100 MEV PRE-INJECTOR LINAC FOR THE PROPOSED ELETTRA BOOSTER

G. D'Auria, C.Rossi, Sincrotrone Trieste, Trieste,Italy
S. Kulinski, E. Plawski, Soltan Research Institute, Swierk, Poland.

Abstract

A new full energy injection system, consisting of a 100 MeV pre-injector Linac and a Booster Synchrotron, has been proposed to overcome the limitations of the present ELETTRA injector [1].

The new pre-injector has to provide single and multibunch operating modes as well, as the possibility to operate the light facility in the so called top-up mode. The proposed layout includes one 6 m accelerating section equipped with a Sled system. First beam dynamics and plant layout are presented.

1 INTRODUCTION AND MAIN SPECIFICATIONS

At present the ELETTRA injector is a linear accelerator that can provide an electron beam up to 1.2 GeV. To reach the operating energy, after the injection the beam is ramped in the Storage Ring to 2.0 GeV or 2.4 GeV, as required by the Users. Since this ramp procedure is necessary anyway, to enhance the injector reliability and to increase the life time of strategic and expensive components, like klystrons and thyratrons, the injection energy has been further reduced to 1.0 GeV. To overcome this limitation and to avoid problems resulting from this scenario (i.e. losses in the overall efficiency of the machine, the ramping stress induced on the Storage Ring components, the impossibility to operate the facility in the top-up mode, etc), a new full energy injection scheme consisting of a 100 MeV Pre-Injector Linac and a 2.5 GeV Booster Synchrotron has been proposed. The new injection system has to provide single and multibunch electron beams as well as operation in top-up mode. Table 1 summarizes the pre-injector beam requirements for single and multibunch modes and Fig. 1 shows the proposed machine layout. The design minimizes costs ensuring at the same time high reliability and good safety margins on the achievable beam energy and on the deliverable RF power from the klystron, which are extremely important for an user facility, and most essential when top-up operation is considered. To reduce costs the whole pre-injector will be assembled using as far as possible spare parts of the present injector with the main accelerating section taken from the existing Linac. Preliminary considerations, in agreement with the present machine performance, show that one of the existing 6 m BTW (Backward Travelling Wave) accelerating structures, equipped with an RF pulse compressor unit (SLED), will be able to guarantee the required beam requirements. Without stressing the operating conditions of the RF plant, we have estimated that the present SLED system can easaly provide an RF power gain of 3 to 4 so that, for a beam pulse not longer than 100 nsec, and 20 mA beam loading, the proposed configuration can easly achieve an energy gain up to 140 to150 MeV if powered with 3 μsec at 36 to 38 MW, in accordance with the present operating conditions. Moreover operation without the SLED compressor has also been considered. With the SLED cavities detuned the machine will still provide an energy gain of 90 to 100 MeV at a moderate klystron power level of 38 to 40 MW peak.

Table 1: Pre-Injector main specifications

Parameter	Units	Single Bunch	Multi Bunch
Beam Energy	MeV	100	100
Pulse width	nsec	≤ 2	10 to 100
Beam current (@ 100 nsec)	mA		≥ 20
Charge/pulse	nC	≥ 0.15	≥ 2
Beam fine structure		≤ 3 contigous S-band bunches	Pulse train of S-band bunches
Pulse repet. freq.	Hz	1 to 10	1 to 10
Emittance (@ 100 MeV)	π mm mrad	≤ 1.0	≤ 1.0
Energy spread	%	≤ 0.5	≤ 0.5
Expected Storage Ring filling time	min.		≤ 5

The RF plant will be based on the Thomson TH 2132A S–band klystron; this 45 MW peak power tube has been successfully operated on our plants since 1991. We still have in operation klystrons with more than 20000÷25000 hours (filament), moreover, to minimise down time in case of faults or klystron replacement, the new pre-injector will be eventually equipped with a spare RF plant ready for operation.

