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OPERATION IMPROVEMENTS OF THE ACTUAL BOOSTER-INJECTOR FOR ELETTRA 2.0

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Abstract

The current injector system, composed of a linac and a synchrotron booster, will also be used to inject into the new storage ring. After 15 years of operation, some upgrades of the instrumentation devices are required to well characterize the beam parameters extracted from the booster, before and after the implementations in action to reduce the beam emittance.

INTRODUCTION

The Injector should guarantee that the injection efficiency into the new ring will be high i.e. >90%.

The extraction beam energy pulse can be selected from 100 MeV to 2.5 GeV with repetition rate of 2 Hz with max e- beam current of 2 mA (400 uA in top-up operation mode)

Due to the tight constraints imposed by e.g., the dynamic aperture of the new storage ring [1], a series of on-field measurements of the extracted beam is in progress. The strategy is to replace some obsolete or underperforming parts from the pre-injector, transfer line and booster. Several works started 2 years ago, some are in completion and some will have to be finished before Elettra 2.0 commissioning.

PREINJECTOR STATUS AND UPGRADE

For the existing pre-injector (100 MeV linac) an upgrade plan consists in replacing the old electronics with new ones that will improve its performance and stability, the construction of a spare thermionic gun and other actions on the hardware in order to achieve spare parts compatibility with FERMI@Elettra.

Gun Upgrade:

The gun will get 3 main improvements, increase high voltage operation from 57 kV to 90 kV, replace the obsolete TH306 oxide electron source with CPI Y-646 oxide electron source (mechanical modification) and change the electronic part of gun modulator.

The gun will be able to operate in three different modes: single bunch mode, multi bunch mode and crab cavity mode [2] (Fig. 1).

High Voltage Modulator Power Supply Upgrade:

The power supplies currently installed on the Elettra pre-injector have accumulated more than 25 years of operation and are not adequate to operate with the new Elettra 2.0 pre-injector modulators. The new Elettra 2.0 pre-injector modulators will require the fabrication and installation of 2 new positive-polarity high-voltage power supplies (Table 1) that can operate them in both the actual mode (with doubling coil) and the mode adopted in FERMI@Elettra (at double output voltage without using the doubling coil).

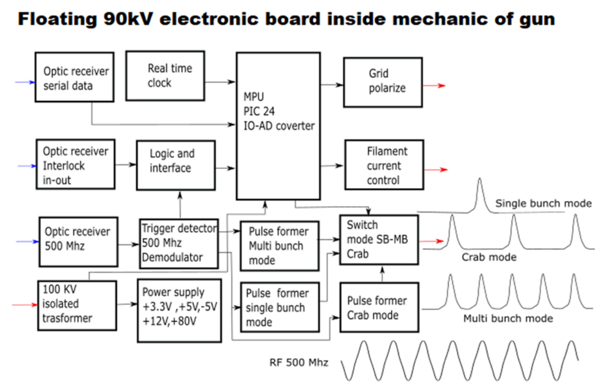

Figure 1: Gun modulator block schematic and mode operation.

Table 1: High Voltage Power Supply Specification

Max V output	50kV	Positive output
Max current	600 mA @ 50% nominal voltage	400 mA @ 25-50 kV output
Max Repetition rate	10 Hz conditioning mode	3Hz operational mode

The mode adopted in FERMI@Elettra allows continuous control of the charge voltage of the PFN (Pulse Forming Network), which results in more stable characteristics in the radio frequency accelerating pulse.

BOOSTER OVERVIEW

The booster has been in operation for Elettra for the last 15 years bringing the electron beam energy from 100 MeV to 2.5 GeV, the energy of the extracted beam selected by changing the extraction time along the energy ramp of the magnets [3]. The used optic is the nominal 226 nm rad at 2.4 GeV. The beam current in top-up mode is 400 uA, however the maximum achievable current is about 2-3 mA. Measurement of tunes involved dedicated shifts and was not available online or during top-up mode. The radio frequency is Elettra's nominal one at 499.654 MHz. Now for user shifts in top up mode we reach high injection efficiency in the storage ring without need to use online

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BPMs orbit control, extraction bumpers, and online tunes measurement.

