IMPROVEMENT OF THE ELECTRON INJECTION FOR THE ALS ELECTRON LINAC

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Introduction

A smaller transverse beam emittance has been a long required improvement at the ALS electron linac. The goal has been reached by installing a new electron gun, designing a new transition beam line between the gun and the buncher, and changing the first focusing solenoids to more axially symmetric ones.

These transformations resulted in a noticeable reduction of the beam emittance as well as in an improvement of the injector accessibility, monitoring and understanding.

The new electron gun (fig. 1).

We still had in operation the original Thomson-CSF gun with a direct emitting cathode. The new one, built by Hermosa Electronics [1] is equipped with a dispenser cathode of 0.5 cm² emitting surface.

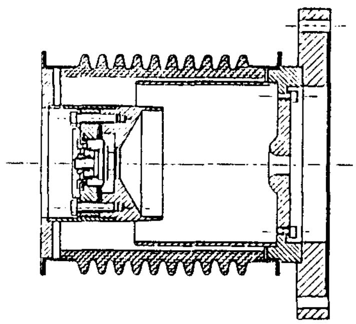

Fig. 1. New electron gun.

The technology is similar to SLAC guns. It operates at 40 KV. Its emittance is optimized for an output current around 100 mA. We measured it [2] and found 7.5π mm-mrd rms and 60π mm-mrd for marginal emittance.

Typical working parameters are 1.4 A heating current, 7V grid bias, 14V grid pulse for a 40 mA output current. The beam is delivered by pulses 10 µs long, repeated at 1000 Hz. The beam power is therefore about 1 kW peak and 10 watt average.

Transition beam line between gun and buncher (fig. 2).

The first purpose of this line is a limitation and a definition of the beam emittance.

It is obtained by using 2 collimators of 3 mm and 8 mm placed 200 mm apart. The acceptance thus defined is A = 30π mm-mrd.

Collimators are made of copper (fig. 3), brazed to stainless flanges. They are water cooled by 3 turns of a 3 mm copper pipe. They present to the beam a cone of 10° to 15° half angle in order to increase the incidence area and to avoid the cathode poisoning reported in ref. [3].

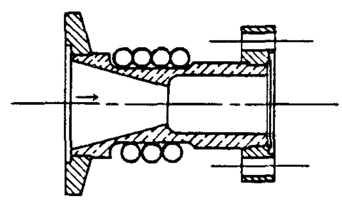

Fig. 3. ϕ 8 mm collimator.

A precise tuning requires 3 intensity monitors : before, between and after the collimators. A magnetic lens L1 located 10 cm after the gun flange permits to obtain maximum transmission through the first collimator. A better total transmission could be obtained by setting lens L1 for maximum current after the second collimator, but this would result in more current lost in the first one, what could

