hard X-ray FEL which was designed for single bunch operation. Although most uaer experiments are not interested in many bunches of an S-band linac due to their short (ns) separation, there are some advantages with a few bunches. Starting with two bunches where the delayed light of one bunch is

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used to seed the light of a second bunch, to many more bunches to increase the likelihood of rare target collisions, multi-bunch operation would open more options for the LCLS. In the past the SLAC Linac has operated with a few dedicated bunches for the SLC (SLAC Linear Collider), and up to 1400 bunches for some fixed target experiments, so a few bunches for the LCLS seem possible even with the original single bunch design. This paper will describe how the current RF implementation can support many bunches, while many diagnostics will make it hard to even distinguish the bunches, but averages could be measured. Two bunches seem to be the first logical choice and will be discussed in detail. Initial experimental tests with two bunches are investigated.

WEPB34 **Bunch Compression by Linearising Achromats for the MAX IV Injector**

S. Thorin, M. Eriksson, S. Werin (MAX-lab) P.H. Williams (STFC/DL/ASTeC)

The MAX IV linac will be used both for injection and top up into two storage rings, and as a high brightness injector for a Short Pulse Facility (SPF) and an FEL (in phase 2). Compression is done in two double achromats with positive R56. The natural second order momentum compaction, T566, from the achromats is used together with weak sextupoles to linearise longitudinal phase space. In this proceeding we present the design of the achromat compressors and initial results from particle tracking through the MAX IV Injector in high brightness mode.

WEPB35 **Photon and Electron Beam Diagnostics for the LBNL VHF Photo-Gun**

F. Sannibale, S. De Santis, J. Feng, D. Filippetto, C. F. Papadopoulos, G.J. Portmann, R.P. Wells (LBNL) M.A. Prantil (LLNL)

A high-brightness high-repetition rate photo-gun, based on a normal conducting 187 MHz (VHF) RF cavity operating in CW mode, is under development at the Lawrence Berkeley National Laboratory. The gun has been designed to accelerate the electron bunches up to ~ 750 keV, with peak current, energy spread and transverse emittance suitable for FEL and ERL applications. The APEX (Advanced Photo-injectro Experiment) injector is under construction at the Advanced Light Source Beam Test Facility to fully characterize the performance of an injector based on the VFG gun. The plans for the photon and electron beam diagnostics for APEX are presented.

WEPB36 **Status of the LBNL Normal-conducting CW VHF Electron Photo-gun**

F. Sannibale, B.J. Bailey, K.M. Baptiste, J.N. Corlett, S. De Santis, L.R. Doolittle, J. Feng, D. Filippetto, G. Huang, D. Li, H.A. Padmore, C. F. Papadopoulos, G.J. Portmann, J. Qiang, J.W. Staples, M.E. Stuart, T. Vecchione, R.P. Wells (LBNL) M. J. Messerly, M.A. Prantil (LLNL)

The fabrication and installation at the Lawrence Berkeley National Laboratory of a high-brightness high-repetition rate photo-gun, based on a normal conducting 187 MHz (VHF) RF cavity operating in CW mode, is in its final phase. The cavity will generate an electric field at the cathode plane of ~20 MV/m to accelerate the electron bunches up to ~750 keV, with peak current, energy spread and transverse emittance suitable for FEL and ERL applications. The gun vacuum system has been designed for pressures compatible with high quantum efficiency but "delicate" semiconductor cathodes to generate up to a nC bunches at MHz repetition rate with present laser technology. Several photo-cathode/laser systems are under consideration, and in particular photo-cathodes based on K2CsSb are being developed and have already achieved a QE of 8% at 532 nm wavelength, or close to 20% including the Schottky barrier lowering. The cathode will be operated by a microjoule fiber laser in conjunction with refractive optics to create a flat top transverse profile, as well as a birefringent pulse stacker to create a flat top temporal profile. The present status and the plan for future activities are presented.

WEPB37 **Multiobjective Optimization for the Advanced Photoinjector Experiment (APEX)**

C. F. Papadopoulos, J.N. Corlett, G. Penn, J. Qiang, F. Sannibale, J.W. Staples, M. Venturini (LBNL)

The Advanced Photoinjector Experiment (APEX) is a part of the Next Generation Light Source (NGLS), a proposed soft x-ray FEL concept being studied at LBNL. The requirements for the beam delivered to the FELs pose restrictions on the beam parameters at the injector. In addition, different modes of operation of the machine may pose different requirements on the beam. In order to optimize the performance of the injector, a genetic multiobjective algorithm has been used. A genetic algorithm is used because of the inherent complexity of the beam dynamics at the energy range in question (0-30 MeV) and the large number of parameters available for optimization. On the other hand, the multiplicity of requirements on the beam, which include beam emittance, beam pulse length, energy chirp, as well as pulse shape and peak current, leads to a mutliobjective approach for the optimization technique. In this paper, we present the status of the optimization simulations, using the ASTRA particle-in-cell code. Different injector setups are presented and the resulting transport solutions are compared to each other and the requirements of the downstream sections of the accelerator.

WEPB38 **Commissioning of FERMI's Laser Heater**

S. Spampinati, L. Badano, D. Castronovo, M.B. Danailov, A.A. Demidovich, S. Di Mitri, B. Diviacco, M. Veronese (ELETTRA)

High brightness electron beams needed by X-FELS are potentially affected by microbunching instability developed by the coupling between initial density non homogeneity and impedance due to space charge and synchrotron coherent radiation in bunch compressor. FERMI linac, as other fel drivers, is equipped with a laser heater to cure this instability. In this paper we report the first commissioning results of this device.

WEPB39 **Laser Heater Induced Longitudinal Space Charge Instability in FERMI@Elettra**

S. Spampinati (ELETTRA)

The FERMI@elettra linac is equipped with a laser heater to cure microbunching instability . It consists of an undulator located in a small magnetic chicane that allows seeding of the electron beam with an external laser. The particles interact in a short undulator with the laser pulse and then gain an energy modulation on the scale of the optical wavelength. The R52 transport term of the second half of the chicane leads to smearing of any x-t correlation induced by laser- electron interaction in the undulator while produce a x'-t correlation that at a certain part of the linac comes up as a tilted microbunchig. This density modulation can couples with longitudinal space charge producing energy modulation and energy spread. We study this mechanism in the FERMI@Elettra linac.

WEPB40 **Optics Design and Collimation Efficiency of the FERMI@elettra Collimation System**

S. Di Mitri, S. Ferry (ELETTRA)

Horizontal scraping, geometric and energy collimation of the Fermi@elettra electron beam has been investigated analytically and with the elegant particle tracking code. Beam scraping in the first magnetic bunch length compressor has been characterized in terms of reduction of the transverse emittance and variation of the energy chirp induced by the succeeding linac longitudinal wake field. The locations of the geometric and energy collimators have been identified in the machine lattice. A novel definition of collimation efficiency is proposed that allowed us to identify a configuration of the collimation system that is a compromise between the collimation performance, optics design and available space.

WEPB41 **First Operation of the FERMI@Elettra Bunch Length Monitor System**

M. Veronese, R. Appio, T. Borden, P. Craievich, S. Di Mitri, M. Ferianis, G. Gaio, S. Grulja, M. Tudor (ELETTRA)

Both absolute and relative bunch length measurement are key information for FERMI@Elettra commissioning and operation. In this paper we present the relative Bunch Length Monitor (BLM) system that has been designed and implemented at Sincrotrone Trieste. The first BLM station has been installed downstream the first bunch magnetic compressor (BC1) of FERMI@Elettra. In this paper we report about the first operation of the BLM system; it is based on the power measurement of the coherent radiations. To allow for efficient performances in the extended range of the foreseen bunch lengths for FERMI@Elettra, the system has adopted a pyro detector for coherent edge radiation from the last dipole. Also, the coherent diffraction radiation generated in a ceramic gap located downstream of BC1 is detected by a set of mm-wave diodes. The design of the system, along with its layout, is presented as well as the first measurement results obtained from the FERMI@Elettra compressed bunches.

WEPB42 **Compact Multi-Purpose Optics Insertion in the FERMI@elettra Linac Bunch Compressor Area**

S. Di Mitri, M. Cornacchia (ELETTRA)

The optics design of the first bunch compressor area in the FERMI@elettra linac is presented. Several constraints on the Twiss parameters are set by the preservation of beam quality in the first magnetic compressor, the optimization of diagnostics performance, the collimation process and the beam matching to the downstream lattice. A compact multi-purpose arrangement of magnetic and diagnostic elements is presented that, in principle, satisfies several different needs over a total length of 14m.

WEPB43 **A Low-Energy Deflector for the FERMI@Elettra Project**

P. Craievich (ELETTRA) M. Petronio, R. Vescovo (DEEI)

A microwave deflector is a useful tool to completely characterize the beam phase space by means of measurements of the bunch length and the transverse slice emittance. At FERMI@Elettra, a soft X-ray next-generation light source under development at the Sincrotrone Trieste laboratory in Trieste, Italy, we are installing low-energy and high-energy deflectors. In particular, two deflecting cavities will be positioned at two points in the linac. One will be placed at 1.2 GeV (high energy), just before the FEL process starts; the other at 250 MeV (low energy), after the first bunch compressor (BC1). This paper concerns only the low-energy deflector. The latter was built over the past year in collaboration with the SPARC project team at INFN-LNF-Frascati, Italy and the University of Rome. We will describe the RF measurements performed to characterize the standing wave cavity before the installation in the FERMI linac, and will make a comparison to the simulation achieved with Ansoft HFSS. The preliminary electron bunch length measurements using the RF deflector will also be reported, and we will describe the deflecting voltage calibration procedure and other technical details.

WEPB44 **Cold Testing of a Coaxial RF Cavity for Thermionic Triode RF Gun**

M. Takasaki, M. A. Bakr, Y.W. Choi, K. Ishida, T. Kii, N. Kimura, R. Kinjo, K. Masuda, K. Nagasaki, H. Ohgaki, T. Sonobe, S. Ueda, K. Yoshida (Kyoto IAE)

A triode rf gun has been developed aiming at drastic reduction of back-streaming electrons at the thermionic cathode. Thermionic rf gun shows some advantages over photocathode gun such as low cost, easy operation and high average current, which are suitable for oscillator FELs. However, use of thermionic rf gun leads to inherent back-bombardment effect, which not only limits the macro-pulse duration, but also degrades the electron beam quality. In order to reduce the back-streaming electrons, we developed a thermionic triode rf gun which employs coaxial rf cavity much shorter than rf wavelength as the first cell. The phase and amplitude of the electric field for the first cell are independently controlled from successive cells. The results from simulations showed that the back-bombardment power was expected to be reduced by more than 80% without loss of beam brightness. The coaxial rf cavity to be installed in the rf gun for KU-FEL has been developed and a cold test has been performed. In this paper, we will report on the cold test results and comparison of them with the designed performance as well.

WEPB45 **Benchmarking Multipacting Simulation for FEL Components**

P. Stoltz, C. Nieter, C. Roark (Tech-X) J.D.A. Smith (TXUK)

Multipacting is a potential limit on the power one can deliver to different components of an FEL source, including the power couplers and the electron source cathode. Simulation is a main tool in helping to understand and mitigate multipacting. We present recent work on benchmarking multipacting simulation, including comparison with other codes and with rectangular waveguide experiment.

WEPB46 **Resonant Tunneling and Extreme Brightness from Diamond Field Emitters and Carbon Nanotubes**

J.D. Jarvis, C.A. Brau, J.L. Davidson, N. Ghosh, B.L. Ivanov (Vanderbilt University)

We report recent advances in the development of electron sources of extreme brightness approaching the quantum degenerate limit. These cathodes comprise either a diamond field emitter or carbon nanotube and an individual adsorbed atom or molecule. Both emitters are covalent carbon structures and thus have the benefits of high activation energy for atomic migration, chemical inertness, and high thermal conductivity. The single adsorbate produces surface states which result in dramatic resonant enhancement of the field emission current at the allowed energies of those states. The result is a beam with a narrow energy spread that is spatially localized to roughly the size of a single atom. Thus far, we have observed short lived (~1 sec) beams from residual gases of ~6

microamps corresponding to a normalized transverse brightness of ~$3 \cdot 10^{18}$ A/m^2-str. Whereas conventional field emitters have a quantum degeneracy of <10^{-4}, we estimate the degeneracy of our observed beams to be ~0.1. The use of metal adsorbates should stabilize the effect, allow higher current operation, and provide a long lived source whose brightness approaches the quantum limit.