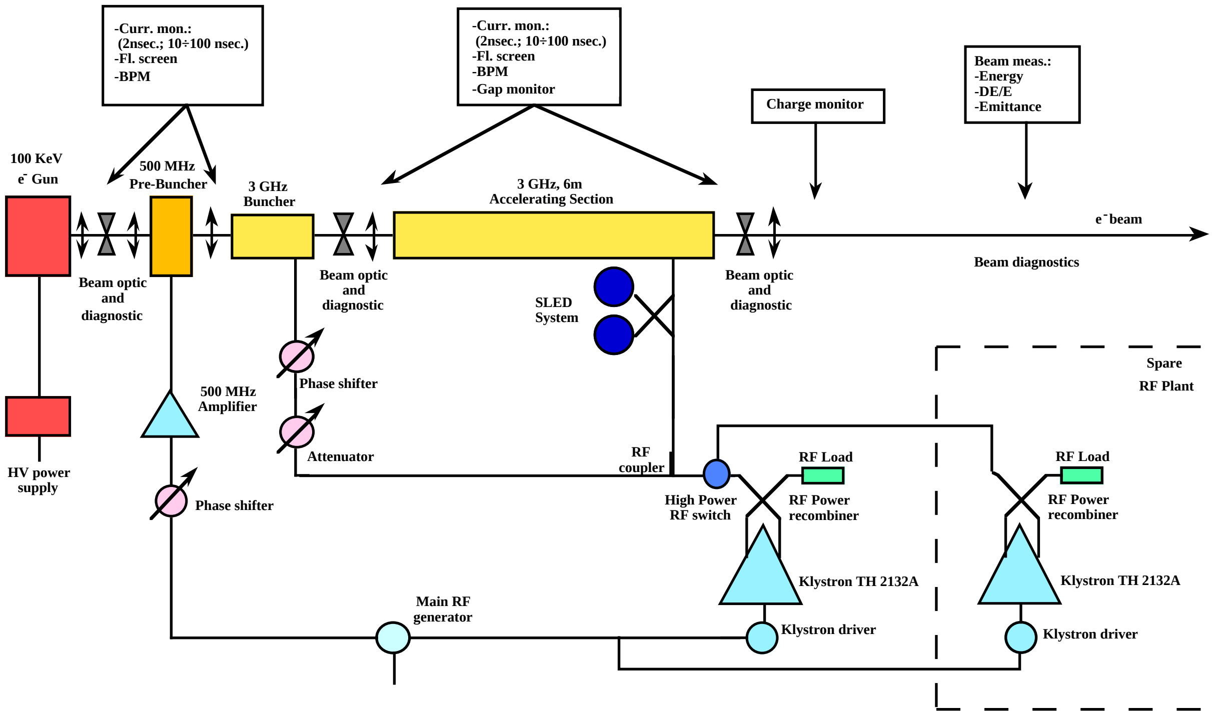

Figure 1: 100 MeV Pre-Injector schematic layout

The 3 MW RF power for the buncher is derived from the main line with a 9 dB high directivity waveguide coupler. We are olso evaluating the possibility to use an additional low power klystron to separately feed the buncher.

In multibunch mode, with a charge of 2 nC per pulse, it will take less than 5 min. to fill the Storage Ring with 400 mA operating at 3 Hz and assuming an overall transfer efficiency of 20%.

2 MACHINE DESCRIPTION

2.1 Electron gun

Ease of procurement and reliability as well as demands for continuous operation over long periods of time, top-up injection and long life time have led to the choice of a conventional thermionic electron source. The selected source is a commercial planar triode (Thomson TH 306), operated up to 100 KeV. The triode is the same model in operation since 1991 on the present ELETTRA injector with lifetimes of at least 10,000 hours. It is a dispenser type with an emitting surface of about 1 cm^2 able to deliver up to 750 mA in the multibunch mode. A prototype of the gun electronics have already been developed in house for a different project [2].

2.2 Bunching section and accelerating structure.

The bunching section is composed of a 500 MHz subharmonic pre-buncher, and a 3 GHz buncher. The first one is a pill box cavity with 90 mm gap operating in the fundamental TM_{010} mode at a maximum modulating voltage of 50 KV. The latter is a 1.2 m long standing wave biperiodic structure, operating in the $\pi/2$ mode and consisting of 25 nose cone cavities, on axis coupled, with β ranging from 0.76 to 1.0 in the first cells; an energy gain not less than 10 MeV with 2.6 MW input power is expected.

The main accelerating structure is one of the existing 6.15 m long, backward travelling wave (negative group velocity) sections, working in the 3/4 π mode and consisting of 163 nose cone accelerating cells magnetically coupled [3]. This type of section has been specially designed for RF pulse compression operation: the group velocity has been optimised for SLED operation, leading to a filling time of less than 0.8 µs and a peak-to-accelerating field ratio ranging from 1.9 to 2.26.

