OVERVIEW OF THE STATUS OF THE ELETTRA BOOSTER PROJECT

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Abstract

The Elettra Booster Project is in its final phase. The 100 MeV pre-injector Linac and the 2.5 GeV Booster were constructed and installed on schedule and within the foreseen budget. Elettra was shut down during the last autumn to switch from the old Linac injector to the new Booster. The new 2.5 GeV transfer line was successfully connected to the Storage Ring by December 2007. During the same period the Booster commissioning was started. Operation for users of the light source, with the Booster as injector, restarted in March 2008. An overview of the Booster systems and of the current status of its commissioning and operation is presented and discussed here.

INTRODUCTION

Elettra is again operating for users since March 3rd, 2008. Injection is performed by the new full energy Booster (table 1), ready for operation on schedule. The light source was shutdown for 5 months between October 2007 and February 2008 to allow the connection between the Booster and the Storage Ring. The new 2.5 GeV Booster To Storage Ring (BTS) transfer line was installed in autumn and commissioned in February 2008.

Table 1: Main Parameters of the Elettra Booster

Energy (Injection, Extraction)	100 MeV, 2.5 GeV
RF Frequency	499.654 MHz
Circumference	118.8 m
Nominal repetition rate	3.125 Hz
Nominal Current	5 mA
Nominal (low) emittance optics	226 (166) nm.rad

The Booster project started in March 2005 and lasted therefore exactly 3 years. The allocated budget over this period was 13.9 M€, including 20% VAT. Of that amount about 60% went into the accelerator hardware, 40% in building and services. As for manpower, 79 people of the Elettra staff contributed to the project, mostly part time. The total manpower employed was 100 man-year.

The main project challenge was to replace the existing Linac injector with a full energy Booster injector, located in a new building inside the Storage Ring main building, without affecting significantly the operation of the facility for the users. This required careful planning of both installation and commissioning, foreseeing the consequences of possible delays and programming appropriate back-up plans. Strong overlap between hardware and beam commissioning phases was needed to mitigate the effect of unexpected issues.

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INSTALLATION

The new Booster building and the technical services were completed only in July 2007 (fig. 1), with several months of delay on the foreseen schedule, for various reasons. In the shadow of the building delay there were delays of 3 to 5 months in the delivery of hardware components, like magnets, power converters, Linac sub-systems. Magnets, in same cases pre-assembled on their girder, and supports started to be available in April 2007.

Figure 1: Booster building during construction, May 2007.

Thus, end of April 2007 co-occupancy of the building allowed to start installation of the accelerator components, starting from the Linac accelerating sections and going on with the Booster dipoles and with the quadrupole girders [1]. Three months later the installation of the Linac, of the low energy transfer line, of the Booster and of a first part of the BTS transfer line was complete. The Booster west arc is shown in figure 2.

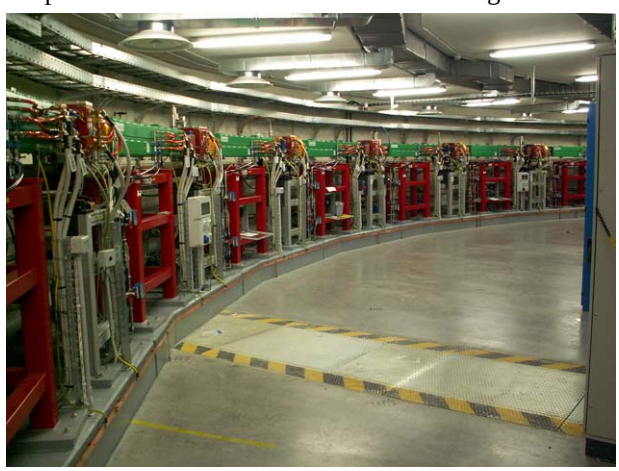

Figure 2: Booster Arc West.

July and August 2007 were then dedicated to hardware commissioning of the various sub-systems. Linac RF conditioning started beginning of August and was completed after about one month [2]. The overall performance of the new injector sub-systems is good: RF system [3], injection and extraction system [4], [5], control system [6], timing system [7], safety system [8], beam diagnostic tools [9], magnets [10] and vacuum.

The exception is the Booster magnets power converters sub-system, which is not yet performing to specification. The performance of these converters was improved in several steps during the commissioning, *de facto* fixing every time the performance in terms of maximum energy and repetition rate which one could get from the Booster in a given commissioning phase. A refurbishment program of the Booster power converters is still running, under the responsibility of the supplier [11].