WEPB47 **Design of a High Brightness Electron Linac for FEL Experiments at NSRRC**

A.P. Lee, S.B. Hung, W.K. Lau (NSRRC) N.Y. Huang (NTHU)

The design of a high brightness driver linac for single pass high gain FEL experiments is being studied at NSRRC. Simulation of beam dynamics starting from the cathode of the 2998 MHz photo-injector to linac exit are performed by LiTrack and Elegant. To obtain a ``flat-flat'' distribution of electron bunches, the reverse tracking technique has been used to optimize the longitudinal dynamics. Results of beam dynamics and reverse tracking will be presented in this report.

WEPB48 **Photo-induced Field Emission Spectroscopy for High Brightness Electron Sources**

B. Bornmann, D. Lützenkirchen-Hecht, S. Mingels, G. Mueller (Bergische Universität Wuppertal)

Photo-induced field emission (PFE) combines the short pulse duration of a laser and the low emittance of field emitted electrons from a robust metal or semiconductor cathode which might increase the brightness of electron sources. In PFE, electrons are photo excited to states between the Fermi and vacuum level from where they tunnel into the vacuum subsequently. The systematic investigation of the PFE process requires monochromatic light sources and energy spectroscopy of the emitted electrons. A new UHV system for PFE spectroscopy (PFES) has been constructed. Measurements of the energy distribution of electrons emitted at electric fields of up to 500 MV/m and laser illumination of up to 5 eV in energy will be possible. The resolution of the hemispherical spectrometer is limited by the noise of the retardation potential, the entrance angle of the electrons and the entrance aperture. The commissioning performed with a tungsten needle yielded a spectrometer resolution of less than 50 meV. The acquisition time for a spectrum varies between 5 s and a few minutes. First results on the energy distribution of electrons emitted from different materials will be shown.

WEPB49 **Multi-Stage Gain of the Microbunching Instability**

R.A. Bosch, K.J. Kleman (UW-Madison/SRC) J. Wu (SLAC)

Bunch compression for a free-electron laser (FEL) may cause growth of current and energy fluctuations at wavelengths shorter than the bunch length. This microbunching instability may disrupt FEL performance or it may be used to produce coherent radiation. We give analytic formulas for the microbunching growth and apply them to the Wisconsin FEL (WiFEL).

WEPB50 **Kinetic Microscopic Analysis of Space-Charge Induced Optical Micro-Bunching**

A. Marinelli, J.B. Rosenzweig (UCLA)

Longitudinal space-charge forces can be a major source of micro-bunching instability. We will discuss a three-dimensional theoretical model for the high frequency limit of space-charge interactions leading to density modulation at the optical scale. Particular emphasis will be given to the effect of transverse thermal motion on the angular distribution of micro-bunching and to its connection to the physics of Landau damping in longitudinal plasma oscillations. A comparison with the results of high resolution molecular dynamics simulations will also be discussed.

WEPB51 **Linear Focal Cherenkov Ring Camera for the t-ACTS Injector**

H. Hama, F. Hinode, S. Kashiwagi, M. Kawai, F. Miyahara, T. Muto, K. Nanbu, Y. Tanaka (Tohoku University, School of Scinece)

The t-ACTS (test Accelerator as Coherent THz Source) at Tohoku University will provide intense terahertz radiation employing novel sources such as an isochronous accumulator ring and a pre-bunched free electron laser. Stable production of the very short electron pulse is a key issue for the t-ACTS accelerator system, in which a thermionic RF gun is being used. Particularly observation of the longitudinal phase space of the beam extracted the gun is crucial for efficient bunch compression. Because of space charge effect, the beam has to be diagnosed within a short drift space. We have studied a novel energy spectrometer using Cherenkov radiation (Linear Focal Cherenkov ring camera, LFC-camera). Though the method is valid for the lower energy less than 3 MeV, the energy distribution can be measured immediately at the gun exit. In addition to the present status of the t-ACTS project, we describe the principle of LFC camera and discuss energy resolution, prospect of the direct measurement of the particle distribution in the longitudinal phase space as well.

15:30 | 17:00 **FEL Technology I (Injector and Linac)**
Chair: T. Hara, RIKEN/SPring-8 (Hyogo)

WEOCI1 **Review of Laser Pulse Shaping for High Brightness Beam Generation**

Y.L. Li (ANL)

We review the development of pulse shaping techniques for high brightness beam generation. A scheme of generating a uniform ellipsoidal laser pulse for s is discussed. The scheme is based on the chromatic aberration of a dispersive lens. Fourier optics simulation reveals the interplay of group velocity delay and dispersion in the scheme, as well as diffractions. Particle tracking simulation shows that the beam generated by such a laser pulse approaches the performance of that by an ideal ellipsoidal laser pulse and represents a significant improvement from the traditionally proposed cylindrical beam geometry. The scheme is tested in an 800-nm, optical proof-of-principle experiment at lower peak power with excellent agreement between the measurement and simulation.

WEOCI2 **Fast Distribution of Pulses in Multiple Beam Line Facilities**

W. Decking, V. Balandin, N. Golubeva, F. Obier (DESY)

Superconducting drive linacs for FEL facilities offer long rf-pulses which can accelerate thousands of electron bunches. Individual bunches are distributed to several beam lines for quasi-simultaneous operation of different user stations. We will present various schemes that fulfill this task and take the fast beam distribution of the European XFEL as an example for design choices. The main challenge is the preservation of the excellent electron beam quality, transversely and longitudinally, which leads to demanding hardware requirements to ensure beam stability and advanced electron optics to prevent emittance degradation due to self-fields.

WEOC3 **Construction of 8-GeV C-band Accelerator for XFEL/SPring-8**

T. Inagaki, T. Hasegawa, H. Maesaka, T. Ohshima, Y. Otake, T. Shintake (RIKEN/SPring-8) C. Kondo, T. Sakurai, K. Shirasawa (JASRI/SPring-8)

An 8-GeV C-band (5712 MHz) accelerator is employed as a main accelerator for XFEL/SPring-8. Since a C-band accelerating structure generates a high accelerating gradient of higher than 35 MV/m, the total length of the accelerator fits within 400 m, including the injector and three bunch compressors. We use 64 C-band rf units, which consist of 128 accelerating structures, 64 rf pulse compressors and waveguide components, 64 klystrons and modulators, etc. Mass-production of the C-band rf components has been done by several Japanese manufacturers. The components reliability has been improved during the production, and all the components finally have excellent quality. The production quality was also confirmed by a high power rf test. We achieved the accelerating gradient of 40 MV/m without any problem. Since XFEL realizes high bunch compression with precise control of the energy chirp, the rf should be quite stable. We developed a high precision high voltage charger combined with a low-noise klystron modulator. The pulse-to-pulse stability of the PFN voltage was less than 0.01%. Installation of the components started in August 2009 and was now almost completed on schedule.

WEOC4 **Phase Space Measurements with Tomographic Reconstruction at PITZ**

G. Asova, J.W. Baehr, H.-J. Grabosch, L. Hakobyan, M. Hänel, Ye. Ivanisenko, M.A. Khojoyan, G. Klemz, M. Krasilnikov, M. Mahgoub, M. Otevrel, B. Petrosyan, S. Rimjaem, A. Shapovalov, L. Staykov, F. Stephan, G. Vashchenko (DESY Zeuthen) S. Lederer (DESY) B.D. O'Shea (UCLA) R. Richter (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH) J. Rönsch-Schulenburg (Uni HH) R. Spesyvtsev (UCL) I. Will (MBI)

The major objectives of the Photo-Injector Test Facility at DESY in Zeuthen, PITZ, are research and development of high brightness electron sources suitable to drive FELs like FLASH and the European XFEL. In the 2008/2009 run period the facility has been operated with a new photo-cathode laser system and a dry-ice cleaned RF gun cavity. Characterization of the transverse phase space of the electron source has been performed in details using a single slit scan technique with a dedicated Emittance Measurement System. In preparation for the forthcoming run, a number of quadrupole magnets have been installed and tomography reconstruction with data from quadrupole scans with two magnets has been carried out in semi-parallel manner to the slit scans. This contribution summarizes the experience from the phase-space tomography reconstruction with nominal beam conditions. Advantages and drawbacks of the measurement procedure and the analysis are superimposed and results are compared to ones obtained with the slit scans.

17:15 | **18:15**	**Tutorial** **Chair:** A. Meseck, BESSY GmbH (Berlin)

WETUI1

About Accelerators for X-Ray FELs

M. Dohlus (DESY)

Linac-based X-ray-free-electron lasers require very short bunches of high- brightness electron beams with peak currents of the order of kilo-Amperes and energies of the order of 10GeV. Essential components of a typical drive linac are a laser driven photo injector, the accelerator and a bunch compression system. Non linear effects from external fields (f.i. rf curvature and higher order longitudinal dispersion) as well as self effects due to space charge, wakes and coherent synchrotron radiation have to be considered for machine design. These main components will be described in principle, the layout of some drive linacs will be discussed and the magnitude of higher order effects and of self effects will be estimated.

08:30 | 10:00 **Synchronization and Stability**
Chair: G.J. Hirst, STFC/RAL (Chilton, Didcot, Oxon)

THOAI1 **Femtosecond Synchronization for Next Generation FELs**

J.M. Byrd, L.R. Doolittle, G. Huang, J.W. Staples, R.B. Wilcox (LBNL) J. Arthur, J.C. Frisch, W.E. White (SLAC)

The scientific potential of femtosecond x-ray pulses at linac-driven FELs such as the LCLS is tremendous. Time-resolved pump-probe experiments require a measure of the relative arrival time of each x-ray pulse with respect to the experimental pump laser. To achieve this, precise synchronization is required between the arrival time diagnostic and the laser which are often separated by hundreds of meters. For seeded FELs, synchronization is necessary between the seed and pump laser. We describe an optical timing system based on stabilized fiber links which has been developed for the LCLS. Preliminary results show stability of the timing distribution at the sub-20 fsec level. We present details of the results measured during LCLS operation for the first pump-probe experiment in October 2009 and the present user run starting in April 2010. We conclude with a discussion of potential for development.

THOAI2 **Intra-train Longitudinal Feedback for Beam Stabilization at FLASH**

W. Koprek, C. Behrens, M.K. Bock, M. Felber, P. Gessler, H. Schlarb, Ch. Schmidt, S. Schulz, B. Steffen (DESY) J. Szewinski (The Andrzej Soltan Institute for Nuclear Studies, Centre Swierk) S. Wesch (University of Hamburg)

The Free electron LASer at Hamburg (FLASH) is a linear accelerator of 330m length. It provides laser pulses with pulse duration between 10 and hundreds fs in the soft X-ray wavelength range below 5nm produced in SASE process from electron bunches with an energy up to 1.2 GeV. FLASH works in pulse mode with repetition rate of 10 Hz where up to 800 bunches at a bunch spacing of 1 us are accelerated in one macro-pulse. The electron beam time structure is well suited for fast intra-train feedbacks using beam based measurements incorporated to the Low Level Radio Frequency (LLRF) control system of the accelerator structures to further improve the bunch compressions, bunch arrival and bunch energy stability directly impacting the quality of the FEL photon beam. In this paper, we present the beam based signal pre-processing, the implementation into LLRF system, the mandatory exception handling for robust operation and the imbedding of the real-time ~ 2us latency fast intra-train feedback with feedbacks for the removal of slow and repetitive errors. First results of the achieved intra-train bunch arrival and peak current stability will be presented together with observed limitations.

THOA3 **RF-based Synchronization of the Seed and Pump-Probe Lasers to the Optical Synchronization System at FLASH**

M. Felber, M.K. Bock, P. Gessler, K.E. Hacker, F. Ludwig, H. Schlarb, B. Schmidt (DESY) S. Schulz, L.-G. Wissmann (Uni HH)

At FLASH, UV and soft X-Ray pulses with durations in the order of 10 fs are generated. To fully exploit the opportunities provided by these short laser pulses, an optical synchronization system provides the possibility to synchronize external lasers and stabilize the electron bunch arrival time with 10 fs precision. A seeded free-electron-laser (FEL) section, called sFLASH, is installed upstream of the existing SASE undulators. After higher-harmonic-generation, the femtosecond seed laser pulse needs to be temporarily

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and spatially overlapped with the electron bunch. Furthermore, for time-resolved pump-probe experiments, using an experimental laser and the FEL pulse, either of sFLASH or of the ordinary SASE process, the synchronization between pump and probe laser pulses is crucial. While the best performance for synchronizing these lasers within 10 fs will be achieved by using an optical cross-correlator, in this paper we present a precursor that relies on an RF-based locking mechanism. The setup includes a coarse and a fine phase measurement between the laser pulses of the reference and the synchronized system after their conversion to an RF signal.

