ELECTRON INJECTOR DESIGNS FOR LIGHT SOURCE

D.Tronc, D.T.Tran, G.Meyrand, A.Setty
General Electric CGR MeV
BP 34, 551 rue de la Minière, 78 530 Buc, France

Summary

We presents two electron linacs injectors with emphasis on the beam line designs. They make use of 100 MeV units each made of a 6 m TW accelerating waveguide powered by a 37 MW klystron. The high stored energy reduces the beam loading at short pulse duration. Overall length and cost are reduced. The first injector is part of a lithography source built for IBM. Its reliable design includes a subharmonic chopper/ prebuncher. The second one will delivers more than 2.5 A in less than 2 ns at 200 MeV within an energy spread of 1% for positrons production at ESRF. The designs aims to high currents at low emittances. This may open in the future their uses for FEL.

Introduction

Electron linacs are the best injectors for synchrotrons/ storage rings as the (relative) simplicity of linear beam dynamics insures a good conservation of the beam brightness B defined as

$$B = \frac{\text{beam current}}{(\text{emittance})^2 * \text{energy spread}}$$

Their design is simple due to the separation of the focusing and acceleration functions. They rely on a wide technological effort induced by others industrial and medical field applications. A deep understanding of electron dynamics helps to eliminate several beam line components together with critical parameters adjustments . Cost analysis leads to the choice of few powerful standard units. This reduces also the total overall linac lenght.

The 100 MeV standard accelerating unit

Figure 1 shows the diagram of such accelerating unit in the case where it is used as a linac front end with a gun and a buncher. The klystron TH 2094 delivers 37 MW for an RF pulse of 4.5 microseconds and will be able to deliver up to 45 MW in the next future.

The main part of this available power feeds only one 6m TW structure. This simplifies the otherwise costly transmission line. The main line without the optional gun-buncher front head derivation is reduced to windows and waveguides. A new carefully designed input magnetic coupler to the TW structure makes provision for very high power flow. It is similar to the LIL design [1]. The structure of the constant gradient type is designed to optimize energy gain at moderate beam loading [2]. A 5:1 c/vg ratio between output and input together with a slight field decrease near output gives a 8:1 ratio of the available power to the output unused one. It includes a magnetic output coupler on a non- resonant flat waveguide load. All is included in a steel jacket allowing good vacuum conductance.

The derivation for the optional gun-buncher has a coupling value of -9 db (for ESRF) to -12 db (for IBM). It feeds a standing- wave buncher. The choice of the SW instead of TW allows for an excellent beam radial control by

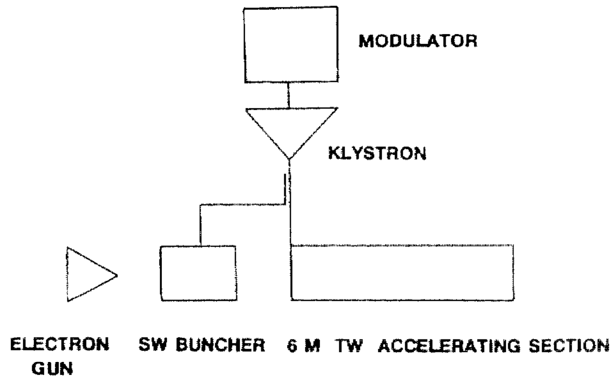


Figure 1 : 100 MeV standard accelerating unit

cell to cell coupling adjustment and careful field shaping near the axis [3-6]. Radial assymetry near the beam input is eliminated as the coupler can be put elsewhere.

Table 1 caracterizes this standard unit and its output beam parameters values for an "averaged" case (see also Table 2).

Table 1 : Standard unit and beam characteristics

Unit length	< 8 m
Klystron power	37 MW
Beam energy	100 MeV
Beam current	50 mA
Beam pulse length	100 ns
Energy spread	-+ 1 %
Emittance	1 pi mm mrad

The IBM injector

This linac designed and built by GE CGR MeV will deliver 200 MeV electrons to the compact synchrotron /storage ring light source built by OXFORD Instr. for IBM. Figure 2 shows one of its two 6 m TW structure in the RF room.