COMMISSIONING

Originally the commissioning was due to start end of July and to last until September 30th, 2007. Three months of shutdown should have followed until Christmas, to install the BTS transfer line. Its commissioning should have followed in January 2008 together with the first injection into the Storage Ring. Because of the delays and of the issue with the power converters the actual commissioning time was limited to three periods of few weeks, every time also dedicated to hardware commissioning. Hence, the commissioning activities were much more oriented to get a working injector, to avoid any delay in the restart of the facility for users, rather than to fully characterize the new accelerator [12], [13].

Linac commissioning started on September 7th and it was rather smooth to meet the expected performance [2].

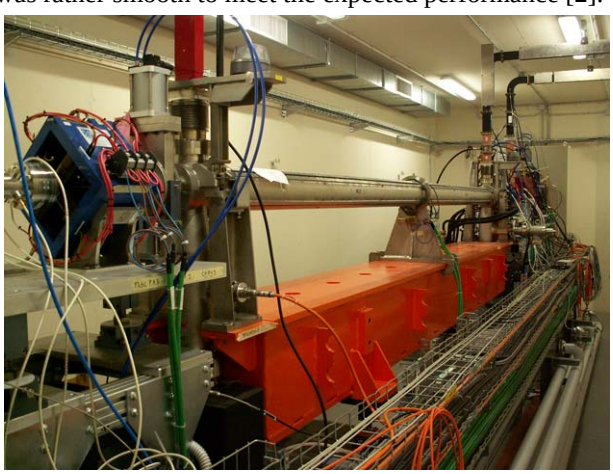

Figure 3: First Linac accelerating section.

Table 2: Main Parameters of the Linac

Energy (Injection, Extraction)	100 MeV
Pulse length	100 ns
Charge	2 nC

On the first day beam was extracted from the gun; beam was then soon transported through the first (fig. 3) and second accelerating section and few days after the 110 MeV beam could be observed at the entrance of the low energy transfer line, even exceeding the nominal parameters listed in table 2. After a first upgrade step on the Booster magnets power converters, on September 26th 100 turns were obtained for the first time in the Booster. In the following days the beam could be ramped in energy up to 800 MeV and extracted from the Booster before the end of the first run, on October 13th.

On December 11th the BTS transfer line installation was completed. During the same shutdown new injection septa magnets, capable of operating up to 2.5 GeV, were also installed in Elettra. This required venting two vacuum sectors of the Storage Ring itself. Meanwhile, also improvements on various sub-systems were carried out. In particular one of the limiting factors on the power converters, a distortion of the output current waveform at low currents, could be removed. Just prior to the Christmas shutdown, the beam could then be extracted from the Booster at 2.0 GeV, Elettra nominal operating energy for 75% of the users' time. Still single shot ramps were performed and the extracted beam current intensity was limited to 0.4 mA.

The Christmas shutdown allowed completing the hardware commissioning of the BTS transfer line and to further improve the performance of the power converters. In this way Booster operation at 1 Hz, 2.0 GeV could be consolidated at the end of January 2008 and soon afterwards the beam could be transported along the BTS transfer line. On February 11th it was finally possible to inject for the first time into Elettra at full energy, i.e. 2.0 GeV, with the Booster operating conditions shown in fig. 4: extracted beam current 1.7 mA, 1 Hz repetition rate.

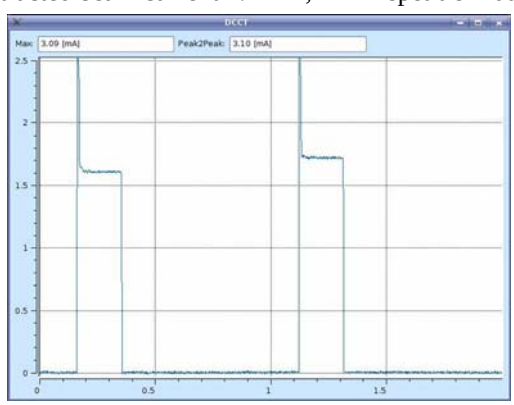

Figure 4: Booster operating conditions on February 11th.

Due to the installation of the new septum, to recover the beam lifetime a period of vacuum conditioning of the Storage Ring was needed. Since the users' operation starting date was approaching quite rapidly we decided to accelerate vacuum conditioning by keeping the beam current intensity in the Storage Ring as high as possible, and so we successfully tested the frequent injection mode, as shown in figure 5 (here insertion device gaps are opened, beamlines closed).

