EU contract number RII3-CT-2003-506395 CARE/ELAN Document-2007-023

Overview of the EuroLEAP project

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1) CNRS- LPGP, Orsay, France

Abstract

The European Laser Electron controlled Acceleration in Plasmas to GeV energy range (EuroLEAP, www.euroleap.eu) project is funded by the EU for 3 years (2006-2009) and involves 11 groups in France (CNRS: LPGP - B. Cros, LOA - V. Malka, LLR - H. Videau, LAL - R. Roux), the UK (U. of Strathclyde - D. Jaroszynski, Imperial College – Z. Najmudin, U. of Oxford – S. Hooker, CLF RAL – M. Dunne), the Netherlands (U. of Eindhoven – M. van der Wiel, U. of Twente – F. van Goor) and Portugal (IST – L. Silva). An overview of this project was presented at the Laser Plasma acceleration meeting held in the Azores in July 07.

Introduction

The main objective of the EuroLEAP project is the achievement of a laser-plasma accelerator to test the issues related to the control of the properties of an electron beam accelerated to the GeV range in a plasma wave. Short pulse electron beams, produced by laser injectors in a plasma or by RF photo-injectors, will be injected and accelerated in a plasma wave created inside wave guides over a few centimetres. Different techniques to produce short bunches of electrons will be tested and compared, as well as different techniques for laser guiding and creating the accelerating plasma wave. Specific diagnostics will be developed to characterise the produced electron bunches. Simulation will support the joint experimental efforts. Recently commissioned facilities at the U. of Strathclyde and at the CLF-RAL will provide unique opportunities to benchmark optical injection and RF photo-injection techniques. The goal is to produce electron bunches in the GeV range, with an energy spread close to 1% in a reproducible way over a distance less than 10 cm.

Acknowledgements

We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 “Structuring the European Research Area” programme (CARE, contract number RII3-CT-2003-506395)

European Laser Electron controlled Acceleration in Plasmas to GeV energy range

Project: NEST ADVENTURE STREP
Coordination: Brigitte CROS (CNRS- LPGP)

Sept. 2006 -2009

euro LEAP

Objectives

- To build a laser-plasma accelerator
- To accelerate electrons to the GeV energy range in a plasma wave.
- To test the issues related to the control of the properties of the electron beam
- Expected result: accelerated e-beam with
  - energy in the GeV range,
  - energy spread of the order of 1%,
  - pulse duration of the order of 100 fs,
  - charge in the range 10 pC to 100 pC.

Participants

- **France . Centre National de la Recherche Scientifique (CNRS) : LPGP, LOA, LLR, LAL**
- **UK . STFC- CLF RAL, U STRATHCLYDE, Imperial College, U OXFORD**
- **The Netherlands. U. Twente (UT), Eindhoven U. of Technology (TUE)**
- **Portugal. Instituto Superior Técnico (IST-GOLP)**

Resources

- Accelerator laboratories and laser facilities
  - TUE, UT, LAL
  - RAL, LOA, USTRAT, IST
- Waveguide development labs
  - OXFORD, IST, LPGP
- Diagnostics development labs
  - LLR, USTRAT, TUE, UT
- Modeling and simulation infrastructures
- European funds: 2M Euros are for
  - Post-doc or PhD
  - Consumables, transfer of equipment, missions for collaborative experiments, collaboration meetings, management

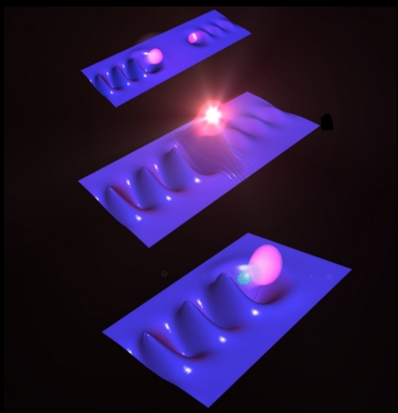
Research activities

- WP1: Laser Injector Development
- WP2: RF Photo-Injector Development
- WP3: Production of a plasma wave over a long distance
- WP4: Injection & Controlled Acceleration
- WP5: Diagnostics