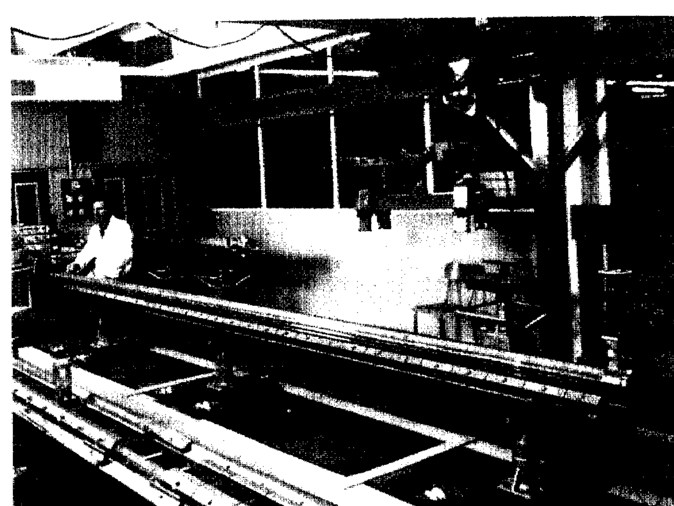


Figure 2 : 6 m TW accelerating structure

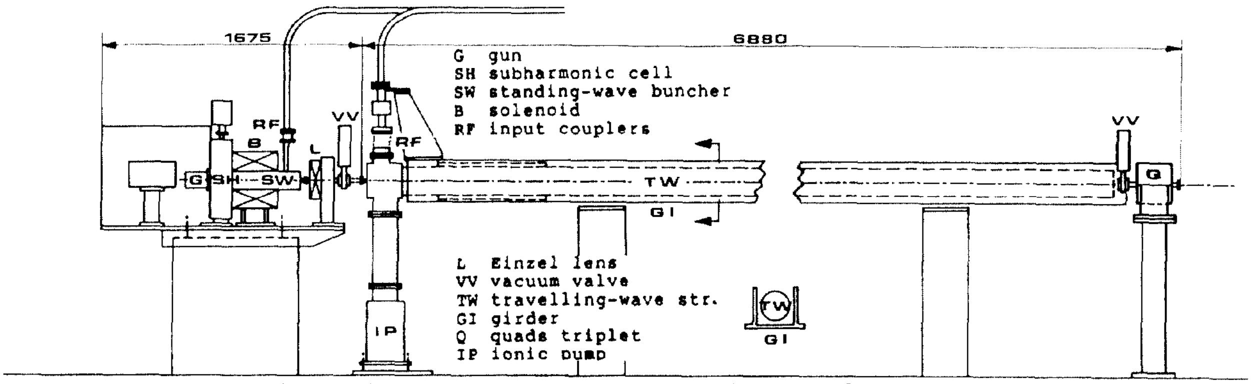


Figure 3 : IBM injector first unit beam line

A low accelerated peak current value of 20 mA allows for a simplified radial focusing. Electron microbunches must repeat at 500 MHz or 1:6 of the linac RF frequency. Figure 3 shows the beam line for the first full 100 MeV unit. The gun G has a low convergence and can deliver .7 A inside a .5 mm crossover radius at 50 keV. A grid controls the 100 ns pulse timing and duration for a .2 A current.

The SH subharmonic cell strongly modulates the beam so that chopping and bunching occur simultaneously on a short total length of about 100 mm from the gun crossover to the SW buncher input cell. This time selection implementation [7] makes parameters adjustments less critical and is more compact. It reduces the natural radial beam divergence. This opens the way to much larger currents up to 10 A for FEL instrumentation. The mechanical structure is such that the subharmonic cell has a simple shape and supports the gun and the buncher on each side. This eliminates misalignment. However the cost paid for these advantages is a required 4 kW subharmonic power.

The buncher SW is a .4 m triperiodic structure. With < 2 MW RF power the beam is accelerated to > 4 MeV. The field amplitude law is carved to insure beam radial autofocusing as well as bunching and acceleration even without any applied magnetic field [5,6]. However provisional solenoidal focussing insures a better space charge control. At the exit, beam radial expansion occurs due to two factors: (i) the decreasing solenoidal field which acts as a half diverging magnetic lens (ii) the end of the strong alternate RF focusing (at each cell input) and defocusing (at each cell output). This is corrected by an Einzel magnetic lens L. A slightly convergent beam will enter the 6 m TW structure to obtain a waist at 3 m.

The valves VV with insulated targets insure vacuum separation and beam control. A nearby collimator (not seen on fig.3) selects radially the beam. This also increases the ratio of the useful microbunch charge to the total charge of one subharmonic period. Acceleration from 4 MeV to 100 MeV occurs all along the TW structure. It has steerings but no external focusing. This allows for a simple mechanical design where the steel vacuum jacket which contains the copper structure is supported by a U-shaped girder GI (see cross-view). Finally a quadrupolar triplet Q controls the beam before the second TW structure (not seen on fig.3).

Figure 4 shows some simulation results obtained with our new PARDYN code integrating in time the trajectories all along the beam line with realistic fields (i.e. with each cell field laws for the 6 m structures).

