THE THOMX PROJECT STATUS#

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Abstract

A collaboration of seven research institutes and an industry has been set up for the ThomX project, a compact Compton Backscattering Source (CBS) based in Orsay – France. After a period of study and definition of the machine performance, a full description of all the systems has been provided. The infrastructure work has been started and the main systems are in the call for tender phase. In this paper we will illustrate the definitive machine parameters and components characteristics. We will also update the results of the different technical and experimental activities on optical resonators, RF power supplies and on the electron gun.

INTRODUCTION

There is a growing interest in bright monochromatic and tunable X-ray sources used in medical (imaging and therapy) and social science (cultural heritage), as well as in technology and industry. Synchrotron Radiation (SR) is the primary high quality source meeting both brilliance and tunability criteria. But the significant costs, high energy (few GeV) and large size of SR facilities are heavy constraints on their large diffusion. Nevertheless, recent R&D results on lasers and optical resonators have shown that Compton Back Scattering (CBS) can provide directional and quasi-monochromatic X-rays beams with very high brilliance. The ThomX project aims to provide a fully operational hard X-ray CBS source upgradable to be operated in a non-expert environment and with a relatively reduced cost. The compact source, installed in the Paris Sud University Campus, will produce a flux of $10^{11}\div10^{13}$ ph/s with a tunable energy cut-off. To meet this performance, both electrons bunches and laser pulses will be stacked respectively in a storage ring and in a high gain Fabry-Pérot cavity. Moreover, the ThomX source

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will provide the industrial partners and the academic community with an open access facility for medical and cultural heritage applications. It will also provide a multidisciplinary approach and numerous academic and industrial partnership opportunities, granting different scientific users an open access and offering companies a great opportunity to explore new markets. Medical science applications are expected in the imaging field, in static and dynamic imaging, 3D compressionless mammography, broncography, catheterless coronary arteries angiography. Another very important developing field is the K-edge radiography and therapy. The operation of a dedicated light source in a hospital can be envisaged, leading to an enormous increase in the number of patients and researchers having access to it and a consequent impact on clinical aspects. As far as social sciences are concerned, the hard X-rays techniques should provide a thorough material analysis for cultural heritage studies. The result concerns works of art dating, employed techniques, attribution, primitive sketches detection and underlying drawings non-destructive analysis.

Many other users would be able to benefit from CBS sources in such fields as protein crystallography, litography, chemistry, metallurgy and biology. An energy upgrade can also explore applications to nuclear waste management and processing.

THOMX PROJECT STATUS

ThomX [1] project has been approved and financed in the framework of the EQUIPEX program of the French Research Ministry. After a first study phase a Conceptual Design Report has been provided [2] summarizing the main aspects of the scientific case, the accelerator complex, the lasers and the users' X-line. This phase was followed by a detailed study of the expected parameters and of all the technical systems of the machine leading to the publication of the Technical Design Report [3].

In parallel, an important decision was taken concerning the infrastructure. ThomX will be integrated with the other EQUIPEX accelerator project of the Orsay campus, ANDROMEDE, in the old "IGLOO" building creating the new IGLEX research platform. After many definition studies the infrastructures contracts are now being released and the final delivery is expected by the end of the year 2015. At the same time, the majority of the equipment contracts have been awarded for the industrial production. A team, formed by different laboratories teams, has also been set up to face all the aspects of radiation protection and shielding for the French Nuclear Security Authority regulatory

Machine Upgrade

To favour flexibility and compactness, the Thom-X ring design is based on a Double Bend Achromats (DBA) configuration with a two-fold symmetry including eight dipoles, two long and two short straight sections. The Fabry Perot optical cavity is integrated in between the adjacent dipoles of one of the short straight section. Other equipment as RF, feedback and injections pulsed magnets are accommodated in the dedicated two long sections. After a first mechanical design phase the full integration of the machine was assessed. Considering the final set-up, the calculated mechanical stresses on the bellows were taken into account to find a more flexible solution. For this reason it was decided to lengthen the ring circumference passing from 16.8 m to 18 m. Consequently, the ring passes from the 28th to the 30th RF harmonic of the 500 MHz RF system. In this context, minor modifications were taken into account in the specification of the BPM electronics, the synchronization system, the optical resonator feedback, the laser frequency and the pulsed magnets power supplies. This has an impact essentially on the ring and Fabry-Perot cavity repetition frequency, thus reducing respectively the available average current and laser circulating power. The ring optical functions (see Fig. 1) were adjusted to fit the new length constraints, preserving the β* of 0.1 m at the IP to keep the luminosity constant. In this context, the Betatron tunes and the momentum compaction factor were slightly modified compared to the original design [3]. The new parameters are listed in Table 1.