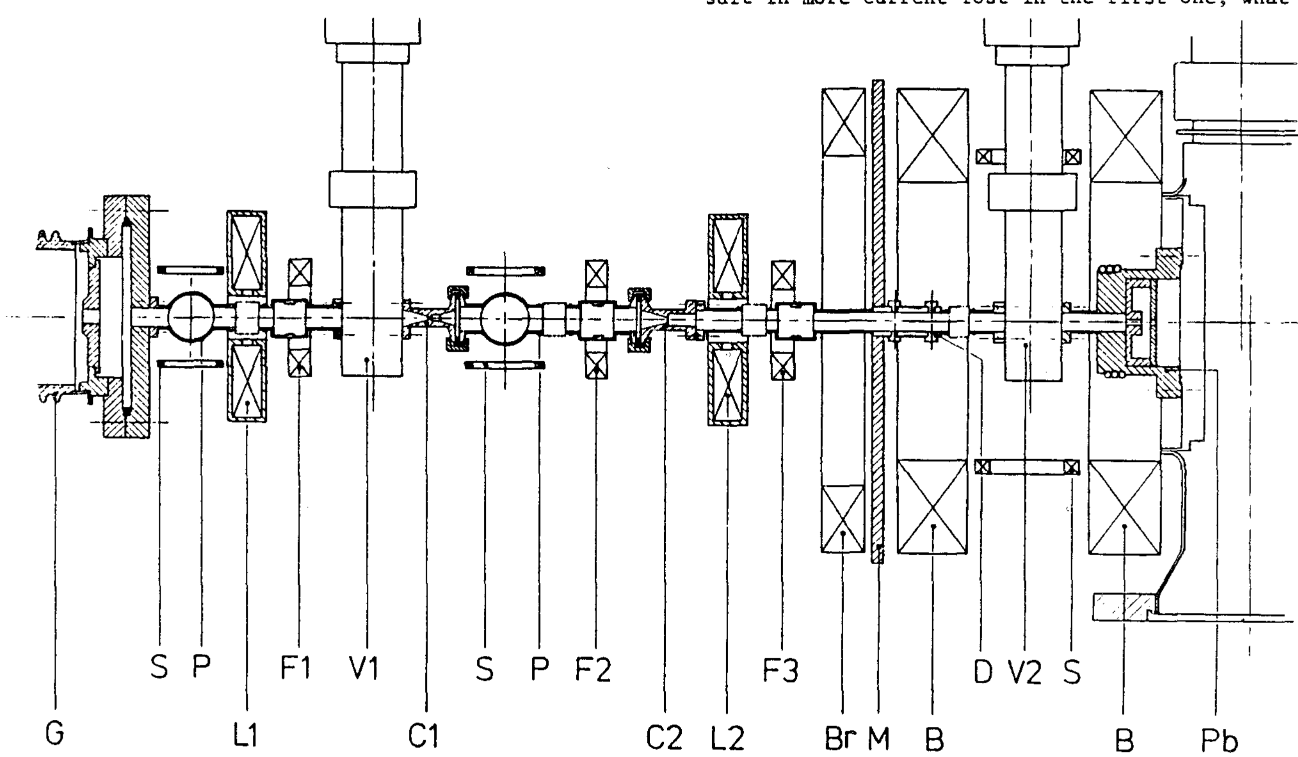

Fig. 2. 40 KV beam line.
G gun L1,L2 lenses C1,C2 collimators M magnetic shielding B focusing solenoid Br reverse field solenoid Pb prebuncher S steerers P pumping pipes F1,F2,F3 ferrite intensity monitors V1, V2 vacuum valves D beam detector.

in turn result in outgasing near the gun and cathode lifetime reduction.

A second lens L2, refocuses the selected beam onto the transition of focusing magnetic field to form a beam waist of the dimension required by Brillouin's conditions.

If space charge is neglected, this beam radius is given by :

$$r^2 = \frac{\varepsilon}{B}\,\frac{2m_0c}{e}\,\beta\gamma.$$

where B is the axial magnetic focusing field, ε is beam emittance, $\beta\gamma$, m_0c, e have the usual meanings.

For 40 kV electrons ($\beta\gamma$ = 0.4) and ε =30π mm-mrd, we have chosen to work with B = 700 gauss and r $\cong$ 0.75 mm.

Focusing solenoids

Brillouin's scheme requires zero field in the cathode and a steep transition to the focusing value.

Complete shielding of both line and gun like NBS RTM injector [4] is possible but certainly unconvenient. We preferred, like for SLC injector [5], the entrance face of the first solenoid to be shielded by an iron plate of the same diameter, 10 mm thick. The residual field can be further reduced bv a coil situated on the side of the gun and reversely powered. Computer simulation using PANDIRA code have been done for evaluating the required coil. Measured fields are plotted on fig. 4.

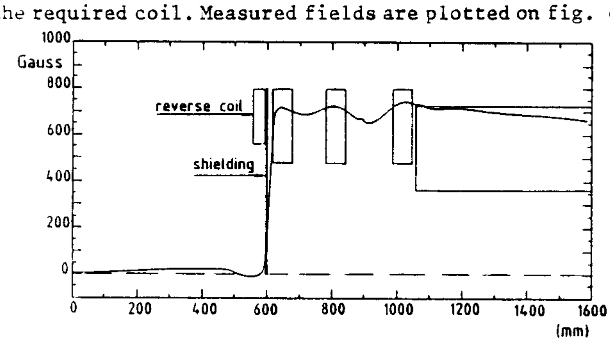

Fig. 4. Focusing magnetic field 0 is at gun output flange.

This coil, and the next three first have been built by winding of a 16 mm large, 0.2 mm thick aluminium conductor. This technique permits to obtain very symmetric fields.

Focusing tuning

To help the beam steering and lens L2 tuning we have installed, 20 mm after the iron plate and mechanically linked to it, a beam detector consisting in 2 sets of 4 insulated pins in 2 plans perpendicular to to the beam axis (fig. 5). In each plan, pins are 90° apart. Their radial position is such that they define a 2 mm bore around the axis. If the beam gets bigger, electrons are intercepted and a signal is observed on an oscilloscope. The distance between the 2 plans is the order of 1/4 period of the non tuned beam envelope scalloping. So, the beam radius cannot be minimum at both plan locations. Beam interception is detected for a high and low value of the L2 current and average value is considered as the right setting.

