ELETTRA BOOSTER COMMISSIONING AND OPERATION

F. Iazzourene*, on the behalf of the Elettra team
Sincrotrone Trieste, Trieste, Italy

Abstract

The new injector, consisting of a 100MeV Linac and a 2.5GeV booster synchrotron, replaced the old limited energy 1.2GeV Linac by the end of 2007. The paper reports on its commissioning phases and results together with its present status of operation.

INTRODUCTION

ELETTRA is a 2.5GeV 3rd generation light source in operation since October 1993. In order to operate in top up mode, a full energy injector has been designed [1], commissioned and is now in operation since March 3rd, 2008. The main booster parameters are summarized in table 1.

The new injector commissioning had 3 deadlines:

- The users should have beam with the previous injector 1.2GeV linac until 8th of October 2007.
- The 1.2GeV linac had to be available for the FERMI@Elettra project within October 2007
- The new injector had to deliver the beam to the users in March 3rd, 2008

To achieve these requirements, the commissioning has been divided in 3 phases followed by normal storage ring machine physics shifts:

- 1st phase, i.e. run 1 (14/09/2007 - 14/10/2007): extract a beam from the booster at 2.5GeV, or at least 0.75GeV, which is the minimum energy of the storage ring. This includes the commissioning of the 100MeV pre-injector linac (P), the pre-injector to booster transfer line (PTB) and the booster. At the end of this phase we had to make sure that the new injector can replace the previous one. Successively, we disconnected the 1.2GeV linac and the transfer line linac-to-storage ring.
- 2nd phase, i.e. run 2 (26/11/2007 - 21/12/2007): optimization of the linac (P), the transfer line (PTB) and the booster. Meanwhile, we installed the transfer line booster to storage ring (BTS) and the new storage ring injection system.
- 3rd phase, i.e. run 3 (21/01/2008 - 10/02/2008): commissioning of the BTS and injection into the storage ring

To make up with some delays, the beam commissioning has been also dedicated to some systems commissioning. Furthermore, the pre-injector, the low energy transfer line and the booster have been commissioned in parallel, when possible.

- After the 10th of February, started the storage ring machine physics shifts dedicated to the preparation of the storage ring and the new injector for the delivery of the beam to the users.

* fatma.iazzourene@elettra.trieste.it

Table 1: Booster general design parameters

Magnet lattice	2 fold symmetry
Injection/Extraction energy (GeV)	0.1 - 2.5
Repetition frequency (Hz)	3.125
Nominal beam current ▪ multi-bunch/pulse length ▪ single bunch/pulse length	 4mA/150 ns 0.4mA/2 ns
RF frequency operation (MHz):	499.646 - 499.654
Circumference (m)	118.8
Revolution period (ns)	396
Harmonic number	198
Equilibrium emittance @ 2.5 GeV ▪ nominal emittance optics (mrad) ▪ low emittance optics (mrad)	 $226\ 10^{-9}$ $166\ 10^{-9}$
r.m.s. energy spread @ 2.5 GeV	$7.18\ 10^{-4}$
Energy loss per turn @ 2.5 GeV	388 keV
Damping times τ_x,τ_y,τ_z @ 2.5 GeV	5.1,5.1,2.6 ms
Betatron tunes Q_x, Q_y ▪ nominal emittance optics ▪ low emittance optics	 5.39, 3.42 6.80, 2.85
Natural chromaticity ξ_x, ξ_y ▪ nominal emittance optics ▪ low emittance optics	 -6.6, -4.7 -11.1, -5.2
Momentum compaction factor ▪ nominal emittance optics ▪ low emittance optics	 0.0443 0.0308
Maximum β_x, β_y, D_x (m) ▪ nominal emittance optics ▪ low emittance optics	 10.8,13.8,1.624 15.0,17.2,1.683
Peak effective RF voltage (τ_q~ 60 s) ▪ nominal emittance optics ▪ low emittance optics	 0.84 MV 0.73 MV

COMMISSIONING & OPERATION

25/09/2007: 1st injection tests into the booster.
26/09/2007: hundred turns in the booster at an estimated energy of 104MeV
29/09/2007: 1500 turns in the booster – RF ON
04/10/2007: accumulated 1.2mA
03/10/07 to 13/10/2007: ramping tests to moderate energies. Power supplies were instable already at 500MeV. Changing the repetition frequency from 3 to below 1Hz we could reach 800MeV.
13/10/2007: extracted beam at 800MeV – end run 1

After some refurbishing of the booster bending and quadrupole power supplies by the furnisher [2], we were able to extract a 2GeV beam at the end of the second phase. The rise and fall times of the ramp are 160ms, but the repetition time had to be 1.2seconds, during run 1 and 2.