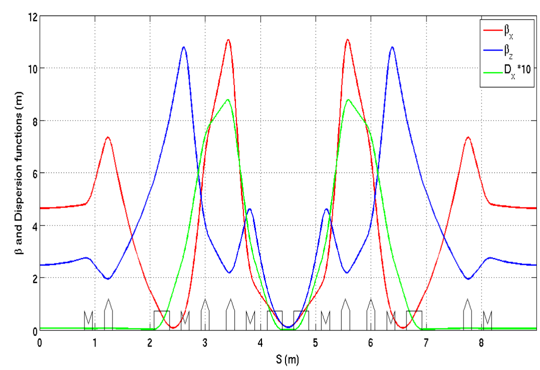

Figure 1: New optical functions for the ThomX ring.

Considering the new parameters a linear scaling allows estimating at a negligible 7 % the reduction of the emitted flux due to the reduced current. Nevertheless, in this framework, one should also take into account that the bandwidth of the optical resonator is proportional to the repetition frequency, therefore the cavity Finesse should be slightly reduced too.

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Table 1: Main Parameters of the New ThomX Configuration

Energy	50MeV
Bunch Charge	1 nC
Revolution Frequency	16.7 MHz
Current	0.0167 A
Circumference	18m
RF frequency / Harmonics	500 MHz / 30
Momentum compaction	0.0125
Betatron tunes	3.17 / 1.74
RMS Bunch Length	25 ps
RMS size at IP	70 μm
Fabry Perot repetition frequency	33.4 MHz
Pulse power @ 100kW	6 mJ

RECENT HIGHLIGHTS

The ThomX design is based on the results obtained in the technology R&D on high finesse Fabry-Perot resonator. To test the insertion of an optical passive amplifier in an accelerator environment the MightyLaser project started as demonstrator of several technologies on optical cavities and laser systems for ThomX. In this framework a laser oscillator, a laser amplification system and an optical resonator with high reflectivity mirrors have been integrated in the ATF ring (KEK, Tsukuba, Japan). Among the goals of this project are the construction [4] and the test of the four-mirror Fabry-Perot cavity inside the accelerator facility and the demonstration of intense flux of the gamma rays sustained for a long period of time.

Recently, several upgrades compared to the experimental campaign carried out in 2011 [5] and made it possible to reach several tens of kW of the laser power stored in the cavity. In this context, an important gamma ray flux of thousands photons per crossing has been measured. For the first time it was also possible to evaluate the effects of the longitudinal recoil of the electrons on the laser pulses by measuring the beam lifetime in the ring that was reduced from ~3 down to ~ 1 minute.

As far as the technological developments are concerned, it is important to point out that the ThomX SR RF cavity power supply is a solid state amplifier (SSA), based on the 6th generation LDMOS transistors. In this context, Synchrotron SOLEIL has worked out elementary modules, which can deliver up to 650 W at 500 MHz with a gain of 16.5 dB and an efficiency of 64%. About a hundred such modules will be combined for achieving the required 50 kW power. In this framework, a 10 kW unit prototype (16 modules) was successfully validated after a test run of 1000 hours (see Fig. 2). The complete 50 kW CW SSA is being built and will be tested on a dummy load, by the end of 2014 at SOLEIL.

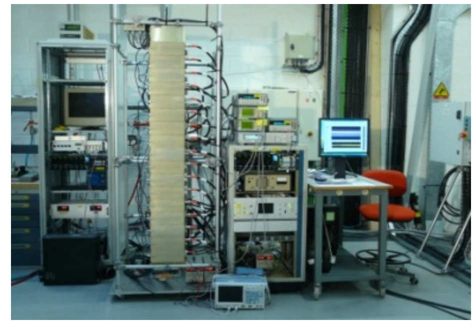

Figure 2: 500 MHz 10 kW unit prototype under long-term test at SOLEIL.

Another important achievement in LAL was the set-up of the RF gun for the photo-injector (see Fig. 3). The gun will be tested in autumn 2014 in the local platform PHIL. In this framework, a lot of different tests were carried out on the Mg photo-cathode technology, attaining a very good charge per bunch of 2.1 nC with a 40 μJ laser pulse at 262nm wavelength.

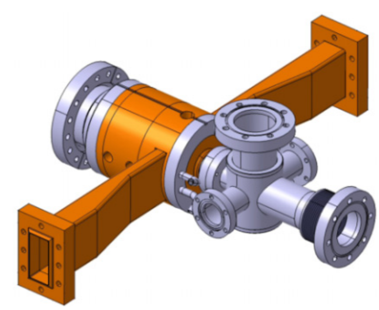

Figure 3: Drawing of the 2998MHz ThomX electron gun.

CONCLUSIONS

The project ThomX has entered the construction and procurement phase. The integration of the machine is expected to start at the end of 2015. Meanwhile different activities are being carried out. A modification of the ring length provides new optics and different R&D are producing excellent results confirming the project technological choices.

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