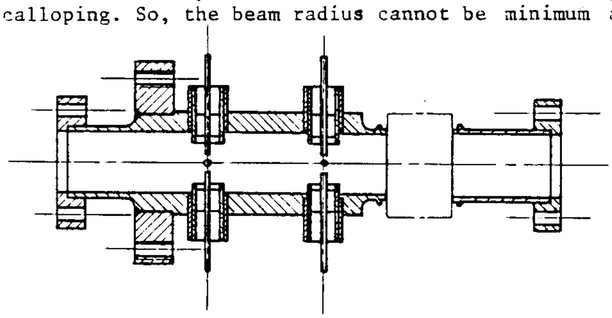

Fig. 5. Beam monitor.

Computed beam envelope by our "ENVELOPPE" code is shown on fig. 6. Collimation is taken into account. Initial conditions are those we have measured as reported in [2].

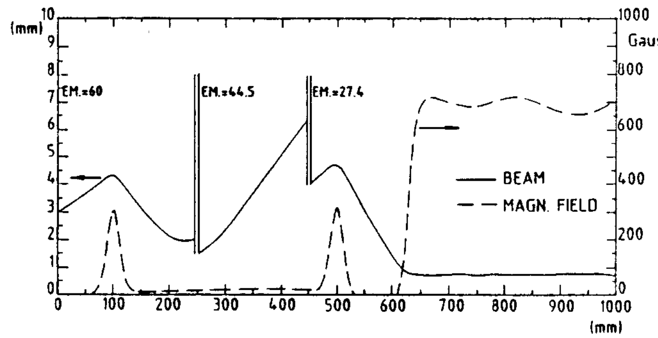

Fig. 6. Computed beam envelope from gun exit. Initial conditions : 40 kV, emittance 60 π mm.mrd, radius 3 mm, angle 10 mrd.

Vacuum system

The dispenser cathode requires a vacuum of 10^{-8} torr. We obtain currently better than 10^{-9} torr. We use two 100 l/s ion pumps and a 200 l/s turbo pump for prepumping.

Two pneumatic all metal gate valves can isolate the gun or the linac in case of vacuum failure. This over dimensioned pumping works also as a protection against a possible SF_6 back flowing due to a breaking of a wave guide window in the linac. In this event, the collimators, the pumps and the pumping pipes act like a resistor-capacitor circuit that damps the high pressure step. Test with nitrogen has shown this system to be quite effective.

Computer prediction of emittance growth in the bunching process.

Our buncher [6] is a 1.70 m travelling wave, tapered phase velocity accelerating guide. For a nominal 3.8 MeV/m accelerating field, an electron is synchronous if its initial energy is 40 keV and initial phase 45° ahead of the maximum field.

The model computed (with a home written code) includes the prebunching cavity and the 25 mm long buncher RF coupler in which a standing wave builds up. RF and focusing forces are expressed at first order, and so are movement equations. Having no chopper, input phases vary over one RF period. Space charge forces are neglected.

For an injected beam emittance of 30π mm.mrd and a focusing field approximately constant of 700 gauss,

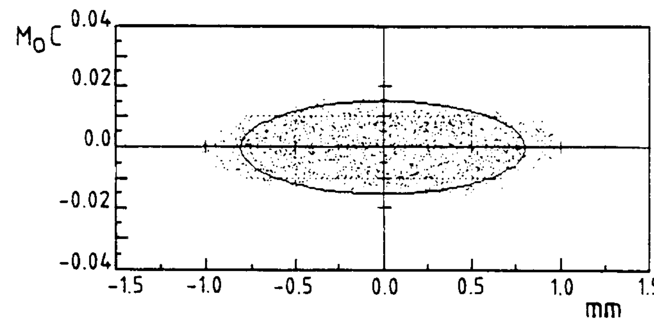

Fig. 7. Computed emittance at buncher output. Ellipse represents injected emittance.

the normalized rms emittance is found to vary from 12 to 13 π mm.mrd (Fig.7), i.e an overall growth less than 10 %.

Beam emittance measurement on the linac.

The beam emittance can be measured at the end of the linac only. The beam profile is measured on a wire chamber monitor with a resolution of 0.5 mm, for different settings of two quadrupoles, 32 m upstream. By fitting these data with their theoretical relationship, we can obtain the emittance ellipse in x and y directions. Measurements have been repeated at 287 and 472 MeV. We found respectively 0.1 and 0.06 π mm.mrd. Normalized values around 60 π mm.mrd are therefore obtained in both cases. This means an emittance growth factor of 5 with respect to the buncher input emittance 12 π mm.mrd. The same factor is found if rms emittances are considered. In this case input and output normalized values are respectively 3 π and 15 π mm.mrd. This growth factor can be explained by non linearities in beam guidance elements (solenoids, triplets, steerers) or by asymmetry in sections RF couplers either in the buncher or in the rest of the linac.

Acknowledgments.

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