THOA4 **On-Line Arrival Time and Jitter Measurements Using Electro-Optical Spectral Decoding**

N. Cutic, F. Lindau, S. Werin (MAX-lab) E. Mansten (Lund University, Division of Atomic Physics)

Electro-optical spectral decoding was used to on-line monitor the arrival time of the electron bunches relative to the seed laser pulse at the test FEL facility at MAX-lab. An infrared chirped pulse coming from the seed laser is influenced by an electron bunch induced birefringence in a ZnTe birefringent crystal and the arrival time is determined from its spectrum. The possibility of running simultaneously with the FEL allowed for a feedback scheme to be built to compensate for the long term drifts in the system. Also, the whole system (the accelerator and the lasers) were synchronized to the power grid frequency. This lock increased the stability and was monitored by the EO setup. Measurements of the bunch length were performed and their correlation with arrival time pointed towards main contributors to the jitter in the system.

10:30 | 12:00 **New Concepts**
Chair: C.B. Schroeder, LBNL (Berkeley, California)

THOBI1 **Laser-wakefield accelerators as drivers for undulator-based light sources**

M. Fuchs, S. Becker, F.J. Gruener, D. Habs, R. Weingartner (LMU) S.M. Hooker (University of Oxford, Clarendon Laboratory) S. Karsch, F. Krausz, Z. Major, A. Popp (MPQ) J. Osterhoff (LBNL) U. Schramm (FZD)

Latest developments in the field of laser-wakefield acceleration (LWFA) have led to relatively stable electron beams in terms of peak energy, charge, pointing and divergence [1--3]. Electron beams with energies of up to 1 GeV have been produced from only few-centimeters long acceleration distances [4]. Driving undulators with these electron beams holds promise for producing brilliant X-ray sources on the university-laboratory scale. In this talk, we will present an experimental breakthrough on this path: our laser-driven soft-X-ray undulator source [5]. In the second part of the talk, we will discuss the physics behind the unique characteristics of laser-wakefield accelerated electron beams such as the intrinsic ltrashort pulse duration (expected to be about 10 fs) and the low normalized transverse emittances (expected to be < pi mm mrad). The properties of state-of-the-art wakefield accelerators as well as their limits will be discussed. Finally new schemes to overcome those limits and further improve the beam quality will be presented.

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THOB2 **Practical solution for compact X-ray FEL laser based undulator.**

V. Yakimenko (BNL)

It was recently suggested[1] to use a laser beam as an undulator for an ultra compact X ray FEL. There are number of challenges in realizing this very attractive approach. This paper will discuss the one related to defining and generating an adequate laser beam. Recent development of a picosecond CO2 laser at Brookhaven ATF allows considering a practical set of laser parameters that would preserve resonant condition over the saturation length of a few mm. Electron beam parameters required for such FEL would be also discussed and will show need for further high brightness beam development. [1] Presentation by Claudio Pellegrini at 48th ICFA Advanced Beam Dynamics Workshop on Future Light Sources. March, 2010

THOB3 **Preliminary Study for the OFFELO**

Y. Hao, V. Litvinenko (BNL)

OFFELO (optics-free FEL oscillator) is a brand new idea for obtaining hard X-ray wavelength radiation using an oscillator without concerning the damage to the mirror. By using an extra electron beam to transport the radiation information, OFFELO also provide pleasant flexibility compared with traditional oscillator scheme. We simulated the lasing process and carry out the saturation condition and explore other properties of this scheme.

THOB4 **Mode Locked Optical Klystron Configuration in an FEL Cavity Resonator**

B.W.J. McNeil (USTRAT/SUPA) N. Thompson (STFC/DL/ASTeC)

Chicanes placed between undulator modules in a high-gain FEL amplifier have been shown to generate a set of axial modes that may be locked to generate attosecond pulse trains in the x-ray [1]. Using numerical simulations, it is shown in this paper that a similar system of undulator/chicane modules may be used in a low-gain FEL cavity resonator to generate a equally spaced set of frequency modes with a spacing much greater than those of the cavity. As with the high-gain FEL amplifier case, these mode can lock to generate a pulse train.

THOB5 **Using the Longitudinal Space Charge Instability for Generation of VUV and X-Ray Radiation**

E. Schneidmiller, M.V. Yurkov (DESY)

Longitudinal space charge (LSC) driven microbunching instability in electron beam formation systems of X-ray FELs is a recently discovered effect hampering beam instrumentation and FEL operation. The instability was observed in different facilities in infrared and visible wavelength ranges. In this paper we propose to use such an instability for generation of VUV and X-ray radiation. A typical longitudinal space charge amplifier (LSCA) consists of few amplification cascades (drift space plus chicane) with a short undulator behind the last cascade. A wavelength compression could be an attractive option for LSCA since the process is broadband, and a high compression stability is not required. LSCA can be used as a cheap addition to the existing or planned short-wavelength FELs. In particular, it can produce the second color for a pump-probe experiment. It is also possible to generate attosecond pulses in the VUV and X-ray regimes. Finally, since the amplification mechanism is broadband and robust, LSCA can be an interesting alternative to self-amplified spontaneous emission free electron laser (SASE

FEL) in the case of using laser-plasma accelerators as drivers of light sources.

13:30 | 15:00 **Poster: Synch. and Stability / X-Ray Optics and Detectors / Application**

THPA01 **Development of a 770 Nm Pump-Probe Laser Directly Triggered by a 1540 nm Optical Master Oscillator at XFEL/SPring-8**

Y. Otake, N. Hosoda, H. Maesaka, T. Ohshima (RIKEN/SPring-8) S. Matsubara (JASRI/SPring-8)

A pump-probe experiment at XFEL/SPring-8 is one of the most prominent parts to extract the future of a coherent short-pulse X-ray laser. A commercial Ti:Sapphire mode-locked laser is presently used as a pump laser, while a probe laser is the XFEL. However, the time jitter of the commercial mode locked laser, as which is caused by the noise of an electrical mode-locking circuit, is around several hundred femto-seconds. This jitter value is not sufficient for a temporal resolution requirement of our pump-probe experiment with a laser pulse width of several ten femto-seconds. To improve this time jitter, the method, using a 770 nm Ti:Sapphire laser amplifiers directly triggered by a 1540 nm master optical oscillator as a time reference signal source for an XFEL accelerator, was devised. This method could eliminate the noise caused by the electrical mode-locking circuit. The basic principle of the method was proved by a preliminary experiment with laser pulse manipulation employing an E/O crystal shutter with a several ten ps response. This presentation describes a basic idea of this pump--probe method, a preliminary experiment set-up to check its feasibility, and experiment results.

THPA02 **Control of the Amplification Process in Baseline XFEL Undulators With Mechanical SASE Switchers**

G. Geloni (European XFEL GmbH) V. Kocharyan, E. Saldin (DESY)

The magnetic gap of the baseline XFEL undulators can be varied mechanically for wavelength tuning. In particular, the wavelength range 0.1 nm - 0.4 nm can be covered by operating the European XFEL with the SASE2 undulator. The length of the SASE2 undulator (256.2 m) is sufficient to independently generate three pulses of different radiation wavelengths at saturation. Normally, if a SASE FEL operates in saturation, the quality of the electron beam is too bad for generation of SASE radiation in the subsequent part of undulator which is resonant at a few times longer wavelength. The new method of SASE undulator-switching based on the rapid switching of the FEL amplification process proposed in this paper is an attempt to get around this obstacle. Using mechanical SASE shutters installed within short magnetic chicanes in the baseline undulator, it is possible to rapidly switch the FEL photon beam from one wavelength to another, providing simultaneous multi-color capability. Combining this method with a photon-beam distribution system can provide an efficient way to generate a multi-user facility.

THPA03 **Scheme for Femtosecond-Resolution Pump-Probe Experiments at XFELs With Two-Color Ten GW-Level X-Ray Pulses**

G. Geloni (European XFEL GmbH) V. Kocharyan, E. Saldin (DESY)

This paper describes a scheme for pump-probe experiments that can be performed at

LCLS and at the European XFEL and determines what additional hardware development will be required to bring these experiments to fruition. It is proposed to derive both pump and probe pulses from the same electron bunch, but from different parts of the tunable-gap baseline undulator. This eliminates the need for synchronization and cancels jitter problems. The method has the further advantage to make a wide frequency range accessible at high peak-power and high repetition-rate. An important feature of the proposed scheme is that the hardware requirement is minimal. Our technique is based in essence on the "fresh" bunch technique. For its implementation it is sufficient to substitute a single undulator module with short magnetic delay line, i.e. a weak magnetic chicane, which delays the electron bunch with respect to the SASE pulse of half of the bunch length in the linear stage of amplification. This installation does not perturb the baseline mode of operation. We present a feasibility study and we make exemplifications with the parameters of the SASE2 line of the European XFEL.

THPA04 **Longitudinal Bunch Arrival-Time Feedback at FLASH**

P. Gessler, M.K. Bock, M. Felber, K.E. Hacker, W. Koprek, F. Ludwig, H. Schlarb, A. Schmidt (DESY) S. Schulz, L.-G. Wissmann (Uni HH)

Electron bunches at the free electron laser FLASH at DESY have a duration of 10 fs to 150 fs and an arrival-time jitter of about 150 fs (rms). It is anticipated that the newly installed optical synchronisation system will stabilize the seed and pump-probe lasers to within ~10 fs. In order to perform reliable and stable seeding, the electron bunch timing jitter needs to be reduced. Bunch arrival-time monitors measure the arrival-time fluctuations at different locations and are used in a beam-based feedback loop to correct the amplitude of the accelerator RF. In order to provide reliable operation and high availability of the bunch arrival-time feedback, intensive efforts have been undertaken in system automation and exception handling. This will be discussed along with the latest results and limitations on the stability of the arrival-times at FLASH.

THPA05 **Performance of the FLASH Optical Synchronization System Utilizing a Commercial SESAM-Based Erbium Laser**

S. Schulz, L.-G. Wissmann (Uni HH) M.K. Bock, M. Felber, P. Gessler, K.E. Hacker, T. Lamb, F. Ludwig, H. Schlarb, B. Schmidt (DESY)

The optical synchronization system of the free-electron laser in Hamburg (FLASH) is based on the stabilized pulse-train distribution of a passively mode-locked laser. This master laser oscillator is based on erbium-doped fiber technology and is built in a sigma-configuration, enabling passive mode-locking through nonlinear polarization evolution. Recently, a commercial laser system has been installed in addition to the existing laser. Besides maintenance-free operation, this SESAM-based laser shows an even lower timing jitter, enabling a tighter synchronization to the accelerator's RF reference. In this paper we report on the commissioning, the characterization and the long-term stabilty of the new laser system, as well as on the performance of the laser with the existing pulse-train distribution scheme and optical front-ends of the synchronization system in comparison to the old one.

THPA06

Real-Time Sampling and Processing Hardware for Bunch Arrival-Time Monitors at FLASH and XFEL

P. Gessler, M.K. Bock, M. Felber, K.E. Hacker, F. Ludwig, H. Schlarb, B. Schmidt (DESY) S. Schulz, L.-G. Wissmann (Uni HH) J. Szewinski (Warsaw University of Technology, Institute of Electronic Systems)

Bunch arrival-time monitors measure the arrival-time of each bunch in the electron bunch train at several locations at FLASH. The temporal reference for the monitors is provided by the optical synchronization system which distributes laser pulses with a repetition rate of 216 MHz and a length of around 200 fs FWHM. The pulses are delivered to the monitors with an arrival-time stability of about 10 fs. The bunch arrival-time is encoded as an amplitude modulation of a laser pulse from the optical synchronization system. These laser pulse amplitudes need to be sampled and processed together with additional input parameters. Because the arrival-time information is used in a feedback loop to adjust the accelerator fields, the signal processing, calibration and transmission of the bunch arrival-time information via a low-latency, high-speed link to an accelerator RF control station is needed. The most challenging problems of the signal processing are the synchronisation of several clock domains, regeneration and conversion of optical laser pulses, on-line calibration, and exception handling.