The linac phase adjustments insures radial focusing in the first unit. Energy spectrum broadening is corrected with particle of lowest energy put at the "wave crest" of the second unit with some radial defocusing. Figure 4a shows the strong focusing in the first half of the first TW structure: the trajectories crosse the axis with a period shorter when RF focusing is stronger. Figure 4b shows some exponential defocusing in the second half of the second TW structure. Figure 4c presents the main microbunch at 200 MeV : it has a 2 mm or 7.2° length inside a 3 mm radius. Figure 4d is the spectrum histogram in the same conditions (with few electrons as a trajectory from gun cross- over to linac end takes 300 s on a 1 Mips MicroVax) : half current lie inside 1% energy bandwidth. These simulations are made in the simplest case where only RF autofocusing occurs without solenoidal field nor lenses effects. Room for large improvement is let open.

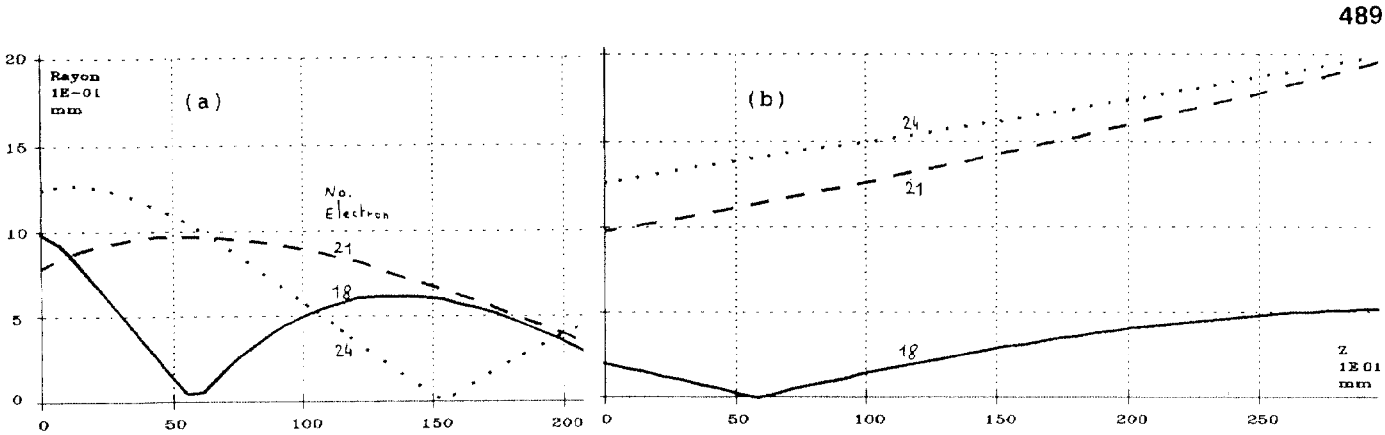
The ESRF injector

This injector will accelerate much higher currents during very short pulses. Then space charge effects are large even with an estimated 3.5 mm radius beam and a .15 Tesla solenoidal focusing going on continuously from the gun crossover onwards.

Figure 5 shows the first beam line unit of this injector. The gun G and the SW buncher are similar to Frascati injection [3,4]. The gun grid has a much thinner mesh to avoid a too turbulent electron flow and its modulator has been improved to obtain < 2 ns pulses. The RF feed in the 1.1 m SW biperiodic buncher is limited to 5 MW to increase the electron capture. We avoid carefully any "hole" in the solenoidal focusing. Design study following the pre-study [2] is under progress.

Conclusion

Table 2 summarizes IBM and ESRF cases. In the future we aim to reduce drastically the total length for similar linacs with helps of a new backward TW structure [8], of higher available RF power and of pulse compression (SLED).



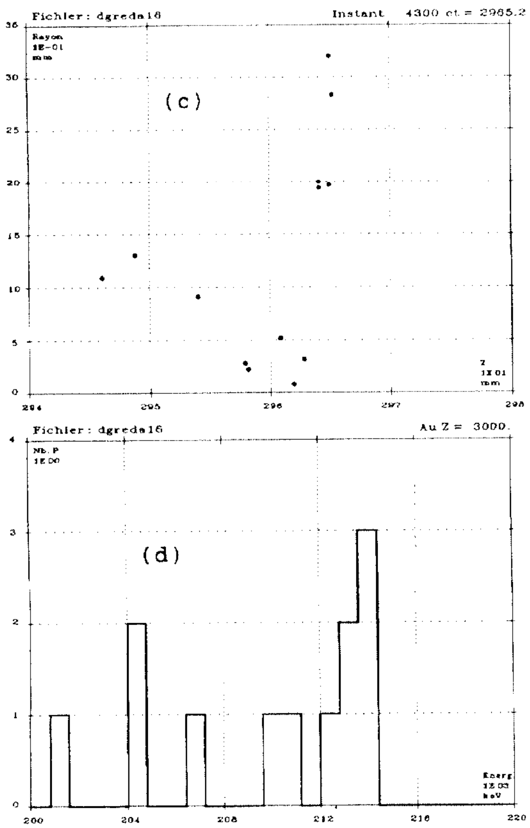


Figure 4 : IBM injector beam simulations
(a) radii for 3 particles at SW1 beginning
(b) at SW2 end (c) microbunch at SW2 exit
(d) full energy histogram