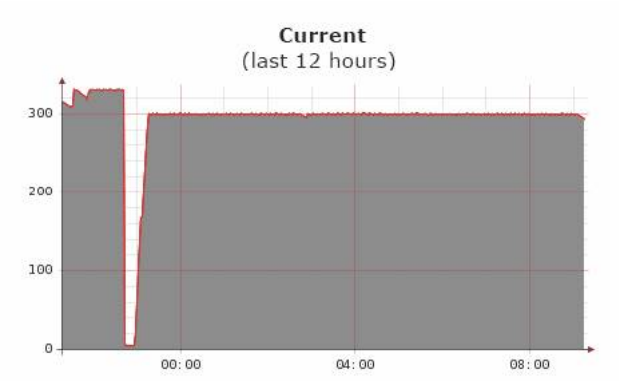

Figure 5: Elettra Beam Current kept constant at 2.0 GeV.

OPERATIONS

Users' operation at 2.0 GeV started on March 3rd, with routine full energy refills on top of the stored current, as shown in fig. 6. On April 13th beam has been injected in Elettra also at 2.4 GeV, operation energy for 25% of the users' time. In May single bunch operation of the injector was established for Storage Ring FEL users, at 0.9 GeV.

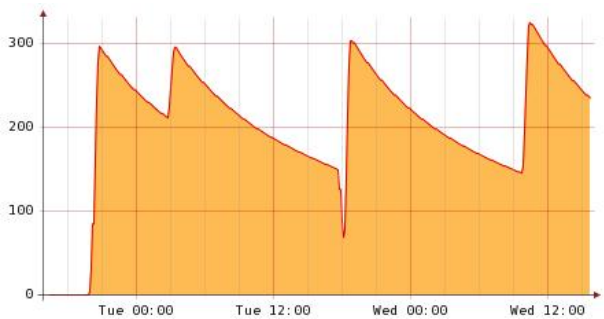

Figure 6: Full Energy beam current refills in March 2008.

At the beginning of operations, refill times from zero to full current exceeded 30 minutes, being thus fairly larger than the expected 10 to 15 minutes. In fact the injection rate in the Storage Ring was lower than 0.5 mA/s, limited both by the Booster repetition rate, still 1.5 Hz, and by the maximum extracted beam current, 1.5 mA. In fact a strong current loss was observed at injection energy so that the Linac to Booster efficiency was typically 50%, while after some hardware commissioning on the BTS transfer line the Booster to Storage Ring efficiency is close to 100%. More recently, by optimizing the Linac phase and energy and the Booster orbit and ramping parameters, the Linac to Booster efficiency attained to 80%. The current at extraction could then exceed the design value reaching actually 5 mA (fig. 7). Injection rates higher than 4 mA/s have then been observed [12].

Results in fig. 7 are obtained at 0.9 GeV, since on April 17th a harmful fault on one of the two cabinets of the bending magnet power converters forced us to operate with only one cabinet, thus at lower injection energy. The faulty cabinet, now repaired, is still monitored to prevent similar faults in the future.

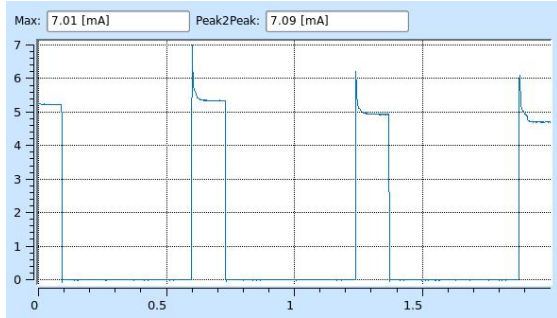

Figure 7: Booster current 5 mA - 0.9 GeV.

CONCLUSIONS

The Booster inauguration ceremony was held on March 28th, 2008. The project was concluded on time and on budget. Key performance achievements are:

- Linac energy and charge specs met (110 MeV, 2 nC)
- Booster energy spec met (2.4 GeV)
- Users' full energy operation (2.0 GeV) established
- Overall efficiency larger than 80%

Goals on nominal repetition rate (3.125 Hz), on users' operation at 2.4 GeV and on improved reliability and reproducibility, will be met once the power converters refurbishment program is completed in August. A top-up experiment campaign is due to start soon afterwards.

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