If necessary SLED-ing can be switched off very quickly detuning the two cavities; we have considered (and measured) that the energy gain without the SLED will still remain close to 100 MeV at a moderate klystron peak power of 38 to 40 MW.

3 BEAM DYNAMIC AND SLED OPERATION

Preliminary beam dynamics calculations have been done to study and verify the pre-injector configuration. The specified emittance at 100 MeV, $\leq 1\pi$ mm mrad ($\leq$ 200 π mm mrad norm.) can be obtained starting with a gun emittance $\leq 50\ \pi$ mm mrad @ 100 KeV, considering an acceptable emittance growth in the bunching region of up to 4. Simulations on the gun geometry we intend to adopt give an emittance between 28 ÷ 30 π mm mrad at 100 KeV.

Beam matching into the 3 GHz buncher has been studied with TRACE 3D [4] and the transverse confinement has been achieved with four Glazer lenses, two before the 500 MHz pre-buncher and further two at the entrance of the 3 GHz buncher, where the beam is transported with a 1 m long, 600 Gauss solenoid wound around the accelerating structure.

The bunching process and the beam dynamics have been investigated with PARMELA [5]. With a 25 KV modulating voltage in the 500 MHz pre-buncher, at the 3 GHz buncher exit (10 MeV energy gain), 40% of the beam is bunched in 10 degrees of the synchronous particle within 1% energy spread and the subsequent transport through the 6.15 m accelerating section shows beam parameters inside the mentionned specifications.

In figures 2, 3 and 4 the phase, the energy spread and the transverse emittance at the preinjector exit are respectively shown. Another important aspect of the adopted configuration is the energy spread associated with the SLED operation of the accelerating section. The RF pulse compression technique gives a large no-load energy variation around the optimum injection time, leading to a poor energy spectrum. With more than one RF plant (i.e. on the present injector we have 7 separate SLED plants) it is possible to overcome this unwanted effect advancing the phase reversal time on one or more RF plants taking advantage of the transient beam loading to reach energy spread lower than ±0.5%. In our case, with only one RF plant, we are considering to make use of the RF Phase Modulation technique [6] that keeps the energy spread below ±0.5% at the cost of a moderate energy reduction.

4 CONCLUSIONS

The general layout of the new ELETTRA 100 MeV preinjector Linac has been presented with the simulation of beam dynamics. The construction of the new injector will keep the present Linac operable to minimize user disruption and also leaves open the possibility to use it for SASE experiments as a starting point toward a fourth generation light source [7].

REFERENCES

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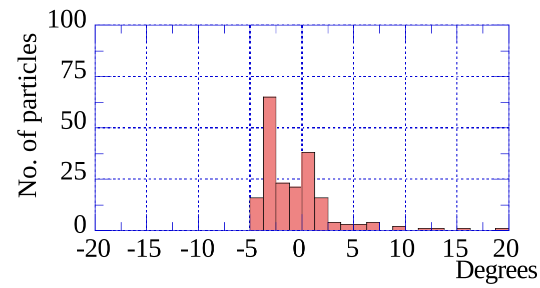

Figure2: Phase spectrum at the preinjector exit

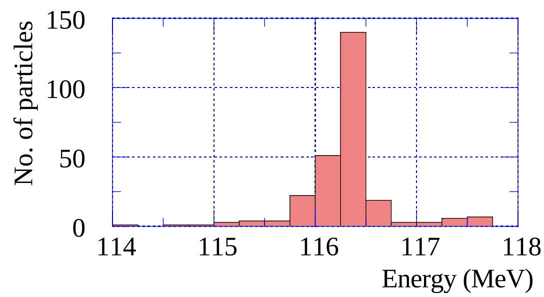

Figure3: Energy spectrum at the preinjector exit

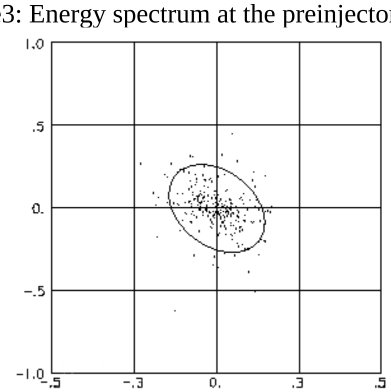

Figure4: transverse emittance at the preinjector exit x(cm), y(mrad)