	IBM	ESRF e-	ESRF e-/e+
Length	14.6 m		
Klystrons power	74 MW		
Beam energy	200 MeV(205/190)		
Beam current	15 mA(20/10)	25 mA	2.5 A (4/2.5)
Beam pulse length	100 ns	1000 ns	2.5 ns(2.0/3.0)
Energy spread(°°)	-+ 0.5 %	-+ 1 %	-+ 5 %(-+1/-+5)
Emittance mm mrad	< 5 pi	0.5 pi	2 pi

(°) if goal and warranty figures are different they are given after an average figure as (goal/warranty)
(°°) for half accelerated current

Table 2 : IBM & ESRF injectors characteristics(°)

References

[1] G.Bienvenu, J.C.Bourdon, P.Brunet,J.Rodier, "Accelerating structure developments for the LEP injector linacs (LIL)",Proc. of the 1984 Acc. Conf., Darmstadt, 463.
[2] Preinjector study for the ESRF, ESRF-SYN/PI-87-01
[3] D.Tronc, C.Bourat, J.P.Georges, A.Setty, "Design of a high intensity electron buncher", 1986 Linear Acc. Conf., Stanford,472.
[4] P.Fernandes, R.Parodi, B.Spataro, F.Tazzioli, D.Tronc,"Fields computations and measurements on a biperiodic buncher structure", 1986 Linear Acc. Conf., Stanford, 523.
[5] D.Tronc, French patents 83 14090, 85 13416, 88 04707
[6] D.Tronc, C.Perraudin, J.P.Georges, A.Setty, "Electron injectors designs...", 1985 Part. Acc. Conf., IEEE Trans. NS 32, 3246.
[7] A.Setty, D.Tronc, French patent 87 03925.
[8] P.Girault, D.Tronc, G.Bienvenu, "4 Pi /5 Backward TW structure...", this conference.

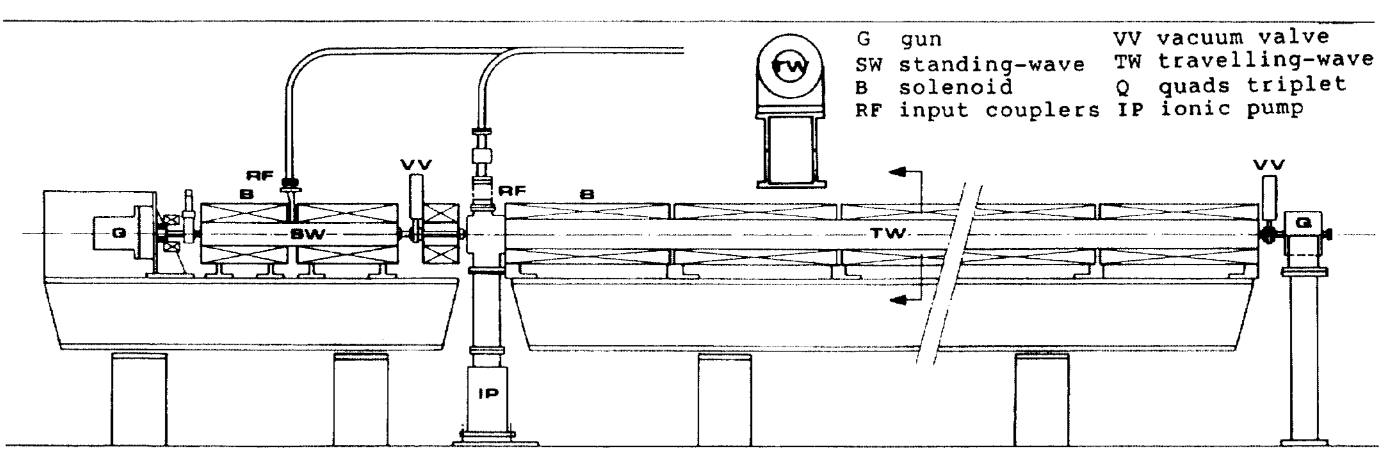


Figure 5 : ESRF injector first unit beam line