THPA07

Synchronization System for Shanghai DUV-FEL Facility

B. Liu, Q. Gu, T. Lan, D. Wang, X. Wang (SINAP)

Many attractive experiments including EEHG, cascading HGHG, etc. are carrying out or planning on Shanghai DUV-FEL facility. These experiments need precise synchronization of electron beam and pulsed laser. In this paper we describe the current synchronization system for SDUV-FEL and some related experiment results. We also have the plan to upgrade the synchronization system to pulsed laser based, which will improve the synchronization precision and stability to sub-picosecond level.

THPA08

Study of Beam Based Alignment and Orbit Feedback for SwissFEL

M. Aiba, H.-H. Braun, M. Böge, C. Calvi, T. Garvey, B. Keil, S. Reiche, T. Schmidt (PSI)

Transverse beam trajectory control is of great importance for SwissFEL as the lasing strategy is based on a relatively low energy and low emittance beam compared with other X-FEL facilities, thus aiming at a reasonable construction cost and size of the facility. A study of beam based alignment and orbit feedback has been performed, and a trajectory correction scenario, which would fulfill the beam requirements as well as the hardware constraints, has been set up. The beam based alignment will be discussed for the linac and the undulator section separately because of the much tighter tolerance in the latter. Several correction algorithms are examined using numerical simulations. BPM requirements and orbit feedback concept will be discussed, with reference to some available data on dynamic disturbances such as ground motion at the PSI site, e.g. at the SwissFEL injector test facility currently under commissioning.

THPA09

Beam Stabilization for FEL Machines

A. Kosicek, G. Jug (I-Tech)

Beam stabilization in terms of control of bunch arrival time, energy and trajectory of particle beams has become a clear necessity for accelerators aiming at the highest level of performance, such as FELs. To improve the beam quality and to reach performance

goals different systems should be considered as a whole and work together. At Instrumentation Technologies such systems have been developed and tested on the field. Precise control of amplitude and phase of the accelerating fields is performed with the Libera LLRF, a digital RF stabilization system. The system is ideally coupled with Libera Sync, a low jitter clock distribution system. In parallel, the Libera Brilliance Single Pass system provides high resolution position information that allows accurate control of trajectories through critical machine sections such as bunch compression modules and FEL modulators and radiators. These systems are described in detail in the paper with examples from field measurements.

THPA10 A Thermal Acoustic Energy Monitor for the LCLS Ultra-Bright X-Ray Beam

T.J. Smith, J.C. Frisch, E.M. Kraft, J. Loos, M. Petree (SLAC) G.S. Bentsen (Rochester University)

A prototype device capable of providing average and shot-to-shot X-ray pulse energy measurements based on calorimetric and radiation acoustic processes has been designed, manufactured, and tested at the LCLS. The device consists of a boron carbide target designed to absorb the total energy of an incident X-ray beam which will cause a rapid thermal expansion of the target, generating an ultrasonic vibration. This acoustic signal is measured by piezoelectric sensors bonded to the target's sides, while the beam-induced temperature increase will be monitored by precision resistance temperature detectors (RTDs). Both the temperature change and the amplitude of the acoustic signal are directly related to the photon pulse energy.

THPA11 Transient Optical Gratings for Short Pulse, Short Wavelength Ionising Radiation Studies - Opportunities and Approaches

W.K. Fullagar, D.M. Paganin (Monash University, Faculty of Science) C.J. Hall (ASCo)

From a detection perspective, short wavelength phase information is lost when event sizes exceed radiation wavelengths, making conventional holography impossible above a material-dependent quantum energy limit. Despite this, and prior to the invention of lasers or holography, Bragg's X-ray microscope* opened the door to optical computation in short-wavelength studies using spatially coherent visible light, including phase retrieval methods. This optical approach lost ground to semiconductor detection and digital computing in the 1960s. Since then, visible optics such as spatial light modulators, array detectors and femtosecond lasers have become widely available, routinely allowing versatile and computer-interfaced imposition of optical phase, detection, and molecular coherent control in pump-probe studies. Today, FELs begin to offer opportunities for atomic resolution and ultrafast studies. Thus we investigate an overlooked aspect of Bragg's X-ray microscope: the short-wavelength to visible-wavelength, incoherent to coherent conversion that is a necessary prerequisite for coherent optical computations. Some potential approaches, techniques and opportunities are outlined.

THPA12 The Effects of Grazing Incidence Mirror Roughness on Coherent Radiation Propagation for the X-Ray FEL Oscillator

R.R. Lindberg, K.-J. Kim (ANL) G.-T. Park (University of Chicago)

The effects of surface roughness on the propagation of x-ray beams whose quality and coherence matches that predicted for an x-ray free-electron laser oscillator are analyzed.

The scattering from a rough surface is calculated perturbatively in the roughness using direct boundary condition matching* and the distorted-wave Born approximation**, and it is shown that the closed-form solutions are identical through second order. These expressions are analyzed under the limits of long and small wavelength perturbations, and an explicit connection to the widely-used Kirchoff/tangent-plane approximation is presented. Finally, the derived reflectivity expressions are used to calculate the mode profile of a high-coherence x-ray beam after reflection from a high-quality grazing incidence mirror.

THPA13 **Preliminary Results of the Multidisciplinary ERL-FEL Program and the Laser Cleaning of Nuclear Power Reactors**

E.J. Minehara (WERC)

A Multidisciplinary and developmental program of the superconducting energy recovery Linac-based free-electron laser and superconducting linac module will be briefly reported and discussed here. Preliminary results of the cooling the superconducting linac module down to 4K as the first activities will be presented. The feasibility study of the laser cleaning for the nuclear power reactor will be added to present the application example using the laser and RI-contaminated samples, and conceptual plan.

THPA14 **A Spectral Calibration Scheme for Terahertz FEL Radiation**

F.J.P. Wijnen, R.T. Jongma, A.J.A. van Roij, W.J. van der Zande (Radboud University) G. Berden (FOM Rijnhuizen)

At the Radboud University in Nijmegen, the Netherlands, we are constructing the free electron laser FLARE, which will operate in the terahertz gap, generating light from 0.2 to 3 THz (100 - 1500 micrometer wavelength). FLARE operates in a short pulse mode with bandwidth limited pulses and a spectral resolution about 1%, but also in a spectroscopic mode with a bandwidth of 10-5. The spectroscopic mode will be realised by generation of a 3 GHz frequency comb in combination with extra-cavity filtering selecting a single mode of the frequency comb. One of the challenges for this system is to perform the spectral calibration of the generated light, in particular for the spectroscopic mode, over the large spectral range that is difficult to access directly. Upconversion of the THz light to the near-infrared (NIR) spectral region, by sum and difference frequency generation with a NIR laser, allows the calibration to be performed with standard optical detectors (as shown at the cw UCSB-FEL). We present the results of experiments performed at FELIX that demonstrate the high sensitivity of this technique and discuss new schemes to extend this technique for FLARE's spectroscopic mode.

THPA15 **Numerical Simulation of Kolmogorov Entropy in a Free-Electron Laser with Ion-Channel Guiding**

B. Maraghechi, M.H. Rouhani, E. Salehi (AUT)

The dynamical stability of electron trajectories in a free-electron laser with planar wiggler is studied. The analysis is based on the numerical simulation of Kolmogorov entropy to investigate how the separation of the trajectories of two neighboring electrons in the six-dimensional phase space evolves along the undulator. Self-electric and self-magnetic fields are taken into account and an adiabatically tapered wiggler magnetic field is used in order to inject the electrons into the wiggler. A considerable decrease in the dynamical stability of electron trajectories was found near the resonance region. It was found that self-fields decrease the dynamical stability of electron trajectories in group I orbits and increase it in group II orbits. Furthermore, the electromagnetic radiation weakens the dynamical stability of electrons as it grows exponentially and become very intense near the saturation point.

THPA16 **Nonlinear Traveling Waves in an Electromagnetically Pumped Free Electron Laser**

B. Maraghechi, M. Olumi, M.H. Rouhani (AUT)

The relativistic cold fluid model is used to study the propagation of the nonlinear traveling wave in a free electron laser (FEL) with electromagnetic wiggler. It is convenient to transform the relevant equations to the frame of reference rotating with the wiggler. The traveling-wave ansatz is employed to obtain three coupled, nonlinear ordinary differential equations that describe the nonlinear propagation of the coupled wave. Saturation and solitary waves in FELs with electromagnetic wiggler may be investigated using these equations. In the small signal limit, the wave equations are linearized and the dispersion relation for the traveling wave is obtained. The numerical solution of the traveling-wave dispersion relation reveals the range of parameters for its unstable solutions. Instability curves with two peaks are found, for which the phase velocity is smaller and larger than the beam velocity.

13:30 | 15:00 Poster: New concepts

THPB01 **A Method for Generating Dominant Higher-Order Optical Modes in an FEL**

E. Hemsing, J.B. Rosenzweig (UCLA)

A technique by which one can generate and amplify a fully coherent higher-order optical mode is described. The proposed scheme utilizes the higher harmonic interaction in an inserted laser-driven modulator section to microbunch the electron beam such that optical modes above the fundamental will be dominantly excited in a downstream undulator section.

THPB03 **Comparative Study of the FERMI@elettra Linac with One and Two-stage Electron Bunch Compression**

S. Di Mitri, M. Cornacchia, P. Craievich, G. Penco (ELETTRA) S. Spampinati (University of Nova Gorica) M. Venturini, A. Zholents (LBNL)

Two machine configurations of the electron beam dynamics in the FERMI@elettra linac have been investigated, namely the one-stage and the two-stage electron bunch compression. One of the merits of the one-stage compression is that of minimizing the impact of the microbunching instability on the slice energy spread and peak current fluctuations at the end of the linac. Special attention is given to the manipulation of the longitudinal phase space, which is strongly influenced by the linac structural wake fields. The electron bunch with a ramping peak current is used in order to obtain, at the end of the linac, an electron bunch characterized by a flat peak current profile and a flat energy distribution. Effects of various jitters on electron bunch energy, arrival time and peak current are compared and relevant tolerances are obtained.

THPB04 **Emittance Growth Induced by Microbunching Instability in the FERMI@Elettra High Energy Transfer Line**

S. Di Mitri, M. Cornacchia (ELETTRA) W.A. Barletta (LBNL)

Simulations of the microbunching instability through the FERMI@elettra lattice have been carried out with elegant particle tracking code. This paper focuses on the emittance growth induced by the microbunching instability in the high energy transfer line that guides the electron beam from the linac to the undulator chain. The perturbation to the transverse emittance induced by coherent synchrotron radiation and longitudinal space charge as function of the R56 transport matrix element in the transfer line have been investigated separately and in the presence of their mutual interaction. Simulation results show that the betatron phase mismatch may have a detrimental impact on the final beam emittance.

THPB05 **Velociraptor: LLNL's Precision Compton Scattering Light Source**

F.V. Hartemann, F. Albert, S.G. Anderson, C.P.J. Barty, A.J. Bayramian, R.E. Bonnanno, T.S. Chu, R.R. Cross, C.A. Ebbers, D.J. Gibson, T.L. Houck, R.A. Marsh, D.P. McNabb, M. J. Messerly, R.D. Scarpetti, M. Shverdin, C. Siders, S.S.Q. Wu (LLNL) C. Adolphsen, E.N. Jongewaard, Z. Li, T.O. Raubenheimer, S.G. Tantawi, A.E. Vlieks, J.W. Wang, F. Zhou (SLAC) V.A. Semenov (UCB)

Recent progress in accelerator physics and laser technology have enabled the development of a new class of tunable x-ray and gamma-ray light sources based on Compton scattering between a high-brightness, relativistic electron beam and a high intensity laser pulse produced via CPA. A precision, tunable, monochromatic ($< 0.4\%$) source driven by a compact, high-gradient X-band linac designed in collaboration with SLAC is under construction at LLNL. High-brightness (250 pC, 3.5 ps, 0.4 mm.mrad), relativistic electron bunches will interact with a Joule-class, 10 ps, diode-pumped CPA laser pulse to generate tunable γ-rays in the 0.5-2.5 MeV photon energy range. This gamma-ray source will be used to excite nuclear resonance fluorescence in various isotopes. A very compact version of the accelerator (2.5 m) will also be used to generate medical x-rays in the 15-25 keV range. Fields of endeavor include homeland security, stockpile science and surveillance, nuclear fuel assay, and waste imaging and assay. The source design, key parameters, and current status will be discussed, along with important applications, including nuclear resonance fluorescence and high precision medical imaging.

