THE ELETTRA 1.5 GeV ELECTRON INJECTOR

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Summary

The ELETTRA light source will be filled at the energy of 1.5 GeV by a linac of only 60 m length. A 100 MeV preinjector includes subharmonic chopper and prebuncher, S-band prebuncher, 4 MeV buncher, two accelerating sections. A FEL mode of operation will be possible. 200 MeV accelerating units follows. Each includes a 6.15 m $3\pi/4$ backward traveling wave (BTW) section powered by a TH 2132 45 MW - 4.5 μs klystron, compressed to 0.76 μs by a Thomson CIDR (Compresseur d'impulsion à Double Résonateur) similar to the CERN design of the SLED. The main parameters choices represents a significant improvement on the RF linac state-of-art in energy gain for given length and power.

Introduction

Light source synchrotrons are filled by electron (possibly positron) beams from less than 100 MeV for lithography to more than 2 GeV. Electrons can be produced by linacs or racetrack microtrons (in the low energy cases) or by synchrotrons (in the highest energy cases). The linac has the advantage of simplicity and high accelerated charges. But its length and cost must be reduced.

We developed earlier 200 MeV linacs with an energy gain of 16.7 MeV/m [1,2]. This relatively high value combined with few long accelerating structures insured compactness. It is known that much higher gradients could be used [3]. However reliability together with the availability and cost of high peak power RF sources have limited until today very high gradients to short lengths for medical linacs of several MeV (where an energy gain of 25 MeV/m is commonly used) and for positron capture (where an energy gain of 40 MeV/m is achieved [4]).

This paper presents the ELETTRA 1.5 GeV electron injector under construction. The expected energy gain is 33.3 MeV/m in short pulse conditions (this corresponds to 30m per GeV or 35m including the focused drifts between sections). The power consumption remains reasonable, compressing the RF pulse and using new high shunt impedance cell profiles [5]. The peak RF power consumption is 225 MW per GeV (at the klystron exit for a pulse of 4.5μs before compression).

The following presentation is an overview. However the reader who wants to ascertain the critical technical points will find referenced below the useful set of the latest specific papers .

The 1.5 GeV linac

Figure 1 presents the linac which is a part of the TRIESTE ELETTRA light source [6]. It includes: (i) a 100 MeV preinjector with a long pulse FEL mode option at rather large beam current, (ii) a short pulses high energy at low current injector made of 200 MeV acccelerating units. The preinjector and the accelerating units are described in the following sections. The lengths are respectively 10m for the preinjector and 50m for the following accelerator.

The on-axis components are listed (only once for each type) from the gun (1) to the triplet (9). The off-axis ones are listed for the preinjector from the subharmonic oscillator (a) to the klystron (f) and for the accelerator first unit from the amplifier (A) to the solenoidal focusing (SF).

The backward traveling wave accelerating section at the $3\pi/4$ mode is zoomed as well as a mechanical part made of two adjacent half cells. This BTW use optimized for SLED is the design innovation.