During the third phase of the commissioning and later, some more improvements have been obtained: 2GeV operation of the storage ring with a 2.0GeV booster beam, together with a whole day dedicated to top off injection tests (ID closed, beam lines closed), 2.4GeV injection tests into the storage ring, booster ramping tests with 1.5Hz repetition frequency, rise/fall time always 160ms. After the major failure on one of the two booster dipole power converters of April 17th, we had to use only the functioning one. This limited the maximum booster energy to 1GeV. At present, the beam is extracted at 900MeV from the booster, injected into and ramped in the storage ring to the required operation energy, 2 or 2.4GeV. Last optimizations give a storage ring injection rate of 4mA/s (fig. 1), with 5mA extracted from the booster at 0.9GeV (fig. 2) and a repetition frequency of 1.5Hz. This has been obtained after an optimization of the phase and energy of the linac, and the correction of the chromaticity (DC part), mainly, and orbit.

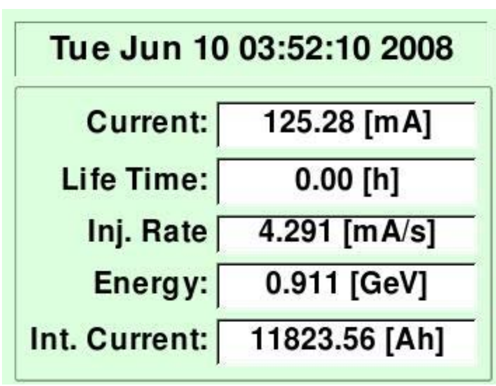

Figure 1: Storage ring injection rate.

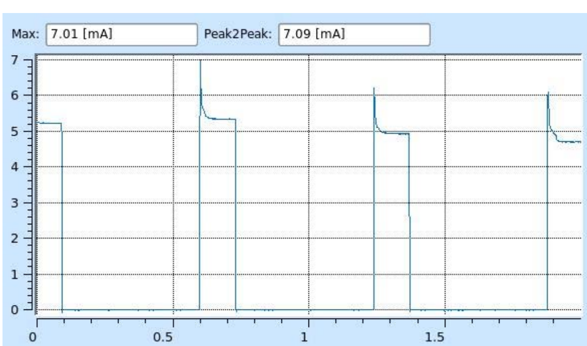

Figure 2: Booster beam current, ramping & extraction.

The extraction efficiency is 100%. The efficiency from the extraction to the injection into the storage ring is above 90%. But, the efficiency from the exit of the pre-injector to the injection into the booster varies between 25 and 75%.

Furthermore, the storage ring has been operated in single bunch for FEL users. The injection rate was around 0.09mA/s.

Personnel Safety System

A new safety system has been developed for the new injector and then interfaced to the storage ring safety system. For details, see [3].

Diagnostics

During the commissioning, we mainly used the fluorescent screens; the beam loss monitors and the strip line pickup of the booster foreseen for the display of the beam filling pattern. Furthermore, the booster DCCT and strip line are used in parallel for the improvement of the accumulated beam. The transfer lines' BPMs were not yet calibrated, but they have been quite useful to monitor and investigate the injection efficiency into the booster relative to the variation of the PTB trajectory. At present, they are calibrated [4].

The Booster BPM system is derived from the electronics of the old Elettra BPMs. The electronics has been refurbished and the communication system has been upgraded. The system consists on 22 BPMs connected with four cables to a dedicated electronics that perform multiplexed signal demodulation to calculate the X and Y position. The 22 BPMs are grouped in four groups that correspond to four CPU with real-time OS. The positions are calculated during the ramp of the booster using a "gate" signal from the timing system. When the complete ramp's data are collected any CPU send the data via TCP to an upper level CPU. This CPU manages the complete BPM Booster system, collects the data from the field and releases all the orbit positions to the Tango Control System with a dedicated software Tango server. At present, we are able to measure and correct the orbit of the booster in DC mode [5].

Furthermore, a new timing system has been developed and gradually implemented. For details see [6].

For the tune measurements, the tests done in static and dynamic lead to some enhancements in the measurement system.

Control System

The control system is fully distributed and based on two layers architecture. The 1st layer is the equipment access level and the 2nd layer is the presentation level, typically the control room workstation. The software control system is based on TANGO. The control system functioned correctly from the start. For details see [7].

Application Programs

Most of the needed tools for the commissioning of the new injector were available from the start. Some made use of the MATLAB package, like the measurement of the linac emittance. Some others were written in Python, like the filling pattern setup of the storage ring and the one shot injection and ramping of the booster. The save and restore of the machine settings/readings is performed by a dedicated application program, based on TANGO tools. For details see [7].