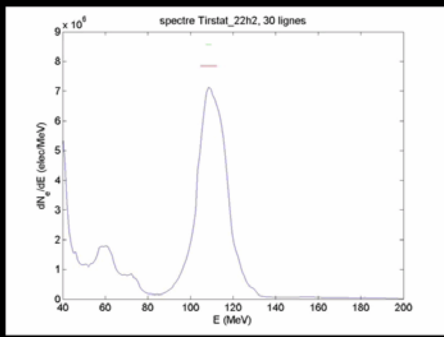
WP1: Laser Injector Development

- Demonstrate all-optical injection (AOI) and acceleration of ultra-short (10 fs) electron bunches by
  - colliding laser pulses (CDP)
  - collinear pulses (CLP)
- Characterize and optimize the spectrum of electrons
- Achieve mono-energetic, low emittance electron beams at a few tens of MeV to 200 MeV

Colliding laser pulses - LOA



Simulation, A. Lifshitz



The ponderomotive force associated to the beating of the two laser pulses accelerates plasma electrons up to trapping threshold

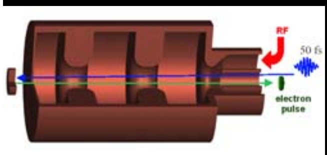
D. Umstadter et al, PRL 76, 2073 (1996);
E. Esarey et al, PRL 79, 2682 (1997)

Faure et al., nature, dec 2006

WP2: RF Photo-Injector Development

- **Improve existing technology in order to build RFPIs to produce e- bunches with:**
  - **50 to 100 pC charge,**
  - **50 fs to 1ps duration,**
  - **energy 3- 4 MeV, energy spread 2%**
- **Transport and focus the electron beam at the entrance of the plasma**
- **Commission RFPIs for acceleration experiment**

RF Photo-Injectors



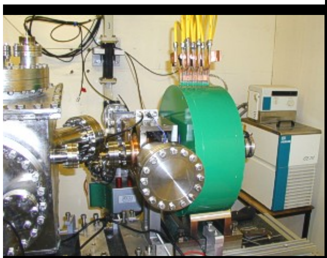
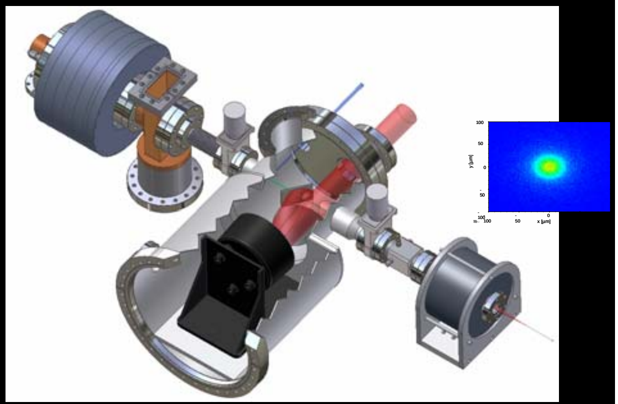
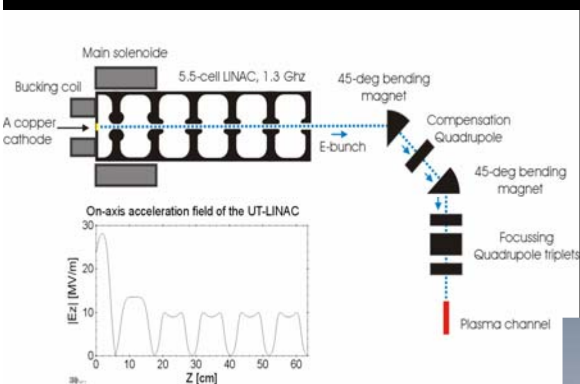


Photo-injecteur build by LAL and implemented at U. of Strathclyde



Injection scheme at TUE. Electrons produced by the PI (left) are accelerated by the RF cavity, then focussed at the entrance of the plasma.

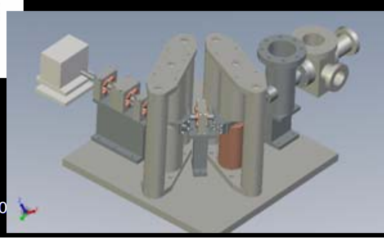
Sub-picosecond beam Compressor at U. Twente



Longitudinal compression section

Two subsequent 45-degree bending magnets and a compensation quadrupole magnet between the bending magnets introduce an energy-dependent path length to compress the bunch.

