ELETTRA NEW FULL ENERGY INJECTOR STATUS REPORT

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Abstract

The Elettra new full energy injector will be based on a 100 MeV linac pre-injector, a 2.5 GeV booster synchrotron and two new beam transfer lines. It will replace the existing 1.2 GeV linac injector and transfer line. Full funding was finally available in 2005, which allowed to start, or in some cases to re-start, the construction activities. The status of the project will be presented in this paper, in particular the progress of the fabrication of various components, like magnets, power supplies, vacuum chambers; also the status of the construction of the building and technical plants will be given. Results of recent optimization studies will also be outlined. The commissioning of the new injector is scheduled to start in Spring 2007, while the first ELETTRA operation for user's with the new full energy injector is expected for the last quarter of 2007.

INTRODUCTION

ELETTRA delivers photons to users for 5,000 hours a year. Including machine studies and optimisations the total amount of operating hours per year attains 6,000 hours. During 2005 almost 1000 users performed experiments on the 22 beamlines. The storage ring energies for users' operation are 2.0 GeV, for 75% of the user's time, and 2.4 GeV, for the remaining 25%. Depending on the energy, the storage ring is refilled every 48 (2.0 GeV) or 24 hours (2.4 GeV); injection is performed at 0.9 GeV and the storage ring energy is then ramped to the operation value. Refilling not at full energy limits the performance of the photon source in terms of available beam time and beam position stability.

A full energy injector is therefore needed to maintain the source attractive for users. While the initial proposal for a new booster injector was already presented in 2000 [1], full funding has been released in April 2005. The 1.2 GeV linac, no more needed as Elettra injector, will then become the core of the new single pass X-ray FEL FERMI@ELETTRA. A new 100 MeV linac will be the pre-injector for a 2.5 GeV booster synchrotron, a two-fold symmetry structure composed of eighteen cells among which two are without bending magnets and four with one missing bending magnet [2].

Equilibrium emittance at 2.5 GeV is 226 nm.rad for the Nominal Emittance Optics (NEO), while it becomes 166 nm.rad for the Low Emittance Optics (LEO) [3]. Repetition rate is 3 Hz. The booster and the extraction transfer line are designed to allow top-up operation [4].

The design has been developed in house, following a cost saving strategy. An integration strategy between storage ring upgrades and booster design was chosen. For instance, this will allow to install on the booster the beam position monitor electronics and the RF transmitter which will be available after completion of the upgrades on the storage ring. Several parts, as the high voltage modulator for the pre-injector klystron, the pulsed magnets power supplies and the kicker magnets are constructed at Elettra.

BUILDING AND LAYOUT

The new injector complex will be hosted inside the existing storage ring building, using the empty space available in the internal courtyard, as shown in fig. 1. This choice allows to optimize the use of available spaces and to minimize any disruption to the operation of the facility.

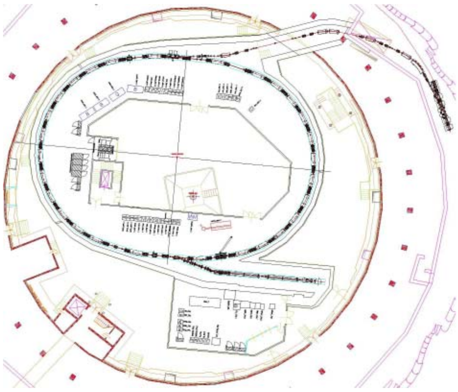

Figure 1: Building and booster layout.

A dedicated crane (fig. 2) was installed already in 2002 to handle all the construction material and machine components above the roof of the storage ring building.

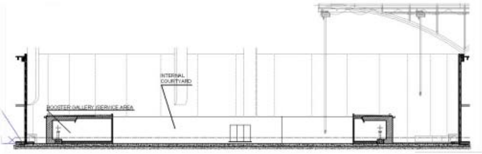

Figure 2: Building cross section.

Given the complex logistic situation and the need to minimize costs, the solution for the building is as simple as possible. A common technical gallery will host both the accelerator and the auxiliary equipment, e.g. the power converters, RF transmitter, control and diagnostic racks.

Construction of the building started on 01/09/2005 and despite a few weeks of delay during the last winter, given the quite severe weather conditions, the deadline of December 2006 to complete construction should be met. The activities for the upgrade of all technical plants have also been started. New fridges, water pumps, transformers, are needed to supply the new accelerator. Installation of cooling systems and electrical plants in the new building is planned to start in October 2006.

BOOSTER COMPONENTS

All components of the booster have been designed and specified by Elettra. Different tenders have then been launched to select the manufacturers. Final assembly of magnets, girder and vacuum vessels is done at Elettra.