The other application programs, like: boosterTOCA, boosterBumpers, PTBTrajectory, PTBEnergy [5] are based on the new high level framework (Hlf) and the new beam optics module named Vicky. They are written in C++ and use the Qt widget libraries for the graphic interface.

Electronic Logbook

A web based electronic logbook dedicated to the new injector has been developed and successfully used during the whole commissioning. It also provides some useful tools, like the statistics of the faults, the trouble shooting and the procedures.

Injection/Extraction

The injection in the booster uses a septum and a kicker. For the extraction, we have foreseen two septa, two kickers and four bumpers, the central two are actually used as one bumper. Both systems functioned correctly. Up to 2GeV, we did not need the bumpers because the beam was not on axis, but nearer to the extraction septa. For details, see [8].

Booster Ramping

Energy ramps follow a cosine-like curve. The actual output of the power supply is the sum of the DC - static - and the AC ramp current: $I(t) = I_{DC} + I_{AC}$. For the bending power supplies, I_{AC} follows the energy. For the quadrupole, sextupole and corrector power supplies, we have: $I_{AC} = I_{Energy}$ * scaling_factor. I_{Energy} is obtained from the magnets calibration current vs field and energy vs strength, where the strength is kept constant during the energy ramping, using the Hlf library. The operator can change the scaling factors through a control panel. Each group of magnets has its own scaling factor, one for the QFs, one for the QDs, one for the SFs, one for the SDs, one for the horizontal correctors and one for the vertical correctors. From a control panel, the operator can also change the rise and fall time of the ramp, together with the I_{DC}. Furthermore, the operator can adjust online the ramp delays between the bendings and the quadrupoles, sextupoles and correctors. The delay between the bendings and the correctors has been quite effective. Typically, the delay was about 100ms.

The current ramp waveform starts with a zero slope, that is, from the static injection values. This strategy allows us to adjust the booster to a good capture condition and ramp with a reduced stress on the power supplies. The down ramping goes instead to a smaller value, typically 50MeV instead of the usual injection energy 110MeV, to provide some cycling of the magnets, as shown in fig. 3. For this purpose we have added a so called recovery segment to the ramp waveform, where the current is set to values lower than the starting point.

Furthermore, the booster is ramped to a higher energy than the storage ring injection one for two reasons: one is to match precisely the energy of the extracted beam to the injection energy of the storage ring by adjusting the extraction time delay, the other is to allow a cycling of the power supplies. At present, the booster is ramped to 1GeV and the storage ring injection energy is 0.9GeV

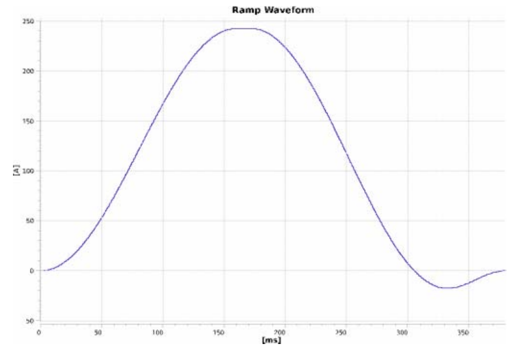

Figure 3: Bending power supplies ramping curve.

RF System

The RF system operated correctly. The cavity voltage ramping follows a simple linear curve. As for the power supplies, the timing provides also a delay with respect to the bending magnets. For more details, see [9].

CONCLUSIONS

The users got the beam and the old 1.2GeV linac injector has been available for FERMI@Elettra project as scheduled. Most of the systems worked correctly. The Power converters refurbishment is in progress. Once the problem of the power supplies will be solved, the next steps will be: Booster operation at 2.4GeV, 3 Hz repetition rate**,** overall improvement efficiency**,** optics characterization**,** and top-up studies and implementation

REFERENCES

[1] F. Iazzourene, “Update on the Linear and Nonlinear Optics of the Elettra Full Energy Booster Synchrotron”, EPAC 2002, Paris, France, 2002

[2] M. Svandrlik,“Overview of the Status of the Elettra Booster Project”, these proceedings

[3] K. Casarin et al., “The Personnel Safety System of the Elettra Booster”, these proceedings

[4] S. Bassanese et al., “The Diagnostic Line of Elettra Booster 100MeV Pre-Injector”, these proceedings

[5] F. Iazzourene & C. Scafuri, “Application Programs for the Elettra Booster Commissioning and Operation”, these proceedings

[6] S. Bassanese et al., “Timing System of the New Elettra Injector”, these proceedings

[7] M. Lonza et al., “Implementation and Operation of the Elettra Booster Control System”, these proceedings

[8] R. Fabris et al., “The Injection and Extraction Kicker Circuits for the Elettra Booster”, these proceedings

[9] A. Fabris et al., “Installation and Commissioning of the RF System for the New Elettra Booster”, these proceedings.