FIRST OPERATION OF THE LELIA INDUCTION ACCELERATOR AT CESTA

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Abstract

An induction linac has been studied and built in order to acquire induction technology for free electron laser (FEL) and other applications. It comprises a 1.5 MeV injector with a thermionic cathode which can deliver a high current electron beam (1 to 2kA) and a 12 cells accelerating block which raises the electron energy up to 3 MeV. The injector has been tested and fully characterized and the accelerator is now being completed. We describe the induction cells and the high voltage generator designed to feed the cells with 150 kV pulses at 1 kHz repetition rate.

I - INTRODUCTION

The LELIA accelerator has been designed and built at CESTA to produce a high current (1-3 kA) and high brightness (10^8 A m^{-2} rad^{-2}) electron beam with an energy of 3 MeV. Initially devoted to microwave FEL experiments [1] it is also used as a test bed for the AIRIX induction accelerator [2] especially in beam transport studies and diagnostic development.

The LELIA accelerator consists of a ten cells induction injector, a twelve cells induction accelerator and a high voltage generator that can deliver 150 kV/80 ns feeding pulses . An osmium coated dispenser cathode is used to produce the electron beam.

Since june 1991 the injector is under operation and has been fully characterized. By the beginning of this year the accelerating module has been assembled and partially tested.

In the following sections we describe the different components of the machine and we present the results obtained.

II - ACCELERATOR ENGINEERING

A - Induction cells

LELIA induction cells are constructed around a core of seven TDK PE 11 B ferrite torroids (250 mm I.D., 500 mm O.D., 25 mm thick) housed in a non magnetic stainless steel body [3]. The beam pipe diameter is about 185 mm and the accelerating gap is 8 mm wide. Oil is used as dielectric and cooling fluid surrounding the ferrites. A pure alumina insulator brazed on the cell provides the oil-vacuum interface and eliminates any possibility of cathode poisoning by hydrocarbons.

Accelerator and injector cells are similar; but for beam transport, only the cells located in front of the cathode are provided with a solenoid capable of producing a 2 kG axial magnetic field (fig. 1)

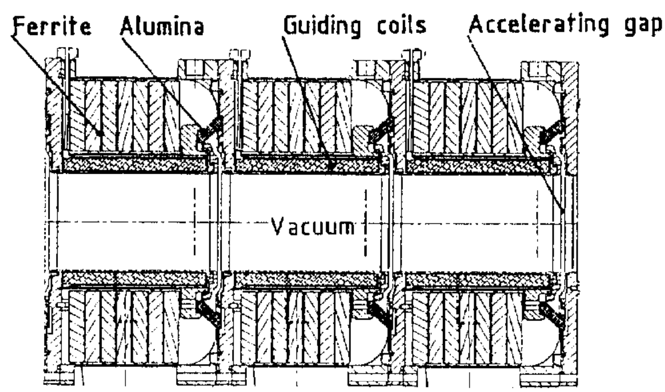

Figure 1 : LELIA induction cells

B - Pulse power

Cells are driven through 100 Ω coaxial cables by a H.V. pulse generator consisting of two parts [3] :

- a command resonant charging system (CRCS)
- a pulse forming and compression device (MAG)

One generator is sufficient to drive the twenty two accelerator cells with 100 to 150 kV/80 ns flat top pulses at 1 kHz repetition rate.

Timing between the cells is controlled by adjusting the length of the cables. A typical feeding signal on resistive load is shown on figure 2.

C - Electron gun

The electron beam is generated by a triode consisting of an 85 mm diam.osmiun coated dispenser cathode, an intermediate electode and an anode.

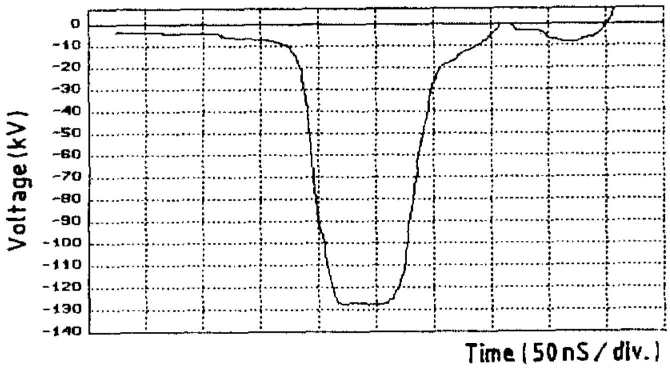

Figure 2 : H.V. Generator output

The geometry has been calculated with FLUX-2D and E-GUN numerical codes in order to minimize the beam emittance.

The cathode has a 300 mm spherical radius and is surrounded by a focusing electrode. The distance between the cathode and intermediate electrode can be adjusted from 25 to 75 mm to control the beam intensity.

The anode internal diameter has been recently increased from 84 mm to 112 mm; it is located 50 mm from the intermediate electrode.

D- Vacuum system

The vacuum in the beam pipe is ensured by three 4500 l /s cryogenic pumps (two are located on injector near the cathode) associated with turbomolecular pumps for rough vacuum.

In operation, with cathode at 1200°C, the pressure was easily maintained at 10^{-8} Torr in the injector section which is consistent with the use of a dispenser cathode.

E - Reset and matching circuit

After each shot the magnetic cores are saturated and must be reset before the next pulse, otherwise the cells will be short circuited.On LELIA this is performed by supplying an inverse D.C. current (30 A) to the cell from a reset circuit equipped with a choke coil for high voltage isolation. In addition this circuit comprises a resistor placed in parallel with the beam to electrically match the cell with the generator and limit overvoltages.