BOOSTER UPGRADE

Booster Alignment:

In 2022 a realignment of the booster magnets, bending and quadrupoles was done bringing them all within +-200 um of the ideal model. As a result the beam now has an orbit with an RMS less than 3 mm vertically and 4-5 mm horizontally with all correctors at zero. Before alignment, it was impossible to inject having the correctors at zero.

Beam Current Measurement:

A digitizer card has been added that acquires the booster beam current accumulated during energy ramp with a time resolution of 200 us, for a total of 1000 points. This allows to see any small current leakage during the ramp and to improve precision of measurement of injection efficiency in top-up.

BPM System:

The old VME-based BPM system dating back to Elettra has been restored. That system is capable of providing about 32 full orbits along the energy ramp (one every 5 ms). Software is being written for orbit correction during the ramp. The resolution with 1 mA accumulated in booster in static mode is +-100 um.

By 2025, the electronics of the booster BPM s will be replaced with the same of the Elettra 2.0 BPM system, which will allow more resolution, better noise rejection and single-turn measurements. Estimated resolution < =10 um.

Tune Measurement:

Measurement is done using an in-house developed custom electronic device that is based on a PC-104 interfaced to electronic board that includes an FPGA, memories, 6 input output channels including 4 input 14-bit ADC channels and 2 output 12-bit DAC channels (Fig. 2).

A radio frequency divider generates from 499.654 MHz the booster revolution frequency to make sampling every booster turn synchronous (Booster Ring Clock).Two input ADC channels are used to sample 4 times each booster revolution cycle the signal of X and Y position of Bergoz BPM analogic front end output channel is used to create a tune excitation pattern, which is connected to a 600-watt power amplifier (MDM electronic model AG1016) connected in turn to an excitation plane selector connected to a strip line in Booster.

The other output channel is used to modulate the output power according to the energy of the beam during the ramp.

The maximum resolution of the frequencies read on the tunes is 1 kHz with a sampling rate of 2 msec.

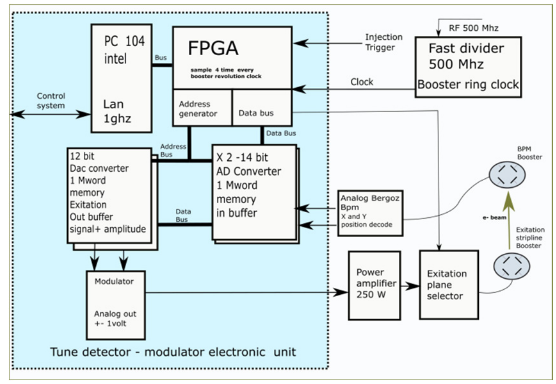

Figure 2: Block schematic of tune measurement system.

The tune measuring instrument communicates with the control system, Tango [4], via a TCP socket. The Tango device server provides the excitation (gain and excitation pattern) and readout channels for the measurement, as well as commands for selecting the measurement plane (h or v) and for starting excitation and sampling. A panel written in Python3 takes care of the user interface for using the instrument and analysing the data received, using the PyQt5 libraries for the graphic components, PyTango (the Python API of Tango) for the interface to the control system, NumPy for mathematical support, Matplotlib for displaying the graphs and SciPy for signal processing.

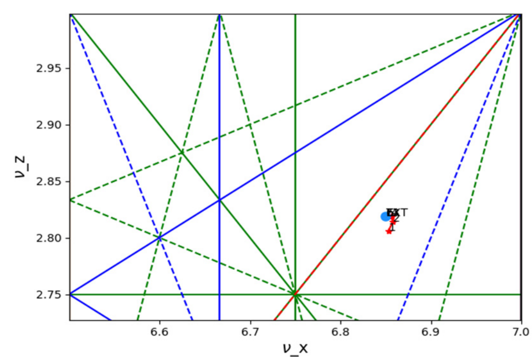

Figure 3: Measured tunes diagram during ramp.