THPB06 **An Analytical Model of Coherent Electron Cooling**

G. Wang, V. Litvinenko (BNL) S.D. Webb (Stony Brook University)

We present an analytical model to investigate the evolution of the electron density in all three sections of the coherent electron cooler, i.e. the modulator, the FEL amplifier and the kicker. Assuming an infinite electron beam with kappa-2 velocity distributions, we solve linearized Vlasov-Maxwell equations for each section taking into account the effects from space charge, energy spread and velocity modulation.

THPB08 **FEL-Based Spin Cooling**

V. Litvinenko (BNL)

Access to the particle spin degrees of freedom is essential for unraveling the underlying forces between colliding particles in modern colliders. In this talk I present novel method of polarizing ultra-relativistic hadron beams using FEL-based spin cooler. This technique could potentially turn LHC in a polarized hadron collider and dramatically improve both polarization and choice of polarized species in RHIC. In addition, this can be the only possible technique to polarize antiprotons and other unique species.

THPB09 **Critical Issues in Laser Undulator and Compton Scattering Based XFEL Concept**

Y. Kim, Y.C. Jing, S.-Y. Lee, T.H. Luo, X. Pang, P.E. Sokol (IUCF)

Recently, several groups suggested the laser undulator and Compton scattering based compact XFEL concept. Since the period of the laser undulator is about one hundred thousand times shorter than that of conventional permanent-magnet undulaltor, generation of hard X-rays at 0.1 nm range can be possible with 25 MeV range low-energy electron accelerators. In Indiana University, we also checked its feasibility to build a compact XFEL facility. But we found several critical issues and difficulties to realize the new XFEL concept. In this paper, we report our feasibility study results, critical issues, and difficulties to realize the compact XFEL facility, which is based on the laser undulator and the Compton scattering.

THPB10 **A Laser-Cooled High-Brightness Electron Source for a Small-Scale SASE-FEL**

S.B. van der Geer, O.J. Luiten, M.J. de Loos (TUE) S.B. van der Geer (Pulsar Physics)

At Eindhoven University of Technology laser cooled sources have been shown to produce very short electron pulses of exceptionally high brightness. These extremely high quality bunches are produced by near-threshold ionization of a laser-cooled gas in a magneto optical trap. This ultra cold source is characterized by an effective electron temperature of ~10 K, which is 2-3 orders of magnitude lower than conventional photoemission sources. The low temperature results in bunches with extremely low transverse emittance making them ideal to drive a SASE-FEL. In this paper we will investigate the use of a laser-cooled source for a 0.1 nm SASE-FEL. The exceptionally low emittance significantly reduces the energy requirements for the FEL and therefore this new source can possibly bring SASE-FEL techniques down to conventional university laboratory scales.

THPB11 **Intracavity Backscattering of FEL Photons: Generation of Polarized Electron-Positron Pairs and Gamma Ray Lasers**

E. Sabia, G. Dattoli, M. Quattromini, V. Surrenti (ENEA C.R. Frascati)

We discuss the possibility of exploiting the intracavity backscattering of FEL laser photons to realize a source of gamma rays to be exploited for the production of polarized positrons. We analyze the concrete feasibility of such a device and the advantages it offers with respect to other schemes. We develop a preliminary design of an electron-positron recombination device for the generation of a ``gamma ray laser''.

THPB12 **Electron Beam Cooling and Conditioning by Thomson Scattering**

C.B. Schroeder, E. Esarey, W. Leemans (LBNL)

Thomson scattering is examined as a method for cooling and conditioning electron beams. As a beam radiates via Thomson scattering, it is subsequently cooled, i.e., the mean energy, normalized energy spread, and normalized emittance are reduced in a similar manner. Thomson scattering can also provide a quadratic correlation between the electron energy deviation and the betatron amplitude of the electrons. This conditioning results in enhanced gain in free-electron lasers. Quantum excitation places serious limitations on the minimum energy spread and normalized emittance that can be obtained by laser cooling, and implies conditioning must occur at high laser fluence and moderate electron energy. Conditioning of x-ray free-electron lasers should be achievable with present laser technology.

THPB13 A Simulation for the Optimization of Bremsstrahlung Radiation for Nuclear Applications Using Laser Accelerated Electron Beam

H.H. Lee, K. Min (KAIST) Y.U. Jeong, K. Lee, S. H. Park (KAERI) H. Seo (Hanyang University) H. Shim (Korea University)

Laser accelerated electron beam can be a compact source for high energetic photon generation for nuclear application. A simulation code using GEANT4 has been developed for the estimation of Bremsstrahlung radiation from laser accelerated electron beams impinging on a metalic target and the photonuclear reaction of a sample target. It includes ElectroMagnetic physics , Photonuclear reaction and Radio Active Decay physics, so that the calculation from Bremsstrahlung radiation to decay process can be conveyed in series. The energy and angular distribution of Bremsstrahlung radiation depending on different target thickness and electron parameters as well as the emission spectrum by radioactive decay due to photonuclear reaction can give us an idea of optimal condition for the desired nuclear applications. We discussed the critical issues of high energy photon generation for photonuclear reaction experiments.

THPB14 FEL Oscillators With Tapered Undulators

G. Dattoli (ENEA C.R. Frascati) P.L. Ottaviani, S. Pagnutti (ENEA-Bologna) E. Sabia (ENEA Portici)

FEL oscillators operating with tapered undulators have been discussed in the past, but the relevant theory and phenomenology is not widespread known as it should. Some misconceptions, regarding the role of the longitudinal mode competition and selection are still persistent and the role of pulse propagation effects does not appear fully understood. We will establish practical formulae concerning the FEL operation with a linear tapering (namely with undulators exhibiting an on axis field amplitude depending linearly on the longitudinal coordinate). In particular we derive the gain dependence vs. the tapering depth, the gain saturation formula, the tapered saturation intensity and the efficiency factor vs. tapering depth. Furthermore we will discuss the influence of the tapering on the harmonic generation. We will discuss the pulse propagation effects and the interplay between slippage, short pulses and tapering, the role of lethargy and the gain and efficiency dependence on the cavity detuning. Finally we develop some criteria aimed at optimizing the tapering in FEL oscillators.

THPB15 Generation of Variable Polarisation in a Short Wavelength FEL Amplifier

L.T. Campbell, B.W.J. McNeil (USTRAT/SUPA) B. Faatz (DESY)

So far, short wavelength Free Electron Laser amplifiers have produced linearly polarised radiation. For several important classes of experiment, variable polarisation is required. For example, in the wavelength range from 1.5 to 2.5 nm, light polarisation is important in characterising magnetic materials where measurements depend critically upon the handedness of the polarisation. It is therefore important that the polarisation does not

fluctuate between measurements. In this paper, we study possible methods to generate variably polarised light and consider its shot-to-shot stability.

THPB16 **Generation of Attosecong X-Ray Pulses With a Pre-Density Modulation Enhanced Self-Amplified Spontaneous Emission Scheme**

C. Feng, D. Wang, T. Zhang, Z.T. Zhao (SINAP)

Attosencond x-ray free electron lasers (FEL) have the potential to open new regimes in many scientific fields. Many FEL schemes are proposed to provide such attosencond x-ray pulses. Recently we propose the pre-density modulation (PDM) scheme to enhance the microbunching and reduce the energy spread which is caused by the additional seed laser of a seeded FEL scheme. Here we study the feasibility of using a PDM enhanced self-amplified spontaneous emission (SASE) scheme to generate intense attosecond x-ray pulse.

THPB17 **Enhance the Seeded Free-Electron Laser Schemes by a Pre-Density Modulation on the Electron Beam**

C. Feng, D. Wang, Z.T. Zhao (SINAP)

The high-gain seeded free-electron laser (FEL) schemes are capable of producing coherent radiation in the short wavelength regions. In this letter, we introduce a pre-density modulation (PDM) on the electron beam to enhance the performance of seeded FEL schemes and significantly extend the short-wavelength range. The PDM is used to enhance the microbunching and reduce the electron energy spread of seeded FEL schemes by gathering most of the electrons in the phase range which makes a contribution to the microbunching. With the nominal beam parameters of the Shanghai soft X-ray free-electron laser (SXFEL) project, we show that using the PDM enhanced echo-enabled harmonic generation (EEHG) scheme, coherent x-ray radiation in the ``water window'' (2-4 nm wavelength) can be generated directly from a 240nm UV seed laser.

THPB18 **Experimental Studies of Volume Fels With a Photonic Crystal Made of Foils**

A. Gurinovich, V.G. Baryshevsky, N.A. Belous, V.A. Evdokimov, E.A. Gurnevich, P.V. Molchanov (Belarussian State University, Scientific Research Institute of Nuclear Problems)

Volume Free Electron Laser (VFEL) is a peculiar kind of radiation generators using volume multi-wave distributed feedback*. Recent years applications of a ``grid'' photonic crystal (crystal-like artificial periodic structure) as a volume resonator for VFEL operation are intensively studied. Theoretical analysis** shows that a periodic metal grid does not absorb electromagnetic radiation and the "grid" photonic crystal, made of metal threads, is almost transparent for electromagnetic waves within the frequency range from GHz to THz. Operation of Volume Free Electron Laser with a photonic crystal formed by thin metallic threads periodically strained inside a waveguide*** confirmed the above conclusions. In the present paper operation of Volume Free Electron Laser with the photonic crystal built from brass foils strained inside a cylindrical waveguide is discussed. Dependence of radiation yield on the crystal length is studied in the range up to 8 GHz. Experimental results are compared with those obtained for the photonic crystal formed by threads.

THPB19 Characterization of Femtosecond, High Peak-Current Relativistic Electron Bunches From a Laser-Plasma Accelerator

O. Lundh, L. Ammoura, J. Faure, J. Lim, V. Malka, C. Rechatin (LOA) A. Ben-Ismail (LLR) X. Davoine, E. Lefebvre (CEA) G. Gallot (LOB)

Laser-plasma accelerators, driven by ultraintense and ultrashort laser pulses, sustain accelerating gradients of several hundred giga-volts-per-metre and can deliver high quality electron beams with low energy spread, low emittance and up to giga-electron-volt peak energy [1-2]. A previous experiment has shown that the use of two colliding laser pulses can produce a stable source of electrons that is easily tunable in energy [3]. Here we demonstrate, through wide-band spectral measurements of coherent transition radiation (CTR), that electron bunches produced using controlled optical injection have indeed femtosecond duration. The shape and intensity of the measured CTR spectrum agrees with analytical modeling of electron bunches with durations of only a few fs and peak currents of several kA. The measurements are supported by three-dimensional particle-in-cell simulations. We anticipate that these results are important for applications requiring short pulses and high peak currents. By improving other important bunch properties such as the energy-spread and emittance, this would open interesting prospects for future, potentially compact free-electron lasers.

THPB20 Laser-Plasma Electron Acceleration for High Energy Photon Generation

S. H. Park, Y. Cha, Y.U. Jeong, K. Lee (KAERI) H.H. Lee (KAIST)

The generation of quasi-monoenergetic electron beams via laser-plasma interaction has been demonstrated at KAERI. A laser pulse with 30 TW and 30 fs was focused on a helium gas jet target using an off-axis parabola (OAP) mirror with a focal length of 272 mm. Tens of MeV electrons were observed with a divergence of 10 mrad, but, with a quite broad energy spread. Laser accelerated electrons can be a compact, ultra-short source for the high-energy photons, which is desirable to nuclear reaction or activation experiments. It is, therefore, essential to optimize the quality of electrons and/or high energy photons for desired applications, by carefully characterizing the effects on each parameter. Simulations for high energy photon generation and expected activation of samples under development using Geant4 code lead us determine criterion of beam qualities for these applications. We discussed the critical issue for high energy photon generation with electron beams accelerated via laser-plasma interaction.

THPB21 Modulation of Electron Beam Energy and Current in FELs

D.J. Dunning, N. Thompson (STFC/DL/ASTeC) B.W.J. McNeil (USTRAT/SUPA)

The effects of pre-conditioned electron beams on FEL behaviour are considered in simulations and in theory. Under consideration are modulation of electron beam energy and current, using long-scale modulation period relative to the resonant FEL wavelength. Structure can be generated in the radiation field and electron beam with extent of significantly less than the FEL cooperation length, without applying spatio-temporal shifts between the radiation and electron beam*.