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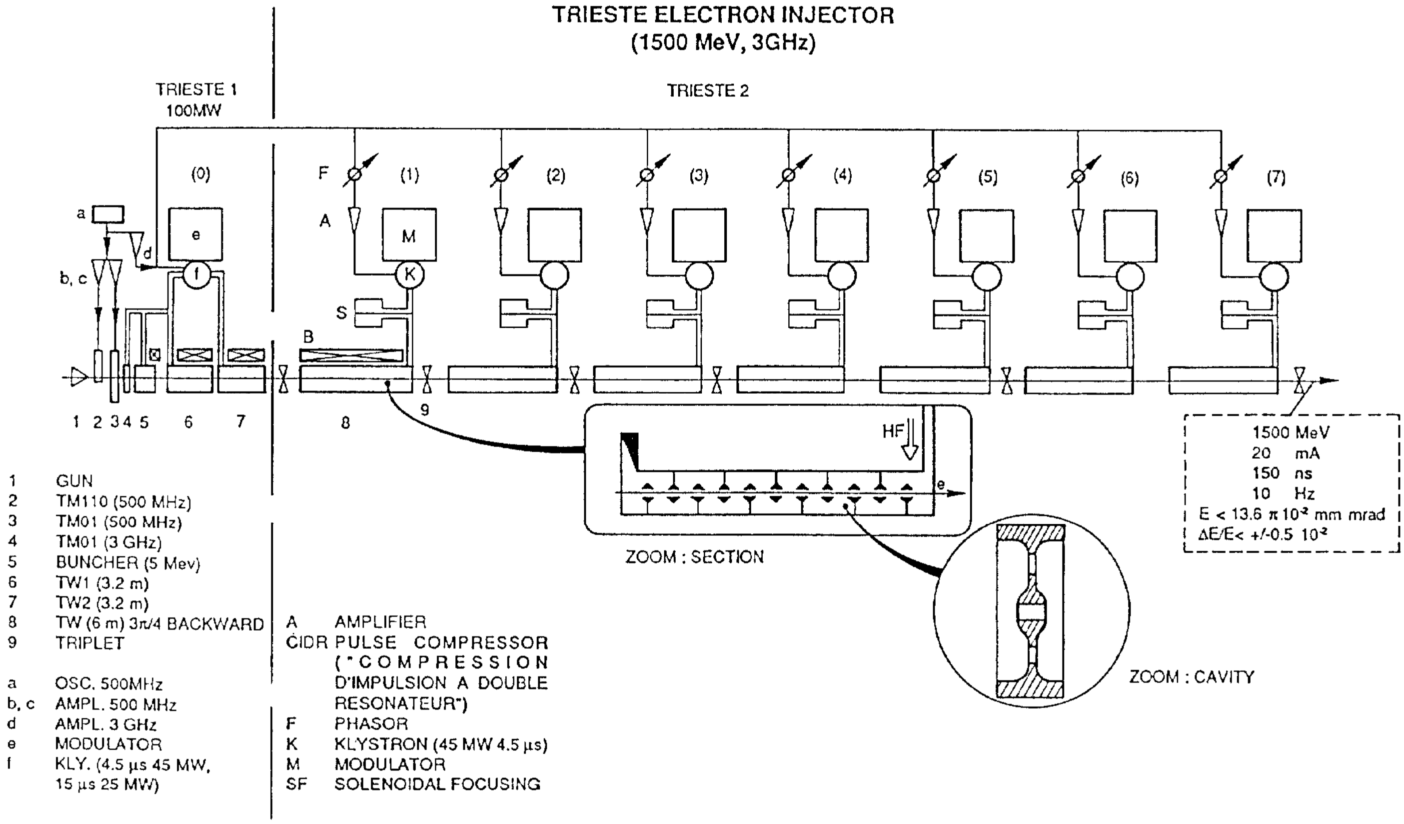

Figure 1: The TRIESTE-ELETTRA 1.5 GeV Electron injector

The expected beam characteristics are summarized in the dotted box: 20 mA will be accelerated at 1500 MeV, for pulses from 10 nanos. to 150 nanos. at 10 Hz repetition rate, within a required emittance of 0.136 mm mrad and a 1% energy band.

The 100 MeV preinjector

Figure 2 presents this part (already built). It is made of a subharmonic chopper cell (C), a subharmonic prebuncher cell (PB5), an S-band prebuncher cell (PB3), the chopper collimator (CO), a 4 MeV buncher (B) followed by two accelerating sections (S1-2).

This preinjector has single-bunch, multi-bunch and FEL modes of operation. Ref. [9,10] analyze the three required modes of operation and simulate the FEL one. More than 0.4 nanoC is expected in the FEL mode within a bucket with a central bunch length (FWHM) of less than 10 picos. The normalized emittance is less than 200π mm mrad and the energy remains within 0.6% (the required values are 0.15 nanoC within 1%).

The 200 MeV accelerating unit

Such units follows the preinjector to rise the energy to 1500 MeV. The parameter values expected for one unit are:

Table 1: Accelerating unit parameters.