In particular, the reading of the fast oscillation data is processed with SciPy's spectrogram functions (signal-spectrogram). Tune points during the ramp can be obtained manually by tracing them directly on the graph, or by using the custom AutoFit function that can be tuned via threshold. The saved file contains all the data for recreating the measurement context or for using the data for off-line processing.

If the measurements of both planes are present, it is possible to display the Tune diagram (Fig. 3) in which the variation of the tunes during the ramp is visible. The data from the measurement during the ramp are used by the other tools we have developed for fine-tuning the current ramps of the power supplies to correct the tunes during the energy ramp.

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The excitation pattern is created using SciPy's signal.chirp functions and sent to the instrument, the user can set the start and end frequency and duration of the chirp. The resulting samples are repeated until the excitation/sampling duration is filled. A repeat measurement function was implemented to evaluate the variation of shot-to-shot tunes.

Big Power Supplies:

The bending and quadrupoles power supplies were installed 15 years ago. During the energy ramp from 100 MeV to 2.4 GeV the power supply current increases from 30 to 700 A for the bending and from 10 to 300 A for quadrupoles.

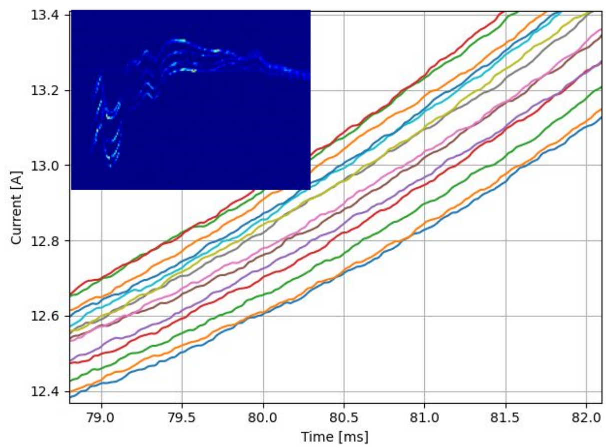

Figure 4: Tunes shift VS current amplitude error of Booster PSQD during consecutive ramps.

A non-repeatability of the output current of the power supplies between one ramp cycle and the next was found: This variation is approximately 300 mA peak-to-peak for the bending and 200 mA for the quadrupoles. This results in an unwanted change in tune frequency shot-to-shot, on the horizontal plane of 40 kHz and 10 kHz on vertical one (Fig. 4).

The present power supplies will be replaced with new ones through a call for tender process to a supplier company that can guarantee a maximum shot-to-shot variation less to 50 mA.

Bumpers:

We realized that using a low emittance optics in booster necessitates increasing the voltage of the extraction kicker up to the limit of the maximum voltage, due to a different orbit in that area [5]. This is not recommended because increases the possibility of producing discharges resulting in breakdown of the magnet insulator itself. Therefore, the choice was to add driver electronics on the 4 horizontal correctors used in bumper mode. These bumpers can be drive with a maximum current of 12 A 5 ms before the extraction time and shift the orbit at that point by 5 mm by bringing the beam accumulated in boosters closer to the magnetic screen of the extraction septum contextually decreasing the voltage at the extraction kicker (Fig. 5).

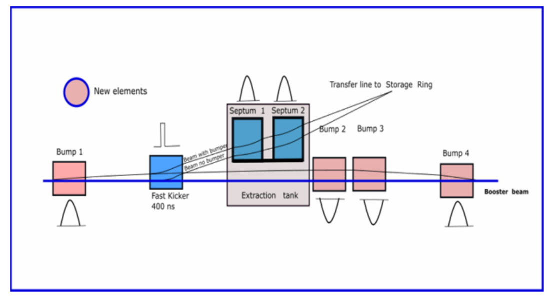

Figure 5: Booster bumpers.

Transfer Lines:

New Libera Spark BPM electronics have been installed on the booster to storage ring transfer lines that provide resolution <= 10 um. New trajectory correction software is in operation in the BTS that provides full control from position to injection point in the storage ring and on the fluorescent screens dedicated to emittance measurement.

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