THPB22 First Emission of Novel Photocathode Gun Gated by Laser-Induced Schottky-Effect

H. Tomizawa, H. Dewa, H. Hanaki, A. Mizuno, T. Taniuchi (JASRI/SPring-8)

A laser-induced Schottky-effect-gated photocathode gun has been developed since 2006. This new type of gun utilizes a laser's coherency to realize a compact laser source using Z-polarization of the IR laser on the cathode. This Z-polarization scheme reduces the laser pulse energy by reducing the cathode work function due to Schottky effect. A hollow laser incidence scheme is applied with a hollow convex lens that is focused after passing the beam through a radial polarizer. According to our calculations (convex lens: NA=0.15; 60-% hollow ratio), a Z-field of 1 GV/m needs 1.26 MW at peak power for the fundamental wavelength (792 nm). Therefore, we expect that this laser-induced Schottky emission requires just a compact femtosecond laser oscillator. We observed the first emission with a hollow laser incidence scheme (copper cathode illuminated by THG: 264 nm as a pilot experiment). The net charge of 21 pC with 100-fs laser pulse (pulse energy: 2.5 μJ; spot diameter: 200 μm). The maximum cathode surface field was 97 MV/m. This new scheme of gun will be investigated on several metal photocathode materials by comparing radial and azimuthal polarizations at 264, 396,792 nm.

THPB23 Experimental Design of Traveling-Wave Thomson Scattering

A.D. Debus, M.H. Bussmann, T.E. Cowan, A. Jochmann, R. Sauerbrey, U. Schramm, M. Siebold (FZD)

Traveling-wave Thomson scattering* is a novel interaction design that allows circumventing the Rayleigh limit in optical undulators, which is interesting for possible realizations of Thomson scattering sources with photon yields per pulse that are orders of magnitudes beyond current designs. The resulting radiation reaction could even be strong enough for driving an FEL instability. Here we present details on how a Traveling-wave setup has to be implemented in experiment. An emphasis is put on the use of varied-line spacing (VLS) gratings for spatio-temporal beam shaping at large interaction angles to achieve optimal overlap. At the FZD we are using the high-power laser system DRACO (250TW) to realize a Thomson source with electrons from the linear accelerator ELBE or laser-plasma accelerated electrons. We present the current status and further progress towards a head-on Thomson source and a Traveling-Wave Thomson scattering source aiming for high photon yields per pulse.

THPB24 Traveling-Wave Thomson Scattering for Scaling Optical Undulators Towards the FEL Regime

A.D. Debus, M.H. Bussmann, T.E. Cowan, A. Jochmann, R. Sauerbrey, U. Schramm, M. Siebold (FZD)

We present a novel concept for optical undulators* that avoids the restrictions by the Rayleigh limit and thus allows to define interaction length and diameter independent of each other. With an ultrashort, high-power laser pulse in an oblique angle scattering geometry using tilted pulse fronts, electrons and laser remain overlapped while both beams travel over distances much longer than the Rayleigh length. For small scattering angles ($<10^{o}$), where dispersive effects become negligible and interaction lengths scale up to the meter range, we discuss with the help of 1D-calculations the possibility of entering the SASE-FEL regime using optical undulators driven by existing lasers.

THPB25 Proof of Principle: The Single Beam Photonic Free-Electron Laser

T. Denis, K.-J. Boller, P.J.M. van der Slot (Mesa+)

Compact, slow-wave, low energy electron beam radiation sources, like Cerenkov free-electron lasers (FELs), emit high power microwaves. However, they seriously degrade in output power, when scaled towards the THz range (0.1-10 THz). This prevents industry from applying THz radiation, although it would allow many new applications, like chemical selective security surveillance. The photonic free-electron laser (pFEL) is a promising concept for a handheld, tunable and Watt-level THz laser. In a pFEL several electron beams stream through a photonic crystal (PhC) leading to the emission of coherent Cerenkov radiation. The beams emit phase-locked due to the transverse scattering inside the PhC, which allows increasing the output power by increasing the number of beams streaming through the PhC. Therefore, scaling the pFEL's operating frequency towards THz frequencies can be done without loss in output power. Furthermore, compact, low energy electron sources (< 15 keV) can drive the laser, due to the strong deceleration of the light by PhC's. As a proof of principle, we developed the setup for a pFEL operating at 20 GHz to study the interaction between a single electron beam and the PhC.

THPB26 **Electron Transport and Ion Kinetics in Dense, Highly Ionized H, He and Li Discharges**

A.L. Godunov, S. Popovic, A. Samolov, L. Vuskovic (ODU)

The generation of relativistic electron bunch in the laser plasma wakefield accelerator experiments develops in the background of dense plasma conditions. A simple assumption of frozen heavy particles eliminates only partly the complexity of electron transport. We are examining a variety of interaction channels and their influence on the self-injection, self-focusing, self-compression, and acceleration by the photon field. In addition, the ion kinetics dissipates a part of laser power in the case of heavier plasma elements. We have developed a detailed model of the dense plasma feedback and ion kinetics and their effects on the accelerating electrons. This works aims to define the conditions and the extent of the self-injected electron yield and energy concentration.

THPB27 **Teraherz Coherent Synchrotron Radiation Induced by Laser: Saturation Effects**

S. Bielawski, C. Szwaj (PhLAM/CERCLA) M. Adachi, M. Katoh, S.I. Kimura, T. Tanikawa, H. Zen (UVSOR) C. Evain (SOLEIL) T. Hara (RIKEN/SPring-8) M. Hosaka, Y. Takashima, N. Yamamoto (Nagoya University) M. Le Parquier (CERLA) A. Mochihashi (JASRI/SPring-8) M. Shimada (KEK) T. Takahashi (KURRI)

We present a theoretical and experimental study of the coherent emission process occurring when an electron bunch is modulated longitudinally, using an external laser. At UVSOR-II, we perform an energy modulation using an external laser (at 800 nm), that is focused inside an undulator. The bunching then occurs at a much longer wavelength (in the millimeter range) than for harmonic generation or FEL operation. The bunched beam then emits coherently in downstream bending magnets. At low power, the scaling of terahertz power emission versus laser power is quadratic (as for second harmonic harmonic generation). At high power, numerical simulations predict a saturation effect, leading ultimately to a decrease of terahertz emission. Recently, we have been able to explore experimentally this effect with a new laser system (50 mJ), and we could confirm the prediction. Further theoretical works also reveal that the saturation effect is correlated to the appearance of oscillations inside the emitted spectrum. We will show that the spectrum deformation is connected to a very peculiar bunch shape modulation deformation.

13:30 | 15:00 Poster: FEL Technology II (Undulator and Beamlines)

THPC01 **A 65 Mm Period Electromagnetic Undulator Using Sheet Copper for the Coils in SDUV FEL**

M. Zhang (SINAP)

An inexpensive electromagnetic undulator, having been installed in SDUV FEL for Echo modulation scheme experiment, has ten 65 mm periods with maximum field of 0.32T and gap of 12 mm. The coils using copper sheet material are cut to serpentine shapes and assembled in stacks insulated with polymer film. The coils are conduction cooled with imbedded cooling water tubes. Details of the undulator's design, construction, and performance are presented.

THPC02 **A Study on Field Error of Bulk HTSC Staggered Array Undulator Originated from Variation of Critical Current Density of Bulk HTSCs**

T. Kii, M. A. Bakr, Y.W. Choi, K. Ishida, N. Kimura, R. Kinjo, K. Masuda, H. Ohgaki, T. Sonobe, M. Takasaki, S. Ueda, K. Yoshida (Kyoto IAE)

The bulk high temperature superconductor staggered array undulator (Bulk HTSC SAU) has potential to generate strong periodic magnetic field in short period and to control K value without a mechanical gap control structure.* However, availability of the bulk HTSC magnets having matched performance of critical current density is a problem to be solved. In this study, we have numerically and experimentally estimated influence of variation of critical density upon field error. It was numerically found that the field error was naturally compressed, because the difference in critical current density was compensated by natural variation of the region where the supercurrent flows. In the conference, the experimental results of the field error compression and principle of the compression will be discussed.

THPC03 **Undulator Commissioning Spectrometer for the European XFEL**

W. Freund, J. Grünert (European XFEL GmbH)

Photon based commissioning of the European XFEL undulators will require a precise adjustment of the K-parameters of all undulator segments and phasing between these segments. The LCLS approach with a double channel-cut monochromator seems to be an appropriate basis for adaptations, which are necessary in order to get a conceptual design for all three SASE undulators at the European XFEL. We have to take into account the large gap setting range and energy ranges of 1 to 4 Ångströms for SASE 2 and 4 to 16 Ångströms for SASE 3, respectively. The spectrometer will analyze spontaneous radiation from single segments up to the full undulator length. The use of 3rd or 5th order harmonics could be an option, in order to reduce the mechanical adjustment range.

THPC04 **Investigation of the R56 of a Permanent Magnet Phase Shifter**

Y. Li, J. Pflueger (European XFEL GmbH)

In the European XFEL permanent magnet phase shifters are routinely between two undulator segments. Its main purpose is to control the phase of the electrons with respect to the emitted radiation. In addition the path length is dependent on the electron energy, which corresponds to a small R56 . In this paper we investigate the R56 of a permanent magnet phase shifter and propose to use it to fine tune R56 by adjusting the phase shifter gap.

THPC05 **Conceptual Design of a THz Source at the ELBE Radiation Source**

U. Lehnert (FZD) A. Aksoy (Ankara University, Faculty of Engineering)

To extend the wavelength range of possible experiments from the FIR into the THz region a dedicated beamline is planned at the ELBE Radiation Source. The beamline will deliver coherent transition radiation and coherent synchrotron radiation as broad-band (essentially single-cycle) radiation. Superradiant undulator radiation will be produced for a tunable narrow-band radiation source in the 100GHz to 3THz range. This requires a compression of the ELBE electron beam down to 150fs bunchlength. The beam transport and bunch compression scheme as well as the properties of the produced radiation are presented in detail.

THPC06 **R&D Collaboration on Superconducting Insertion Devices Between ANKA-KIT and Babcock Noell**

C. Boffo, W. Walter (BNG) T. Baumbach, S. Casalbuoni, S. Gerstl, A.W. Grau, M. Hagelstein, D. Saez de Jauregui (Karlsruhe Institute of Technology (KIT))

Superconducting undulators show, with respect to permanent magnet undulators, a larger magnetic field strength for the same gap and period length, being able to generate a harder X-ray spectrum and higher brilliance X-ray beams. The worldwide first short period length superconducting undulator is in operation since 2005 at the synchrotron light source ANKA in Karlsruhe. To further drive the development in this field a research and development program has been defined. A 1.5 m long superconducting undulator with a period length of 15 mm is planned to be installed in ANKA at the end of 2010 to be the light source of the new beamline NANO for high resolution X-ray diffraction. The key specifications of the system are an undulator parameter K higher than 2 and a phase error smaller than 3.5 degrees. The coils will be cooled using cryocoolers and should have a capability of withstanding a 4 W beam heat load at 4 K. Here we describe the main features of the 1.5 m long superconducting undulator, the test results of the coils in liquid helium and the test results of a prototype switchable period length device.

THPC07 **Seed Laser and Undulator Options for FEL Project at INFPRL**

F. Scarlat, E.S. Badita, M. Dumitrascu, R.D. Minea, E. Mitru, A.M. Scarisoreanu, E. Sima (INFLPR) V.G. Cimpoca, C. Oros, I. Popescu, M. Voicu (Valahia University, Faculty of Sciences) M.R. Leonovici (Bucharest University, Faculty of Physics)

The FEL project proposal at INFLPR, named RO FEL, has considered the frequency domains from infra-red (IR: E > 1.2 MeV) to hard X-ray (E > 5 keV), dividing it in five spectral domains: infrared (1000 μm > λ > 0.770 μm), violet-vacuum-ultraviolet (V/ VUV: 455 nm > λ > 200 nm), extreme-ultraviolet (200 nm > λ > 10 nm), soft X-ray (10 nm > λ > 0.25 nm) and hard x-rays or indirect ionizing radiation (λ < 0.25 nm). The first stage of the RO FEL Project, identified, by the IR Lab and U/VUV Lab, is based on the principle of high-gain harmonic-generation (HGHG). In this work, we present the application of the HGHG method for the obtaining of the helpful wavelengths in the spectral domain 1000 μm - 200 nm for two Labs, as well as the options for seed lasers and undulators.