Klystron RF pulse	45 MW - 4.5 µs
Q twin compression cavities	150 000 min.
Transmission losses	7%
Compressed pulse amplitude	259 to 88 MW
Compressed pulse duration	0.76 µs
Energy for 10ns	217 MeV
Acceleration per m	35.4 MeV/m
Peak field (before beam)	139 MV/m
Peak field (at beam time)	81 MV/m
Energy for 150ns	207 MeV

Power tests made on a 1.3 meter test structure [7,8] verify that one will be able to deliver 200 MeV per unit in the 6 m structure geometry. This one is presented in details including the optimization between compression and BTW in the companion paper of this conference [5].

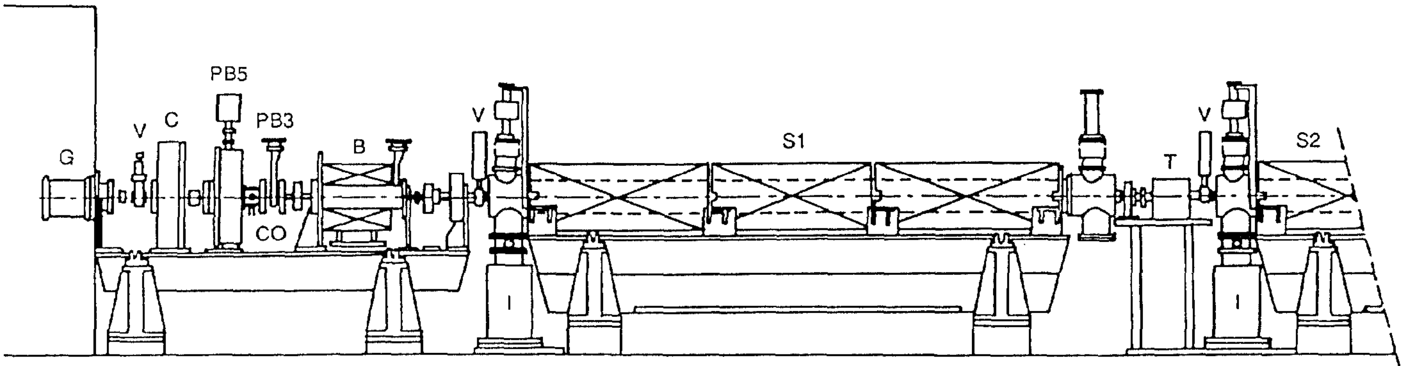

Figure 2: The ELETTRA 100 MeV preinjector beam line

The final choice of the $3\pi/4$ mode results from the (non intuitive) fact that its shunt impedance is near the highest possible value. This value lie between this mode and the $4\pi/5$ one, but NOT at higher modes nearer π: this is attributable to the decrease of Q when coupling slots becomes large. $3\pi/4$ mode is very simple to adjust in frequency.

One sees also that peak field on rounded nose is LOWER than for flat iris in the $2\pi/3$ mode for comparable energy gain. This is attributable to the large aperture at moderate c/vg value in classical iris waveguide which concentrates much field on a modest circumferal surface. The parameters values for the two geometries used along the first 2 m (at lowest peak field on nose) and then along the remaining 4 m (at greater shunt impedance) of the 6 m structure obtained with help of SUPERFISH are:

Table 2: $3\pi/4$ BTW cell parameters.

Beam clearance	10 mm dia.
c/vg	38
Q factor	12 500
Z/Q	6 195 to 6 485 Ω/m
Es/Ea (peak surface/ accelerating field)	1.96 to 2.30

This can be compared to the classical iris waveguide where for the same c/vg value, Q = 14 900, Z/Q = 3 900 Ω/m, Es/Ea = 2.07

Conclusion

The good outcome of this project will be a significant step forward in the electron linac art. The site is under construction, the preinjector has been tested with full RF power but not yet with beam, the first 6 m accelerating structure is under cold test.

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