F - Control system

At first level LELIA control system comprises programmable controllers (TELEMECANIQUE TSX 6740) connected to the machine through several I/0 standard cards. They are used to control all the accelerator components (vacuum apparatus, power supplies, ancillary system, interlocks) as well as personnel safety system.

The second level centers around a HP 9000 computer that supports an ethernet network connected to the operator consoles. It allows supervision of the accelerator through the programmable controllers and ensures data acquisition by monitoring LE CROY oscilloscopes via GPIB interface.

III - EXPERIMENTAL RESULTS

A - Alignments

Mechanical alignment of LELIA cells has been measured with optical instruments . An error of ± 500 µm between the mechanical axis and a reference line defined by an helium-neon laser has been observed.

Magnetic aligment of guiding solenoid has been checked using the stretched wire technique.

Measurements lead to offset errors of ± 700 µm and tilt errors of ± 5 mrad. These latest errors have been easily minimized by energizing the trim coils installed around each solenoid.

B - Cathode current

After a step by step cathode heating up to 1200 °C the electrical tests have begun first with a cable pulser and then with the H.V. pulse generator. During these experiments cathode current I_k was measured versus cathode temperature θ_k. The I_k (θ_k) curves plotted on figure 3 at 0.35 and 1.3 MV accelerating voltage show a knee that determines the transition between emission limited and space charge limited operation.

To maintain a space charge limited operation, where temperature inhomogeneities present less influence, we decided to run the cathode at 1200° C during next experiments.

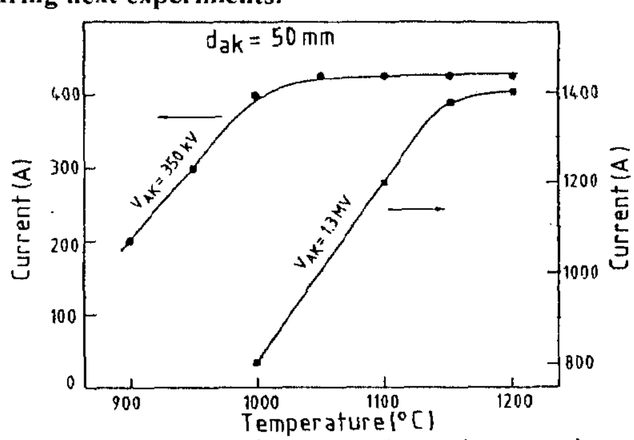

Figure 3 : Cathode current vs temperature

By varying the distance between cathode and intermediate electrode a maximum emission current of 2.5 kA has been obtained. This result corresponds to a high emission density (45 A/cm²) which indicates a good cathode formation.

C - Beam transport

Using the guiding solenoids, current emitted from the cathode has been transported through the anode stalk and the accelerator beam pipe. With a 84 mm anode diameter we observed that a part of cathode current was lost on anode pipe and only 70 % of total amount was effectively extracted from the injector. This constatation has led us to increase anode internal diameter up to 112 mm in order to transport 95 % of emitted current as predicted by TETHYS numerical code. Results obtained experimentally have been in good agreement with the calculations as shown on figure 4 where current profiles measured with Rogowski coils are presented at different locations along the accelerator.

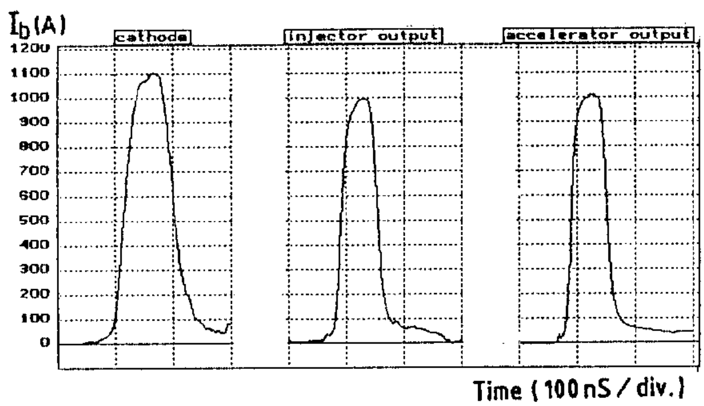

Figure 4 : Beam current

D - Energy spectrum

A magnetic spectrometer placed at the injector output was used to characterize the electron beam. A maximum peak energy has been measured at 1.36 MeV; but, due to problem of H.V. breakdown in gap cells, accelerating voltage has been limited around 1 MV for routine operations.

During the last weeks accelerator cells have been energized at low voltage; the peak energy raised up to 2.1 MeV preserving a good spectrum quality (see figure 5). Experiments at higher energy are in development and will give results soon.

E - Emittance - Brightness

Measurements have been performed at the injector output with 1.2 MV accelerating voltage and 1 kA

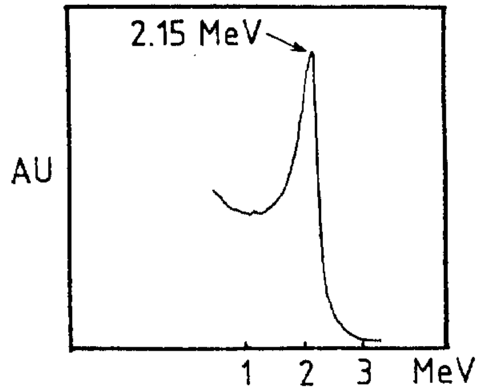

Figure 5 : Energy spectrum

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 of 5×10^{8} A m^{-2}. rad^{-2} which is higher than the design value. We have not yet performed measurements at the accelerator output.

F - Beam stability

Beam centroid position measured with four " B_θ loops " between injector and accelerator module indicates a good stability all the more as trim coils have not still been used. The beam centroid motion was around 2 mm on each transverse axis over 25 ns indicating a relatively low corkscrew instability.

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