Focusing and compression sections

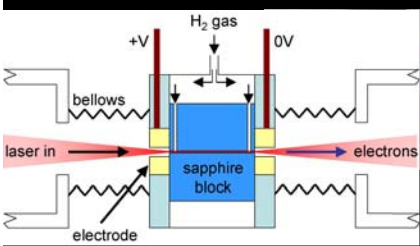


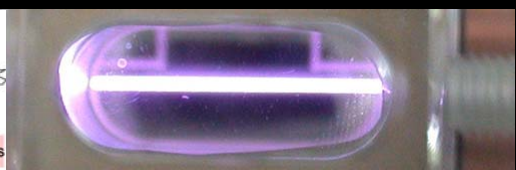
Compression: 2ps --→ 250 fs, 2.88 MeV

WP3: Production of a plasma wave over a long distance

- Develop plasma media allowing to achieve a plasma wave over several centimetres
- Study the propagation of intense laser pulses ($\geq 10^{17}$W.cm^{-2}) in the waveguides
- Control the plasma wave stability, repeatability and lifetime
- Achieve a product of gradient and length of 1 GV

High intensity laser Guiding

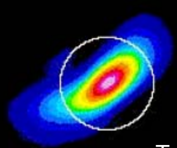


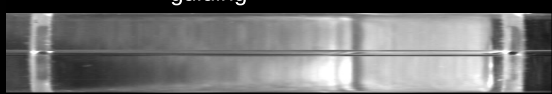


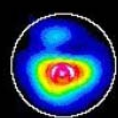
A. Gonsalves et al., PRL 98, 025002 (2007)

Plasma channel, U. Oxford

Comparison of guiding by a plasma channel and by reflection from the tube walls
It is necessary to improve the laser beam quality in order to achieve monomode guiding





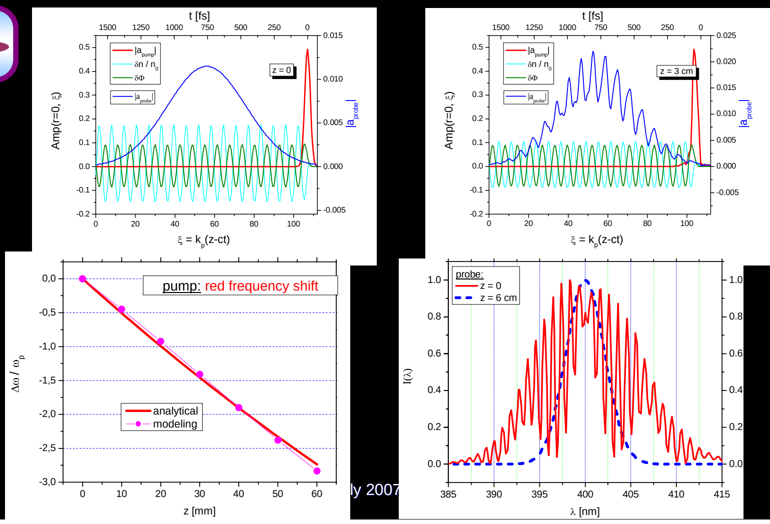


Tube LPGP L= 5cm, r = 50 µm, filled with H2, I = 5 10^{17} W/cm^2

Plasma waves diagnostics -LPGP

Capillary: D = 100 mm, L = 6 cm, ε_W = 2.25, filled with hydrogen
Pump pulse: λ = 0.8 mm, τ_{FWHM}= 35 fs, I_L= 5.×10^{17} W/cm^2, P=8.5 TW
Probe pulse: λ= 0.4 mm, τ_{FWHM}= 490 fs, T_{delay}=760 fs, spectral width 5 nm

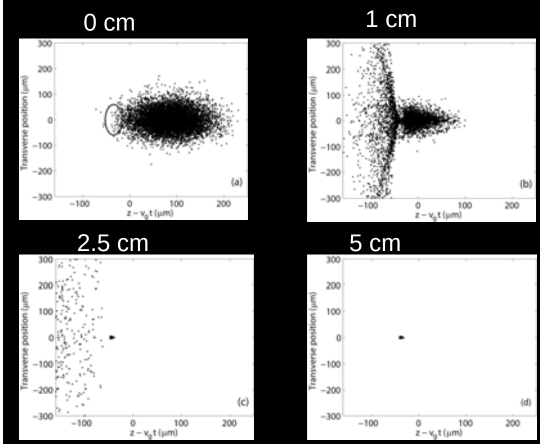
IHED
AIHT of RAS



WP4: Injection & Controlled Acceleration

- Inject and accelerate electrons in a linear plasma wave over a long distance (several centimetres)
- Achieve a precise theoretical modelling and control the different elements of the acceleration process
- Build a prototype to achieve accelerated electron beams with
  - energy in the GeV range,
  - energy spread of the order of 1%,
  - pulse duration of the order of 100 fs,
  - charge in the range 10 pC to 100 pC.