THPC08 **Magnetic Characterization of the FEL-1 Undulators for the FERMI@Elettra Free-Electron Laser**

M. Kokole, T. Milharcic, M. Zambelli (KYMA) B. Diviacco (ELETTRA) G. Soregaroli, M. Tedeschi (Euromisure srl)

During 2009 and the first months of 2010, Kyma Srl, the spin-off company set-up by Sincrotrone Trieste, designed and realized all the insertion devices for the undulator chain at the FERMI@Elettra free-electron laser. The insertion devices manufactured and characterized so far are the following: The Laser Heater Undulator, a short, linearly polarized device, already installed in the FERMI linac. The Modulator, a 3.2 m long, linearly polarized undulator. The Radiator, comprising of six APPLE-II variable polarization undulators, each 2.4 m long. All the above devices have been characterized, both from the mechanical and the magnetic point of view. The measured parameters are in good agreement with the design values. This paper presents the most relevant results of the magnetic measurements carried out on all the above undulators, and describes the characteristics and the performance of the dedicated equipment set-up and used for this measurements.

THPC09 **Fel Simulations Using Measured Undulator Errors for FERMI@Elett**

E. Allaria, B. Diviacco (ELETTRA) M. Kokole (KYMA)

The possibility of producing high quality light pulses in new FEL facilities and also extending the tuning range towards shorter wavelength using the harmonic emission is strongly dependent upon the quality of the undulator magnetic field. Initial requirement studies for the undulator quality for FERMI@Elettra were determined by simulating the FEL sensitivity to different random combinations of possible undulator errors. In particular, limits to the allowed phase, trajectory and magnetic strength errors were estimated, including the effects due to possible correlations between different kinds of errors. In this work we present new simulation results that use actual experimental measurements of the magnetic field in undulators built for FERMI's FEL-1. We also predict the effect of these undulator errors on the expected FEL power for several different arrangements of the available undulators.

THPC10 **The Machine Protection System for FERMI@Elettra**

L. Froehlich (ELETTRA) D. Di Giovenale (INFN-Roma II)

FERMI@Elettra is a linac-driven free-electron laser currently under construction at the synchrotron radiation facility Elettra in Trieste, Italy. In order to prevent damage to accelerator components, an active machine protection system (MPS) monitors beam losses along the linac and, if necessary, inhibits the beam production in the injector. Special attention is paid to the protection of permanent undulator magnets from demagnetization by the excessive absorption of radiation. This paper discusses the system architecture and gives an overview of the major diagnostic subsystems: A beam loss position monitor based on the detection of Cherenkov light induced in quartz fibers, an array of discrete ionization chambers, and a system for differential charge loss measurements. The dose deposition in the undulator magnets will be monitored with electronic RadFET dosimeters; first details of the readout system are presented.

THPC11 Cavity BPM Design, Simulations and Testing for the FERMI@Elettra Project

P. Craievich (ELETTRA) M. Dal Forno (DEEI)

The cavity Beam Position Monitor (BPM) is a fundamental beam diagnostic instrument for a seeded FEL, like FERMI@Elettra. It allows the measurements of the electron beam trajectory in a non-destructively way and with sub-micron resolution. The high resolution the cavity BPM is providing relies on the excitation of the dipole mode that is originated when the bunch passes off axis in the cavity. In this paper we present the prototype of cavity BPM developed for the FERMI@Elettra facility. The RF parameters of the cavities have been determined by means of Ansoft HFSS while using the CST Particle Studio the level of the output signals from the cavities have been also estimated. Furthermore, the design of the prototype electronics for the acquisition and the processing of the signals from the BPM cavities is presented as well. The prototype has been installed in the FERMI Linac during the last commissioning phase and preliminary results with the electron beam are also presented.

THPC12 European XFEL Activities at MSL

A. Hedqvist, H. Danared, F. Hellberg (MSL) W. Decking, B. Krause (DESY) S. Karabekyan, J. Pflueger (European XFEL GmbH)

The Manne Siegbahn Laboratory at Stockholm University is currently involved in two separate projects at the European XFEL. The first concerns the fiducialization and characterization of the quadrupole magnets in the undulator sections. A recently upgraded rotating coil system measures the magnetic centre stability during magnet excitation, magnet gradient and field error components. In connection, a coordinate measuring machine is used to fiducialize the quadrupole magnetic centre to better than 0.050 mm. The second project concerns high precision measurements of the undulator temperature. The SASE radiation intensity depends strongly on the undulator period and the magnetic field strength, which are both sensitive to temperature. Instead of keeping the temperature within 0.1 degrees along the undulator tunnel, a temperature compensation scheme can be applied. Here, a change in temperature initiates adjustment of the undulator gap to compensate for changes in magnetic field. A system for undulator segment temperature measurement, with resolution of 0.03 degrees, necessary for the compensation scheme, is presented together with a brief overview of the upgraded rotating coil system.

THPC14 Magnetic Parameters of Ferromagnetic Plates Used for a Solenoid Induced Wiggler

Y. Tsunawaki, M. Kusaba (OSU) M.R. Asakawa, N. Ohigashi (Kansai University)

An adiabatic transition field in a solenoid induced helical wiggler has been successfully generated using staggered Ni plates with different thickness. However, trials using Fe plates instead of Ni plates failed to generate a suitable adiabatic transition field. To elucidate these phenomena, the magnetic behavior of ferromagnetic (Fe,Co,Ni) plates with regard to the thickness dependence was studied by a fundamental electromagnetic calculation with the aid of a field calculation based on the finite element method. The magnetizing field Hd depends on the thickness of a plate and contains the demagnetizing factor Nb depending only on its geometrical size. Furthermore, the magnetization factor fb in a plate would be introduced into the analysis of magnetic parameters. The combination of fb and Nb led to the determination of various magnetic parameters, and then the consistent explanation was made to the generation of the adiabatic transition field in the solenoid induced wiggler.

THPC15 **Status of Plane Grating Monochromator Beamline at FLASH**

S. Dziarzhytski, N. Gerasimova, H. Weigelt (DESY)

High resolution spectroscopy and diffraction experiments need a monochromatic light and a reasonable photon flux. The plane grating monochromator beamline has been installed at FLASH facility by University of Hamburg in close collaboration with DESY. It provides a free choice of best compromise between flux and resolution on the same grating by varying a so-called fixed-focus constant value. The present beamline is equipped with monochromator of SX-700 type and consists of two branches. Covered spectral range expands from 20 to 950 eV. Two branches of the present beamline provide focal spots of 35 μm and 50 μm. We report on capabilities and performance of beamline and ongoing developments such as: (i) Completing monochromator with new gratings to cover a spectral region of higher harmonics. (ii) Introducing filter unit to block incoherent white light, to filter desired wavelength and to attenuate FEL power. (iii) Modification of Kirkpatrick-Baez mirror holder to reduce focal spot from 35 μm to 6 μm. (iv) New beam monitors for simpler alignment.

THPC16 **Optimization of Transfer Beamline for a Compact Microtron-Based THz FEL**

S. H. Park, K.H. Jang, Y.U. Jeong, K. Lee, J. Mun (KAERI) G.M. Kazakevich (BINP SB RAS)

The compact THz FEL driven by a microtron has been developed at KAERI. In order to reduce the FEL system smaller than the existing system at KAERI the shorter transfer line without losing the FEL gain is necessary. One of main problem is how to match the beam optics using a dispersive beam accelerated from a microtron. We discussed here the modification of extraction beamline from the microtron as well as the beam optics to satisfy the requirement for undulator injection.

THPC17 **Design of a Helical Undulator for a Compact THz FEL**

J. Mun, K.H. Jang, Y.U. Jeong, K. Lee, S. H. Park (KAERI)

We are designing a table-top Terahertz free electron laser (THz FEL) for security inspection. A strong undulator and a low-loss waveguide resonator are necessary for the compact THz FEL. We propose a superconducting electromagnetic helical undulator with assistant permanent magnets. The period of the undulator and the maximum field strength are 24 mm and 0.7 T. Numerical analysis of the helical undulator using a 3-D simulation tool will be presented.

THPC18 **Proposal of a Strong and High-Accuracy Hybrid Electromagnetic Undulator for X-FEL**

Y.U. Jeong, B.H. Cha, K.H. Jang, K. Lee, J. Mun, S. H. Park, J.H. Sunwoo (KAERI)

A hybrid electromagnetic (EM) undulator which combines hybrid permanent magnet (PM) undulator into electromagnetic undulator has been investigated and compared with conventional undulator with a 3-D simulation code. Permanent magnets of the undulator reduce magnetic induction strength in the poles to supply strong electromagnetic field to the undulator gap. The hybrid EM undulator shows advantages compared with the hybrid PM undulator in terms of strength, accuracy and temperature stability of the magnetic field. And the magnetic field strength of the hybrid EM undulator has tunable range of 30% by just changing the current of the coils without any mechanical system for changing gap.

THPC20 **Variable Polarization Undulator Options for Soft X-Ray FEL's**

S. Prestemon, D. Schlueter (LBNL)

A variety of technology options are available for the production of variable polarization radiation from FEL's, ranging from the well-established APPLE-II devices used extensively on storage rings to crossed-undulator polarization concepts utilizing high-performance planar undulators, e.g. hybrid permanent magnet, in-vacuum, or superconducting devices. Access to the soft X-ray spectrum requires a consistent selection of electron energy (i.e. linear accelerator structure), undulator technology, and gap and period selection, resulting in cost and risk tradeoffs that must be evaluated and considered in the design and implementation of a large-scale FEL facility. Here the tradeoffs are quantified with respect to variable-polarization undulator technologies to provide guidance for undulator R&D and FEL design decisions.

THPC21 **Spectral Measurements of the X-Ray FEL Beam at the LCLS**

J.J. Welch, F.-J. Decker, Y.T. Ding, P. Emma, J.C. Frisch, Z. Huang, R.H. Iverson, H. Loos, M. Messerschmidt, H.-D. Nuhn, D.F. Ratner, J.L. Turner, J. Wu (SLAC)

Control and knowledge of the spectrum of FEL X-ray radiation at the LCLS can be important to the quality and interpretation of experimental results. Narrow bandwidth spectra are useful in experiments requiring high-brightness beams. Wide bandwidth beams can be particularly useful for calibration via absorption spectra. In recent months, average and single shot spectra of the X-ray FEL radiation at the LCLS were obtained over a range of 800 to 8000 eV, for fundamental and harmonic radiation. Correlations of the spectral distribution with chirp, bunch current, undulator K-taper, and charge were measured. In this paper we present these measurements and discuss the effects on the spectrum of the electron beam energy distribution and undulator taper.

THPC22 **Performance of Bulk HTSC Staggered Array Undulator at Low Temperature**

R. Kinjo, M. A. Bakr, Y.W. Choi, K. Ishida, T. Kii, N. Kimura, K. Masuda, K. Nagasaki, H. Ohgaki, T. Sonobe, M. Takasaki, S. Ueda, K. Yoshida (Kyoto IAE)

The bulk high temperature superconductor staggered array undulator (Bulk HTSC SAU) has several advantages: such as strong magnetic field, potential of short period undulator, K value variability without gap control. In addition to these advantages, the Bulk HTSC SAU can be used near the electron beam because the undulator is expected to show good performance at 20 -- 30 K. In the conference, we will report the expected performance of the undulator at low temperature through magnetic measurement by using a superconducting quantum interference device (SQUID) magnetometer. Also we will report the results of the first operation at 4 -- 77 K of new prototype undulator consisting of a helium cooling system and a 2 T superconducting solenoid.

15:30 | 17:00 **FEL Technology II (Undulator and Beamlines)**
Chair: S. Biedron, ELETTRA (Basovizza)

THOCI1 **Design of Photon Beamlines at the European XFEL**

H. Sinn (European XFEL GmbH)

The European XFEL will provide up to 2700 X-ray pulses during 600 microsecond long pulse trains with a repetition rate of 10 Hz. This leads to a short time heat load of FEL radiation of more than 10 kW in a sub-mm spot on the optical elements averaged over a pulse train and a less collimated high energy spontaneous radiation of similar magnitude. On the other hand, the conservation of coherence properties requires a stability of X-ray optics on the nanometer scale. Cooling concepts for mirrors and monochromators as well as photon damage aspects will be discussed. The conceptual design of photon beamlines and photon distribution schemes to different experimental stations will be presented.