Magnets

The magnetic lattice of the booster is made up of 28 dipole magnets, 36 quadrupoles (18 QF + 18 QD), 24 sextupoles (12 SF + 12 SD) and 22 correctors (10 horizontal and 12 vertical). The dipole magnet, which curvature angle is 12.86º, has a maximum field of 1 T, is 2.0 m long and the gap is 22 mm (fig. 3). For all magnet types, prototypes are scheduled in summer 2006 and the complete delivery shall be fulfilled by February 2007. More details about all magnets are given in [5].

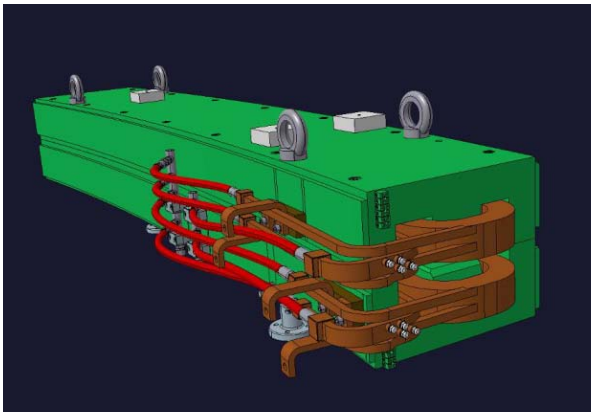

Figure 3: Booster Dipole Magnet.

Power Converters

The Power Converters (PC) for the new full energy injector of ELETTRA are of the Switch Mode Power Supplies (SMPS) type. They will adopt the control system developed by PSI for the Swiss Light Source PC [6].

In order to reduce the inductance seen by the dipole magnet PC and to keep the peak output voltage below 1 kV, the load will be split between two separate converters. The two coils of the magnets will be fed by both power converter units following the scheme presented in fig. 4.

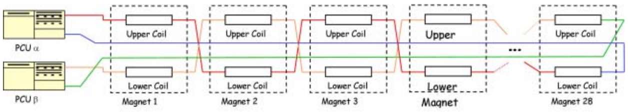

Figure 4: Dipole Magnet Connections.

The main specifications of the dipole PC are given in Table 1.

Table 1: Dipole Power Converters Specifications

Number	2	
Output Voltage	+/- 1000	V_{peak}
Output Current	15 – 800	A
Instantaneous Peak Power	600/ - 400	kVA
Average Power	75	kVA
Maximum Frequency	3.125	Hz

As for the quadrupole PC, there will be two separate DC/AC output modules to supply the two (QD and QF) families, but the AC/DC conversion and the capacitor energy storage (the so-called “DC Link”) will be in common. The main specifications are given in Table 2.

Table 2: Quadrupole Power Converters Specifications

Number	2	
Output Voltage	+/- 400	V_{peak}
Output Current	5 – 400	A
Instantaneous Peak Power	115 / -50	kVA
Average Power	22	kVA
Maximum Frequency	3.125	Hz

The selected manufacturer has proposed a highly modular and redundant solution for both dipole and quadrupole PC. First tests on a prototype are foreseen next October, delivery follows in January 2007.

Vacuum Vessels

The vacuum vessels for the booster are basically of two types: the dipole magnet vessel, shown in figure 5, and the vessel of the quadrupole magnet, with the pumping chamber (see fig. 6).

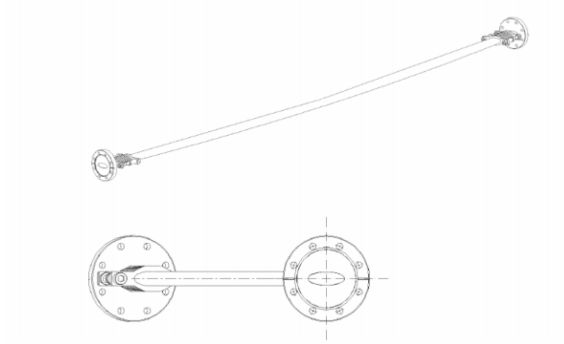

Figure 5: Dipole Magnet Vacuum Vessel

The dipole vessel cross section is elliptical, internal dimension is 18 mm vertical x 48 mm horizontal. At each end of the 2.0 m long vessel, two elliptical bellows are welded in order to compensate for thermal expansion and to allow installation. The thickness of the vessel, built in AISI 316L stainless steel, is 1 mm. The magnetic permeability, μ_r, of the stainless steel shall be lower than 1.02 everywhere inside the magnets.

The vacuum vessels delivery is scheduled from October to December 2006, in four different batches.

