First Results on LELIA Induction Injector

P. Eyharts, P. Anthouard, J. Bardy, P. Eyl, M. Thevenot,
A. Roques, D. Villate

C.E.A. - CESTA
P.O. Box 2
33114 - LE BARP (France)

1. INTRODUCTION

LELIA accelerator has been developed at CESTA as a test bed for induction technology ; it will also serve as a driver for microwave FEL experiment.

The final objective is to produce a high current (1-3 kA) and high brightness electron beam with an energy of 3 MeV [1].

In a first step we built and recently tested an 1.5 MeV induction injector driven by a high voltage pulse generator described elsewhere [2].

By the end of 1991 the beam current was measured in order to evaluate the cathode performance. We also studied the beam transport along the injector and performed a series of experiments to determine its energy spectra and whole emittance. The results are discussed in this paper.

2. INJECTOR DESIGN AND ENGINEERING

2.1. Induction cells

LELIA injector consists of ten induction cells (fig. 1). Each cell comprises seven TDK PE 11 B ferrite cores (250 mm I.D., 500 mm O.D. and 25.4 mm thick) housed in a non magnetic stainless steel body. Oil is used as dielectric and cooling fluid surrounding the ferrites.

The beam pipe diameter is about 185 mm and the accelerating gap is 8 mm wide. A pure alumina insulator brazed on the cell provides the vacuum oil interface. This technology eliminates any possibility of cathode poisoning by hydrocarbons.

The gap shape is curved to prevent induced breakdown by shielding insulator from electron beam ; it has been designed with FLUX-2D electrostatic code in order to limit electric stress to 200 kV/cm.

For beam transport, cells located in front of the cathode are provided with a solenoid capable of producing a 2 kG axial magnetic field; wrapped around the solenoid is a printed circuit correction coil.

Injector cells are assembled using flanges specially designed to allow a mechanical alignment better than 1 mm. The vacuum tightness is ensured by a metal gasket consisting of a slotted tubular aluminum ring backed up with a spring.

The high voltage pulse is applied to each cell on two opposite sides by two 100 Ω coaxial cables.

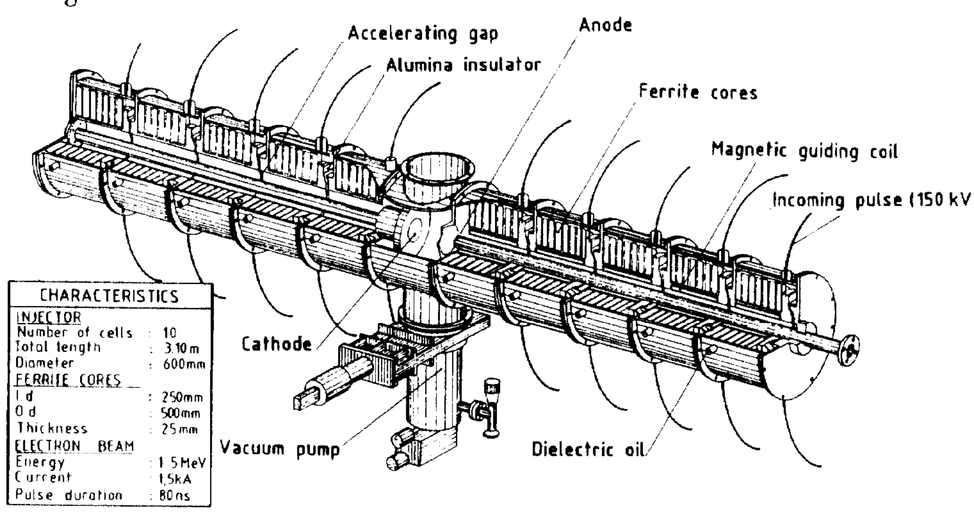

Figure 1 : LELIA injector

2.2. Electron gun

The electron gun is a triode configuration consisting of cathode, intermediate electrode and anode ; it has been optimized using FLUX-2D, SLAC and TETHYS numerical codes.

The cathode is a 85 mm osmium coated dispenser cathode surrounded by a focusing electrode ; it is mounted on a metal stalk and placed at the middle of the injector. The distance between cathode and intermediate electrode can be adjusted from 25 to 75 mm without breaking vacuum in the injector.

The anode pipe, 92 mm in diameter, is located 50 mm from the intermediate electrode.

2.3. Vacuum system

The vacuum inside the injector is ensured by two 4500 l/s cryogenic pumps associated with a turbomolecular pump for rough vacuum.

In operation (with cathode hot) the pressure was easily maintained at 10^{-8} torr and no presence of hydrocarbons was detected by mass spectrometer. This vacuum quality indicates that our mechanical choices are very effective and consistent with the use of a dispenser cathode.

3. EXPERIMENTAL RESULTS

Injector assembly began by the end of 1990 ; three months later, a first electrical characterization performed with a cable pulser allowed to :

- test electrical individual response of each induction cell up to 180 kV without any breakdown.

- observe voltage addition across the injector thanks to a 1000 Ohms resistive load placed between anode and cathode stalks.

Then, mechanical and magnetic alignments were checked using the stretched wire technique.

3.1. Cathode current

After a step by step cathode heating (thermal activation of the baryum and calcium oxides) up to 1200 °C, with an I.R. camera monitoring of the cathode surface temperature, the first electrical tests began using our cable pulser. Single shot operation under 100 to 350 kV accelerating voltage allowed to observe first cathode emission; 1 Hz burst operation completed this electrical activation and an experimental curve plotting cathode current I_k versus heating temperature Θ_k established the efficiency of this process : a knee determines the transition between emission limited and space charge limited operation, where temperature inhomogneities present less influence.