THOCI2 **Characterization of Second Harmonic Afterburner Radiation at the LCLS***

H.-D. Nuhn, F.-J. Decker, Y.T. Ding, P. Emma, J.C. Frisch, Z. Huang, R.H. Iverson, Yu.I. Levashov, H. Loos, M. Messerschmidt, D.F. Ratner, J.L. Turner, J.J. Welch, Z.R. Wolf, J. Wu (SLAC)

During undulator commissioning of the Linac Coherent Light Source (LCLS) x-ray Free Electron Laser (FEL) at the SLAC National Accelerator Laboratory it was shown that saturation lengths much shorter than the installed length of the undulator line can routinely be achieved. This frees undulator segments that can be used to provide enhanced spectral properties and at the same time, test the concept of FEL Afterburners. In December 2009 a project was initiated to convert undulator segments at the down-beam end of the undulator line into Second Harmonic Afterburners (SHAB) to enhance LCLS radiation levels in the 10 -- 20 keV energy range. This is being accomplished by replacement of gap-shims increasing the fixed gaps from 6.8 mm to 9.9 mm, which reduces their K values from 3.50 to 2.25 and makes the segments resonant at the second harmonic of the upstream unmodified undulators. The paper reports experimental results of the commissioning of the SHAB extension to LCLS.

THOC3 **Variable-period Permanent Magnet Undulators**

N. Vinokurov, O.A. Shevchenko, V.G. Tcheskidov (BINP SB RAS)

To change the wavelength of undulator radiation people frequently use the variation of undulator magnetic field amplitude. Another option is to change the undulator period. The scheme for such undulator is described. It provides possibility to change both period and number of periods. For the set of undulator sections (like in x-ray FELs) mechanical motion of periods eliminates the necessity of phase shifters between the undulator sections. Magnetic field calculations for some interesting undulator parameters were performed. Numerous advantages of new undulators (fixed gap, strong dependence of undulator radiation wavelength on period, relatively low field amplitude variation and variable number of periods) look very attractive. Prospects for this new type of undulators are discussed.

THOC4

Improvement in High-Frequency Properties of Beam Halo Monitor Using Dimond Detectors for SPring-8 XFEL

H. Aoyagi, T. Bizen, N. Nariyama (JASRI/SPring-8) Y. Asano, T. Itoga, H. Kitamura, T. Tanaka (RIKEN/SPring-8)

An interlock sensor is indispensable to protect the undulator magnets against radiation damage. The beam halo monitor using diamond detectors, which are operated in photoconductive mode, has been developed for the X-ray free electron laser facility at SPring-8 (XFEL/SPring-8). Pulse-by-pulse measurements are adopted to suppress the background noise efficiently, and to improve the detective sensitivity. The feasibility tests of this monitor have been demonstrated at the SPring-8 compact SASE source (SCSS) test accelerator for SPring-8 XFEL. As the next step, we are trying to improve the high-frequency properties: (a) dimension of diamond detectors was newly designed to optimize the beam halo monitor for SPring-8 XFEL, (b) the microstripline structure is applied in the vacuum chamber to improve the high-frequency property, (c) RF fingers are also applied to suppress the effect of the wake field from intense electron beam. Details of these devices and experimental results are presented.

17:15 | 18:15 **Tutorial**
Chair: A. Meseck, BESSY GmbH (Berlin)

THTUI1

Diagnostics for Free Electron Lasers

J.C. Frisch (SLAC)

Free Electron Lasers require a variety of beam diagnostics for tuning and feedback. This tutorial will cover radio frequency analog and digital signal processing as used in a variety of instrumentation including beam position, bunch length and arrival time monitors. It will also cover beam profile monitors including wire scanners, fluorescent screens, and optical transition radiation foils, including the issues with coherent emission from high brightness beams. In addition, it will discuss the unique requirements for X-ray instrumentation for existing and future XFELs.

08:30 | 10:00	**X-Ray Optics and Detectors** **Chair:** S. Thorin, MAX-lab (Lund)

FROAI1 **X-Ray Diagnostics Commissioning at the LCLS**

J.J. Welch (SLAC)

This talk is about the experience gained in commissioning the X-Ray diagnostics at the LCLS over the past year. Though the designs of the diagnostics are based largely on technology from synchrotron light sources, the high intensity and high brightness of LCLS X-Ray beam are well outside of the range of parameters for synchrotron light sources, so the diagnostics must perform in essentially new territory. It turned out that some capabilities of the diagnostics were not utilized because the FEL beam was so strong right from the beginning. On the other hand, in some cases the diagnostics were used to perform novel measurements that were not envisioned in the original design. The talk will cover each of the diagnostics systems, how it performed, and what it told us about the FEL beam.

FROAI2 **Non-Invasive Diagnostics on FEL Photon Beams: General Remarks and the Case of FERMI@Elettra**

M. Zangrando, D. Cocco (ELETTRA)

The advent of FEL sources has brought new possibilities for experimentalists performing measurements that are challenging in terms of time resolution, flux, coherence, and so on. One of the most important points, however, is the capability of characterizing the FEL photon beam so to determine the different parameters of each pulse hitting the system under investigation. For this reason it is mandatory to realize diagnostics sections along FEL user facilities recording beam pulse-resolved features such as the absolute intensity, the energy spectrum, the beam position, the time arrival, and the wavefront. For other parameters like the coherence and the pulse length, on the other side, a direct and online detection is not possible. At FERMI@Elettra, the Italian FEL facility, a dedicated diagnostic section called PADReS (Photon Analysis Delivery and Reduction System) will be installed after the undulatory' exit, and it will serve as a source of pulse-resolved informations for end-users. In this talk the instruments that are part of typical FEL diagnostic sections will be described using PADReS as a real example to see the roles of the different diagnostic tools.

FROA3 **Beam Diagnostic at SDUV-FEL**

Y.Z. Chen, Z.C. Chen, L.F. Han, Y.B. Leng, Y.C. Xu, K.R. Ye, L.Y. Yu, W.M. Zhou (SINAP)

Abstract: The Shanghai deep ultraviolet FEL (SDUV-FEL) with single-stage to higher harmonics is designed and most equipment of accelerator is performed and operating. In this paper, we present the instrumentations on the proof-of principle experiment of FEL physics study. We discuss diagnostic techniques for testing photo cathode RF gun and magnetic bunch compressors, and undulator sections including a modulator undulator. The multiple alignment-laser station is used for pop-in equipments alignment in the undulators. We also investigated the observed e-beam size using OTR and YAG in the cameras using the near-field focus. Network camera and network techniques are used on monitor components. It will be described in this report also.

FROA4 **Feasibility of X-Ray Cavities for Hard X-Ray FEL Oscillators**

Yu. Shvyd'ko, K.-J. Kim, R.R. Lindberg, D. Shu, S. Stoupin (ANL) H. Sinn (European XFEL GmbH)

Free-electron lasers for hard x-rays can be constructed in oscillator (XFELO) configuration, providing ultra-high spectral purity and brightness [1]. The average brightness is expected to be several orders of magnitude higher than, and peak brightness comparable to that of SASE XFELs. XFELOs can enable revolutionary scientific opportunities as well as drastically improve experimental techniques developed at third-generation x-ray facilities. Low-loss x-ray crystal cavity and ultra-low-emittance electron beams are two major technical challenges in the realization of XFELOs. The requirements to x-ray cavity components are demanding: diamond crystals and curved grazing incidence mirrors must have near-perfect reflectivity, negligible wave-front distortions, and are subject to very tight tolerances on angular, spatial, and thermal stability under high heat load of the XFELO radiation. This paper gives an overview on the recent progress [2-4] and future plans in the R&D on the feasibility of x-ray cavities for XFELOs. The experimental and simulation studies results provide strong evidence for the feasibility of the x-ray cavities.

10:30 | 12:00 **Application of FEL Radiation**

Chair: I. Lindau, MAX-lab (Lund)

FROBI1 **Ultrafast Single-Shot Diffraction Imaging of Nanoscale Dynamics**

A. Barty (CFEL)

The ultrafast, ultrabright, coherent X-ray pulses offered by X-ray FELs open the doors to a range of new capabilities in X-ray science. The ultrafast pulses from X-ray FELs enable X-ray imaging beyond conventional radiation damage limits enabling the ultrafast single-shot images of transient phenomena and material structure to be captured. Although sufficient dose is deposited in a single pulse to completely destroy the sample, it is nevertheless possible to collect meaningful diffraction patterns from the undamaged sample before it is destroyed using ultra-short X-ray pulses that terminate pulse before the effects of sample damage are manifested. Experiments in recent years at the first operational FELs in the X-ray regime -- FLASH and LCLS - have demonstrated the feasibility of flash imaging using soft X-ray FELs. In particular it has been shown that measurements can be made before sample damage occurs. Single-pulse X-ray imaging has been used to study the time evolution of non-cyclic phenomena such as laser-induced ablation with nanoscale resolution and a shutter speed measured in femtoseconds.

FROBI2 **The LDM Beamline at FERMI@Elettra**

C. Callegari, K.C. Prince (ELETTRA) T. Möller (Technische Universität Berlin) F. Stienkemeier (Physikalisches Institut Albert-Ludwig) S. Stranges (Università di Roma "La Sapienza")

The Low Density Matter beamline (LDM) at FERMI@Elettra is scheduled to begin operation in early 2011 as a large collaborative project for experiments on neutral matter beams, and later on trapped species and mass selected ions. FERMI@Elettra is a seeded source comprising two Free Electron Lasers(FELs) that will generate short pulses (25--200fs) of VUV (FEL1:12-60eV) and XUV/soft-X-rays (FEL2:60-300eV; third harmonic: up to 900eV) with close-to-transform-limited transverse and longitudinal coherence, and full polarization control. It includes a synchronized broadly-tunable user

laser for pump-probe experiments. LDM modular design seeks to exploit these unique features with a flexible choice of target system and detection method. It will supply intense beams of neutral atoms, closed-shell molecules, radicals, and pure/doped clusters (the latter ranging from ultracold helium nanodroplets, to atomic and molecular van der Waals clusters, especially water, to clusters of refractory materials such as metals and their oxides). These can be combined with a set of detectors, working in tandem when possible, for photoelectron/photoion spectroscopy, fluorescence emission, and photon scattering.

FROB3 Photofragmentation of Complex Ti Clusters Under EUV-FEL Radiation

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With the advent of short wavelength FEL sources, the understanding of interaction of intense electromagnetic fields with condensed matter is experiencing a boost owing to the access to new directions that were never explored experimentally before. Multi-coincidence techniques applied to rare gas clusters at photon fluxes in the range of 10^{13} W/cm^2 and above have shown strong potential for the investigation of physical processes in these extreme conditions *, as well as for understanding cluster structure; the application of these methods to metal clusters with high structural complexity was never reported to date. We report here on the design and realization of what is to our knowledge the first multi-photon fragmentation study of complex metal clusters in the EUV; the first analysis of results will be presented laying the ground for a tentative physical interpretation. The fragmentation pattern and its evolution with photon flux is discussed in comparison to results from high field interaction of the same systems with visible light and to the behavior of rare gas clusters under similar conditions.

Italic papercodes indicate primary authors

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Time	Monday 23rd	Tuesday 24th	Wednesday 25th	Thursday 26th	Friday 27th
8:30–10:00	**Opening, New Lasing FEL Lecture** MOOA	**Storage Ring and ERL FELs** TUOA	**Seeding and Seeded FELs** WEOA	**Synchronization and Stability** THOA	**X-ray Optics and Detectors** FROA
10:00–10:30	Coffee Break	Coffee Break	Coffee Break	Coffee Break	Coffee Break
10:30–11:00	**(continued)** MOOA	**X-ray and Short Wavelength FELs** TUOB	**Short Pulse Length FELs** WEOB	**New Concepts** THOB	**Application of FEL Radiation** FROB
11:00–12:00	**Status Reports** MOOB				
12:00–13:30	Lunch Break	Lunch Break	Lunch Break	Lunch Break	Lunch Break
13:30–15:00	**Poster Session** MOP	**Poster Session** TUP	**Poster Session** WEP	**Poster Session** THP	**Lund Visit**
15:00–15:30	Coffee Break	Coffee Break	Coffee Break	Coffee Break	
15:30–17:00	**FEL Theory** MOOC	**FEL Oscillator and Long Wavelength** TUOC	**FEL Technology I Injector and Linac** WEOC	**FEL Technology II Undulators and Beamlines** THOC	
17:15–18:15	**Tutorial** MOTU	**Tutorial** TUTU	**Tutorial** WETU	**Tutorial** THTU	
	Conference Reception		**Conference Dinner**		

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