INSTALLATION AND COMMISSIONING OF THE 100 MeV PREINJECTOR LINAC OF THE NEW ELETTRA INJECTOR

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Abstract

A new full energy injector has been installed and commissioned at ELETTRA, the Italian Synchrotron Light Source facility in Trieste. It consists of a 100 MeV pre-injector linac followed by a 2.5 GeV booster Synchrotron, that fills the Elettra Storage Ring with 2.0 GeV and 2.4 GeV electrons.

Here a complete description of the preinjector linac and a first evaluation of its performance will be presented and discussed.

INTRODUCTION AND MILESTONES

The new ELETTRA full energy injector, consisting of a 100 MeV pre-injector linac and a 2.5 GeV booster synchrotron, has been successful commissioned and routinely providing electrons for the storage ring for users operations since 3rd of March 2008 [1].

The new pre-injector linac can fill the booster in two operating modes:

- single bunch mode (SB), with one booster RF bucket (@500 MHz) filled;
- multibuch mode (MB), with up to 75 buckets filled.

The main parameters of the machine are summarized in Table 1, showing the designed and achieved performance.

One of the most important requirements of the new injection system is to guarantee the operation in top-up mode, keeping constant the ELETTRA stored current. This in general implies machine reliability and an adequate safety margin for the operating levels of the main components. For this reasons the pre-injector layout foresees a second RF power station, now under assembly, with a spare klystron that guarantees the machine operation in case of fault of the main RF plant. This will have a noticeably effect on the down time of the machine.

The installation of the pre-injector started at the end of June '07 with co-occupancy of the building and putting in place the two main accelerating sections. The whole machine installation, the first RF plant, the WG circuits and the ancillary systems, was completed in late August. Two weeks were spent for RF conditioning of the accelerating structures (Aug. 24th- Sept. 6th), pushing the klystron peak power up to 38-40 MW for 3.5 μ sec pulse width at 10 Hz pulse repetition rate (prr).

The first electrons from the gun were extracted on September 7th (multi bunch mode) and a week later we transported the first accelerated beam to the exit of the

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second accelerating section, measuring 90 MeV beam energy (September 15^{th}). Then the machine was operated up to Sept. 24^{th} to explore its performance and for beam optimization.

With a quite moderate level of power from the klystron, (≈ 36 MW), we have obtained a beam energy in excess of 115 MeV, with 100 mA current in 100 nsec pulse width. The overall transmission efficiency (Gun-Linac exit) was better than 60% and a first estimation of beam energy spread was less than 1 MeV @ 115 MeV.

After these preliminary tests, from September 25th, the machine was set at 110 MeV, 20 mA, 100 nsec, to allow, the starting of booster commissioning.

Table 1: Preinjector main beam parameters

	De	signed	Achieved	
Parameter	SB	MB	SB	MB
Beam energy (MeV)	100		>115	
Current (mA)	-	20	-	100
Pulse width (nsec)	1	10-150	1	> 300
Charge/pulse (nC)	0.16	> 3	0.14	30
Norm. Emittance (µrad)	< 200 (90%)		142 (E _{90,y})	
Energy spread (%)	<1(peak to peak)		< 1	
Pulse rep. rate (Hz)	1-10		3	
Storage Ring filling time	< 5 min.		< 4 min.	

GENERAL DESCRIPTION OF THE PRE-INJECTOR

Electron Gun

The linac includes a grounded grid triode gun (Thales TH 306), with a 1 cm² emitting surface and a wire grid 100 μ m from the emitting surface. It has a modified Pierce geometry and allows for low voltage grid control. The gun can deliver 2 ns or 10-300 ns electron pulses (SB or MB modes respectively) and a current in excess of 750 mA, at 10 Hz. At present the injection voltage has been set at 60 KeV, and with few a volts on the grid we can extract roughly 7 nC/pulse from the gun (60 mA in 120 ns), sufficient for the present operation. In fact with an overall transmission efficiency, gun to storage ring, of 25% we can accumulate the 330 mA requested for the 2.0 GeV operation in less than 4 minutes. Moreover, with an adequate conditioning, we believe that the injection voltage can be easily increased up to 80-85 keV with an

emitted current of a few hundreds mA if required. The TH 306 triode is the same model we had in operation since 1991 on the previous ELETTRA injector with a lifetime higher than 10,000 hours.

Bunching section

The bunching section is composed of a 500 MHz subharmonic pre-buncher (a TM₀₁₀ pill-box cavity) followed by a 3 GHz standing wave buncher, partially embedded in a focusing solenoid with an iron screen and horizontal and vertical steering coils. Beam focusing is provided by five thin magnetic lenses (L1-L5) made by SIGMAPHI, and two sets of horizontal and vertical steering coils providing for beam trajectory adjustments. All the bunching section, pre-buncher, buncher and focusing solenoid, were designed by the accelerator group of ENEA Frascati. They also performed all the beam dynamics simulations based on the EGUN code inside the gun region and TRACE3D/PARMELA from gun output up to the buncher exit, optimizing the beam transport [2]. The bunching system, shown in Figure 1, was then manufactured from Busato & Satta s.n.c., Roma.