Electrical voltage testing grew up to 800 kV with the cable pulser, then to 1900 kV with the MAG generator and a second curve $I_k(\Theta_k)$ was constructed at 1.3 MV accelerating voltage (Fig 2).

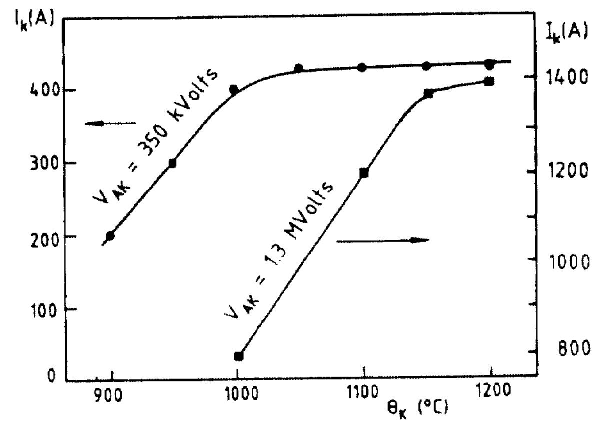

Figure 2 : Cathode formation
Emitted current versus temperature

Fixing Θ_k = 1150° C and D = 110 mm for anode cathode spacing, a curve I_k versus V_{AK} drawn in logarithmic coordinates gave a straight line with a slope 1.3 very close to those predicted for space charge limited operation governed by Child's law $I_k = kV^{3/2}$ (Fig 3).

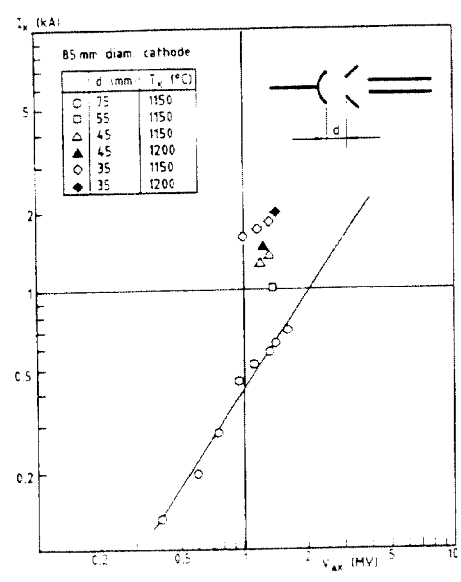

Figure 3 : Cathode current vs accelerating voltage

3.2. Injector current

The current I_k emitted from the cathode must be transported through the anode stalk along 1.5 m before being effectively extracted from the injector. Current probes integrated into the intermediate electrode and in the beam pipe at the injector output allow a comparison between I_k and injector current I_s ; the ratio I_s/I_k depends closely on magnetic guiding and electrode geometry. As predicted by PIC code TETHYS, anode internal diameter is too narrow and a part of the beam is lost on anode wall ; a compromise is to be found: a large anode cathode spacing D allows an efficient transport (I_s/I_k > 90 %) but the cathode emission current decreases when D grows up. By now, maximum emission current I_k has been 2.6 kA, at the lowest anode cathode spacing, but the highest current extracted from the injector has been 1.4 kA, obtained with D = 105 mm. Magnetic guiding and ratio I_s/I_k predicted by numerical codes have been in good agreement with experimental results. A new anode has been designed and will be tested in a near future.

3.3. Energy spectrum

A magnetic spectrometer placed at the injector output characterized the electron beam; reproducibility has been demonstrated at 1.1 MeV peak electron density (and 1.2 MeV maximum energy) ; Fig 4 shows a typical spectrum: the accelerating voltage quality is characterized by the half width of the peak on the high energy side. The maximum peak energy has been measured at 1.36 MeV.

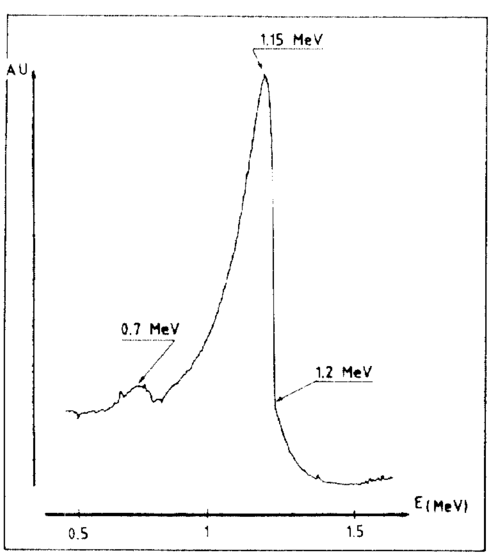

Figure 4 : LELIA injector: energy spectrum

3.4. Emittance. Brightness

Measurements have been performed at 1.3 MV accelerating voltage and 1 kA beam current using pepper pot technique. The measured emittance was close to 200 π.mm.mrad on the two axis, leading to a normalized brightness Bn = 5 10^8 A/m^2.rad^2.

3.5. Beam stability

Beam centroïd position is measured with four "B loop" probes; these measurements have indicated a good stability, all the more so that correction coils have not still been used : peak to peak amplitude of the beam centroïd motion was around 2 mm on each transverse axis over approximately 25 ns, indicating a relativaly low corkscrew instability.

4. CONCLUSION

First results on LELIA Induction Injector have demonstrated a 1.3 MeV, 1kA single shot operation with a high brightness beam. An important work is still necessary to improve higher repetition rate and higher voltage operation of the cells.

A 12 induction cell accelerating module is under construction and will be assembled and tested by the end of 1992 to reach 3 MeV energy level.

Meanwhile, our ONDINE F.E.L. experiment at 35 GHz is under assembly ; coupling with LELIA Injector is expected before June 1992.

5. REFERENCES

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