FIRST RESULTS OF THE AIRIX INDUCTION ACCELERATOR

M. Mouillet, R. Boivinet, F. Bombardier, J. Delvaux, E. Merle, J.C. Ribes
CEA – PEM F51490 Pontfaverger – France

P. Anthouard, J. Bardy, A. Devin, J . de Mascureau
CEA – CESTA F33114 Le Barp – France

Abstract

The AIRIX flash X-RAY radiographic facility is now being characterized at Moronvilliers near REIMS. The 1.92 – 3.5 kA, 60 ns electron beam has been accelerated and transported through the 64 induction cells from 4 to 20 MeV (250 kV/cell).
We present the acceptance tests of the machine, conducted with the 3.0 kA electron beam. We review in this paper, the characteristics and the performances of the induction cells and the 32 High Voltage generators. We relate, also, the experiment that was done to minimize the X-ray focal spot, and to maximize the dose.
The first objectives, to have a diameter of the focal spot smaller than 2 mm, has been reached.

1 - INTRODUCTION

AIRIX is a linear induction accelerator used for flash radiography at CEA\centre DAM Ile De France. It produces a 20 MeV, 1.9-3.5 kA, 60ns electron beam. The accelerator includes an injector (4 MeV, 3.5 kA, 60ns) and 64 induction cells powered by 32 high voltage generators (250 kV-70 ns). A prototype was built and tested at CEA/CESTA, and the accelerator has been manufactured by THOMSON CSF company. Its installation at Moronvilliers was completed in June 1999.

The acceptance tests were conducted in July 1999 using a 3 kA electron beam, they are discussed in the section 2. We expose the quick steps taken to transport the beam to the end of the accelerator. We present particularly, the experiment that was made to minimize the electron beam on the final target.

2 – ACCEPTANCE TESTS

Each component of the accelerator was tested prior to its installation on the accelerator. We tested the operation of each H.V. generators by making 250 shots at 250 kV without any problems. The jitter (σ) of each generator is less than 3 ns for each generator. For each cell, we measured the total available flux swing (26 mV.s). We also applied 300 kV to each cell to test its high voltage integrity.

When the entire accelerator was installed and aligned [1], we began the acceptance tests. This important step in the realization of AIRIX project permitted us to check the operation of the complete accelerator including the :

- behavior of cells at high voltage with an electron beam inside,
- synchronization of the high voltage generators,
- control system for the entire machine,
- reproducibility of the beam at the end of the accelerator.

For these tests, the injector was operated at 3.6 MeV and 3 kA 60 ns.
The beam transport along the accelerator is calculated with the following envelope equation [3] :

$$R'' + k^2 R - \frac{K}{R} - \frac{\varepsilon^2}{\beta^2\gamma^2 R^3} = 0$$

$$K = \frac{2\,I}{17.045\beta^3\gamma^3} \quad (I \text{ in } kAmps)\ ;\ k = \frac{e\,c\,B_z}{2\,\beta\,\gamma mc^2}$$

We tested the first 16 cells in order to compare the OTR (Optical Transition Radiation) measurements with earlier results gotten in january 1999 [5]. Then we used all of the 32 generators to power all the cells. The delays between generators were preliminary adjusted without beam : the high voltage and beam were synchronised at better than 20 ns. The resolution of the adjusting of synchronisation of each generator is 1 ns. So it was very easy to synchronize all the generators, with the passing of the electron beam (Fig.1) :

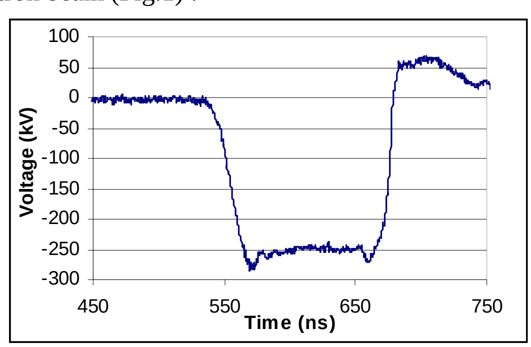

Figure 1 : Cell voltage signal synchronized with the electron beam

After adjusting the synchronization, we spent one day to control the repeatibility of the accelerator.

We checked with 8 shots the beam diameter stability with OTR measurements and the beam position reproducibility (Fig.2) with BPM (Beam Position Monitoring) located at the end of the accelerator :

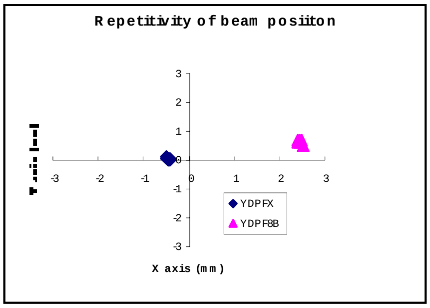

Figure 2 : beam position at the entrance and at the end of accelerator for 8 successive shots

After these acceptance tests, the accelerator was declared operational. Then we chose, as a first running for this radiographic installation, to work with a reduced beam current of 1.92 kA.

3 – TUNING OF ACCELERATOR AT 1.92 kA

After the acceptance tests, we characterized the injector at 3.8 MeV and 1.92 kA [2] to determine the electron beam transport :

Ro (mm)	R'o (mrad)	ε (p mm mrad)	f.o.m.
19,9	69,6	248	2.12

Table 1 : Beam initial parameters for 3.8MeV, 1.92kA

First, we adjusted the centering of the beam at the entrance of the accelerator using four correction coils (2 for vertical correction and 2 for horizontal correction). After, we successively tested the relative displacement of the beam for a current in each coil, we adjusted the beam to the center of the first cell and colinear with accelerator axis.