Injection of electrons in front of the laser pulse – U. Twente



Snapshots of an electron bunch during trapping, compression and acceleration in the laser wakefield at several distances in the plasma channel. The ellipse depicts the position of the laser pulse.

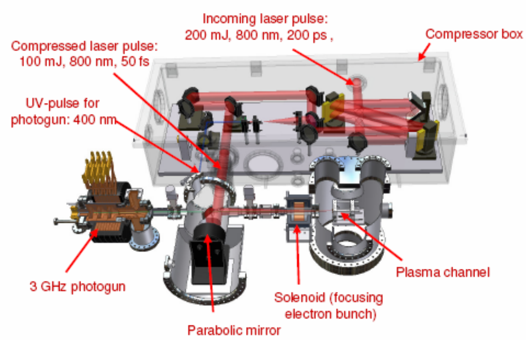
From: NIM A 566 p.244 (2006).

technische universiteit eindhoven

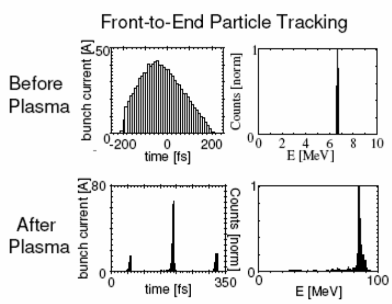
Laser Wakefield Acceleration with External Injection

Injection of 200 fs electron bunch
Into (linear) Laser Wakefield
Driven by 2 TW laser pulse

Setup



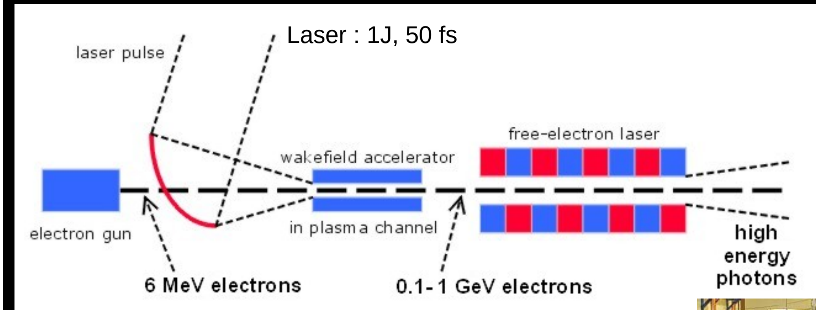
Expected Results



Status:
Testing (training) Photogun

/department of applied physics

Scheme at U. Strathclyde



Schematic overview of the ALPHA-X set-up

WP5: Diagnostics Development

- Develop and implement diagnostics to characterize
  - beam profile,
  - charge,
  - energy,
  - time duration

Plans up to Feb '08

- Commissioning of diagnostics
  - charge measurement (ICT, scintillating screens) and electron
  - spectrometer
- Generation of visible/UV radiation pulses in undulator
  - radiation spectrum provides information on electron bunch
  - energy spectrum and emittance (also charge if no electrons are lost)
- Installation of Coherent Transition Radiation (CTR) detection system
  - diagnostic of electron bunch charge, shape and duration
- Design & Construction of Pepper Pot emittance diagnostic
- LLR imaging spectrometer
  - high energy, high resolution

Conclusion and perspective

- The EuroLEAP partners are developping a project to control the properties of the electrons beams produced in a laser plasma accelerator,which is a necessary step to develop applications and the increase of energy through staging
- Compact controllable e-source in the GeV range
  - Dissemination to University size labs
  - Industrial spin-offs (laser, photo-injector technology, synchronisation)
  - Applications to femtosecond X-ray generation, femtochemistry, radiobiology, …
- First stage of a laser plasma accelerator
  - Will allow to evaluate the feasibility of building a multi-stages accelerator for high energy
  - Basis for a larger scale project at the European level.

Web site www.euroleap.eu