Girder and supports

The layout of the supporting system is shown in figure 6, for a typical cell of the booster, made of a dipole magnet, followed by the sequence steerer, quadrupole, sextupole and then by the subsequent dipole.

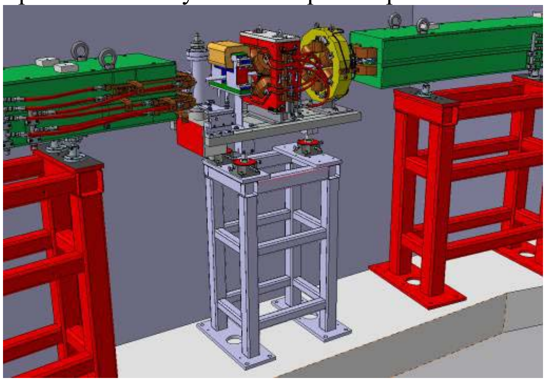

Figure 6: Booster magnets on their girder and support.

The booster beam axis will be located 1.6 m above a basement of concrete. A steel frame of 1.3 m will then support each dipole magnet, which weight is less then 1.5 tons. The computation of the natural vibration frequency of the structure has validated the design.

Each group of steerer, quadrupole and sextupole magnets will be assembled on a common girder. The absolute position of sextupole and steerer will be defined by the mechanical tolerance of the girder, which position will be defined by the alignment of the quadrupole.

PRE-INJECTOR AND TRANSFER LINES

A new pre-injector (PI) followed by a PI to Booster transfer line (PTB) have been designed [7,8] in order to accelerate and transport the electron beam into the Booster. The present thermo-ionic gun will be followed by a bunching system, simulated with the GPT code [8]. Two LIL accelerating sections [9], donated by CERN, interleaved by flexible triplet-like focusing (maximum integrated gradient of 0.4 T) will bring the 100 MeV beam to the PTB, that includes a short dipole, 8 independent quadrupoles and a septum, matching both the NEO and the LEO booster optics (the PI optics remains fixed).

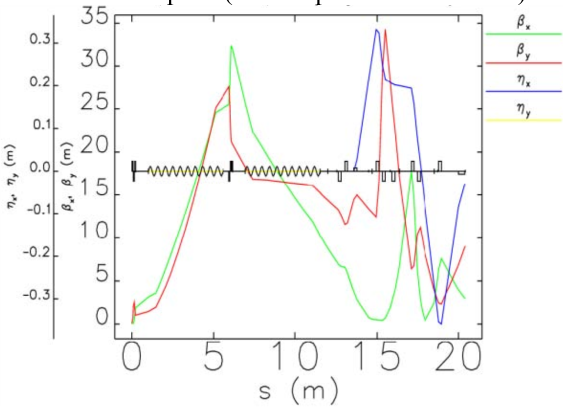

Figure 7: PI and PTB optics for NEO booster optics.

Drift sections include quadrupoles, Beam Position Monitors (BPMs, fig. 8), current monitors and fluorescent screens for diagnostic purposes, in addition to elements for vacuum. A straight diagnostic line is foreseen at the PI exit. The simulated beam transport efficiency is greater than 80%, where the maximum beam stay clear acceptance is 8 mm.

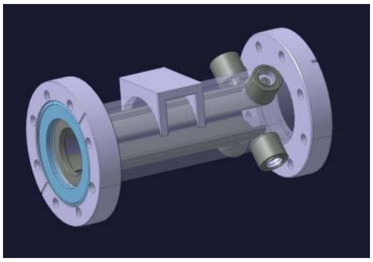

Figure 8: Transfer Line BPM.

A Booster-to-Storage Transfer Line (BTS), 50 m long, is the bridge between the Booster and the Elettra Storage Ring, working at the maximum energy of 2.5 GeV. The beam transport for both NEO and LEO is arranged by mean of 13 independent quadrupoles, 5 short dipoles connected in series and 1 long dipole, followed by 2 septa. Diagnostics for emittance measurement with quadrupole scan, measurement of trajectory and beam current is distributed along the whole line; 8 pairs of steerers guarantee the trajectory correction.

CONCLUSIONS

The Elettra Full Energy Injector construction status has been presented. The building construction shall be completed by the end of 2006. Beneficial occupancy to start components installation is expected for January and February 2007, depending on the areas.

After about 3 months of installation and testing of the different subsystems, the commissioning of the booster shall begin in June 2007.

The manufacturing of all major components is ongoing, without critical delays. Their delivery is scheduled between October 2006 and February 2007. The next most important milestone is the testing of the magnets prototypes, expected for August 2006.

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