The voltage on each cell was adjusted to approximatively 240 kV. When the beam transport was adjusted, we obtained a time resolved spectrum [4] to determine the energy spread and the pulse duration of the beam at the end of the accelerator.

With the time resolved spectrum, we compared the energy of the beam with the sum of cells voltage and injector energy (figure 3).

The energy, measured with spectrometer was 19.155 MeV $\pm$ 0.3%rms during 61.5ns. The addition of the voltage of each cell (mean value of the cell voltage : 240 kV) and the energy of injector confirmed the amplitude of the spectrum.

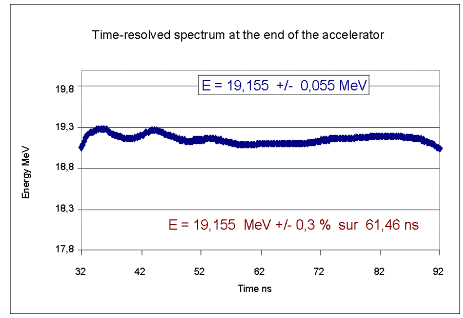

Figure 3 : Time resolved spectrum

We tested the sensitivity of the energy spectrum with timing by shifting the trigger of the generators without changing the trigger of the injector. Fig.4 shows the effect of the synchronization on the duration of the beam spectrum. The jitter of less than $\pm$3 ns of generators permits to have a good repetitivity of the time resolved spectrum.

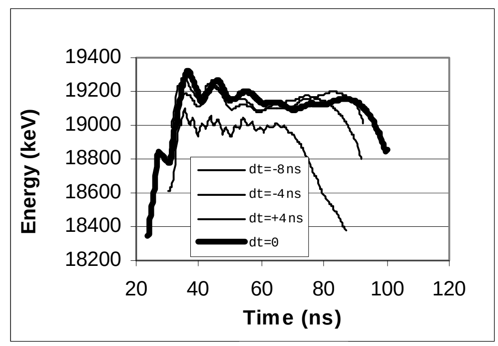

Figure 4 : Variation of duration of beam with synchronization of H.V. generators

To complete the accelerator tuning, we repeated the centering procedure of the beam along the accelerator to maintain the beam centroid to less than 1 mm from the axis of accelerator : Fig. 5 shows the distance between the centroïde of the beam and the axis of the accelerator from injector to the end of accelerator. By centering the beam along the accelerator, and with the precise mechanical alignment [1], we minimized the BBU (Beam Break Up) oscillations.

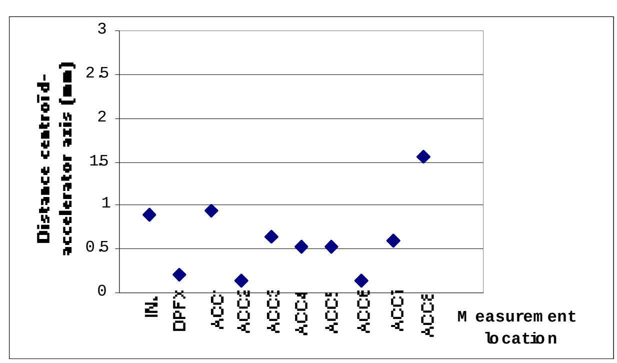

Figure 5 : Positon of the beam along the accelerator

Prior to focusing the electron beam on the target to obtain a minimum spot size, we had to first optimize the electron beam transport through the drift section. The drift section lies between the accelerator and the electron beam target and consists of 3 guiding coils, 7 correction coils and 1 final focus coil.

4 – FOCALISATION OF THE ELECTRON BEAM

The final focus coil is located 28 cm before the target which produces X-rays. The focusing coil is very important because it focuses the 40 mm diameter electron beam to a diameter of less than 2 mm at the target.
To measure the electron beam spot size as a function of the focusing coil current [2], we use a fast gated camera with a 10ns window duration. We observe the Optical Transition Radiation (OTR) produced on a 45° tilted target covered of 10 µm of aluminium.

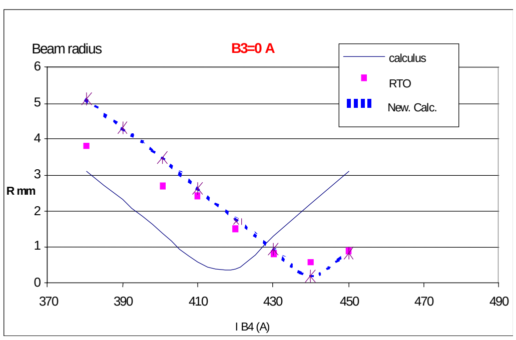

Figure 6 : Comparison of OTR measurements and calculus

The OTR measurements agree closely with the calculated values obtained when the actual magnetic field measured in the focusing coil is used in the transport code (New Calc on Fig. 6).

CONCLUSION

The AIRIX accelerator has reached the objectives. The focal spot observed has a diameter less than 2mm. The accelarator has demonstrated a very good reproducibility and day to day operational stability.
We are now in the process of increasing the electron beam current to 3 kA in order to further improve the radiographic performances of AIRIX.

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