Table 2 and 3 summarize the main parameters of the pre-buncher and the buncher.

Table 2: Parameter list of the Pre-buncher cavity.

Frequency	499.654 MHz
Gap aperture diameter	40 (mm)
Gap length	90 (mm)
Overall length	140 (mm)
Inner diameter	459 (mm)
Material	Aluminium (copper plated)
Q (measured)	15530
Cavity Voltage	19 KV
Input Power	160 W

Frequency	2998 MHz
Type of structure	Standing Wave, β-graded
Number of cells	1 half cell + 12 full cells
Qo	12600 (measured)
Average field E _o	14 MV/m
Kilpatrick factor	1.23 (max)
Input power	1.2 MW
Solenoid magnetic field	700 gauss (max)
Output Energy	6.4 MeV
Total length	625 mm

Table 3: Parameter list of the Buncher

The PARMELA tracking of the 6-dimensional phase space of the beam, based on 20000 macro-particles distributed over a range of 6 S-band cycles (± 1080 °RF at 3 GHz), gave the beam parameters at the buncher exit under optimized transport conditions reported in table 4.

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Capture	60%
Normalized emittance	51 π mm-mrad (90%)
RMS energy spread	22%
Twiss parameters α_{xy}, β_{xy}	0.2, 0.23 m/rad



Figure 1: 3GHz buncher and its focusing solenoid (in red) and 500 MHz pre-buncher cavity.

Accelerating sections and beam transport

The main accelerating sections are two 4,6 m long LIL structures (S1 and S2), donated by CERN after LIL decommissioning. Since CERN was working at a different frequency (2998.55 MHz @ 30 °C), they have been measured in order to be characterized for a 2997.924 MHz operation. Based on the operating frequency the temperature of the sections has been set at 42.5 °C (fine beam tuning confirmed that value). The two travelling wave sections are quasi-constant gradient, with an average group velocity of 0.0117c and a filling time of about 1.28 μ s. The attenuation of the sections, is 7.4 dB and we have measured about 1°S random fluctuation from the 120° cell to cell phase shift.

The beam transport line [3] includes three identical and independent quadrupoles, inserted between the buncher and S1, as well as between S1 and S2. Two pairs of steering coils (H-V) are positioned at the input and output of each accelerating sections. A diagnostic line is installed at the exit of S2 for beam characterization and tests. It includes an integrated current monitor, for charge measurements, a bunch arrival monitor (BAM), and an emittance measurement with a quad scan apparatus technique. The beam energy spread is measured using the 15° bending magnet and using a pre-injector to booster transfer line includes a 15° bending magnet and the machine optics directs the beam to the booster transfer line to measure the beam energy spread.

RF plant

Figure 2 shows the layout of the pre-injector RF plant. It includes two high voltage klystron modulators (MDK1 and MDK2) equipped with Thales TH 2132A tubes and a waveguide (WG) system that allows use of only one of the two available RF transmitters to feed the accelerating structures. The remaining klystron is connected to RF water loads using two high isolation WG switches (> 60 dB). This scheme will completely decouple the power of the two RF generators. In case of a fault it is possible to

disconnect one RF plant leaving the second one in operation to minimize the downtime of the machine.



Figure 2: layout of the RF plant

The high voltage modulator is a conventional line type design (PFN with resonant charging choke) that uses an e2V CX1536X thyratron as switch, and is essentially an upgrade of the existing ELETTRA modulators. The RF source adopted, the TH2132A, 45 MW peak power, has two RF outputs, one for each accelerating sections and the power for the buncher (≈ 1 MW) is taken out from a 0-8 dB variable coupler (VC) installed on the S1 WG.

The low level RF system consists of a 500 MHz master oscillator (MO) that drives two solid state pre-amplifiers with frequency multipliers (3 GHz, 300 W). At the moment the system does not include any RF feedback. Figure 3 shows some typical pulse shapes from the RF plant.

PRELIMINARY MEASUREMENTS AND BEAM TESTS

The new pre-injector has been successful operated in single and multi bunch modes, but its potentialities and performance have not been explored in detail yet. As reported before, energy and energy spread have been satisfactory achieved, with a charge (in multi bunch mode) noticeably higher than expected. However, in SB mode the designed performance is not fully reached yet. As reported in Table 1, the requirement is to provide at the linac exit a minimum of 160 pC in 1ns (i.e. half of the sub-harmonic bucket), in no more than three consecutives S-band micro-bunches. To do this, avoiding satellites, a grid pulse of an adequate amplitude/duration (less than 2 nsec width @ 50 % of amplitude) is required. In the present conditions it is not possible to get more than 140 pC at 110 MeV without satellites and better control of the gun modulator will be necessary. Preliminary emittance measurements have been made in SB mode with the result in good agreement with the simulations. For more details on the beam measurements see [4,5].



Figure 3: some typical pulse shapes from the RF plant

CONCLUSIONS AND ACKNOWLEDGEMENTS

The new ELETTRA pre-injector linac has been successfully commissioned and is now in daily operation providing electrons for ELETTRA. Most of the designed parameters have been achieved and exceeded, but a complete characterization of the machine is still pending. Some improvements are necessary on the gun modulator to fully reach the SB design specifications.

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