INSTALLATION OF THE AIRIX INDUCTION ACCELERATOR

E. Merle, R. Boivinet, M. Mouillet, O. Pierret
CEA / B3-M / PEM 51490 Pontfaverger-Moronvilliers - France

Ph. Anthouard, J. Bardy, C. Bonnafond, A. Devin, P. Eyl, C. Vermare
CEA / CESTA BP n°2 33114 Le Barp - France

Abstract

The AIRIX flash X-Ray Radiographic facility will consist of a 3.5kA/4.0MeV/60ns injector and 64 induction cells powered by 32 H.V. generators (250 kV per cell). The induction cells studies made on the PIVAIR accelerator [1], which is the prototype of AIRIX, have allowed to design specific vacuum technology cells (ferrite are under vacuum). In this paper, we will present the technical features of the injector, and particularly the time-resolved energy measurement, the pepper-pot emittance measurement and the results of the three gradient method experiment which has been made by optical transition radiation and Cerenkov radiation observation. In a second part, we will present the design of the induction cells and their HV performances. We will see also the different tests and characterizations we make on each cell, and how we install the accelerator. Finally, we will expose the intermediate experiment we plan to do with the electron beam, after the first 16 cells, that are just installed. Those experiments will be a comparison between PIVAIR and AIRIX accelerators. They will allow to characterize the electron beam, and to optimize beam transport and beam centering procedures, before continuing the installation.

1 INTRODUCTION

The AIRIX induction accelerator has been designed to generate an intense bremsstrahlung X-ray pulse of 500 rads @ 1m using a 3.5kA/20MeV/60ns electron beam. It is made up by an injector that delivers a 3.5kA/4MeV/60ns electron beam, and 64 induction cells powered by 32 H.V. generators (250 kV per cell).

The PIVAIR prototype at CESTA, that is a validation step of AIRIX up to 8MeV, has allowed to test two different technologies for induction cells [1] and to improve beam transport and centering procedures [2].

The AIRIX installation at PEM has begun in 1997 with the reception of the injector. The accelerator part (H.V. generators and induction cells) is now under construction and partly installed.

We present in the first section the experimental results obtained with the injector. In the following paragraphs we expose the different tests made on the H.V. generators and induction cells before their installation. We will see, in particular, the magnetic alignment constraints for the cells. Finally, we expose the beam characterization experiments we plan to do at the end of this year in order to validate industrial production.

2 INJECTOR

The AIRIX injector is a reproduction of the PIVAIR one, and has been made by PSI corporation [3]. The association of a 4 MV pulsed generator and a vacuum diode create a 4MeV,3.5kA,60ns electron beam. The time-resolved energy spectrometer that we use [4], has shown that the energy spread is very low: ΔE/E = 1% over 60ns (figure 1).

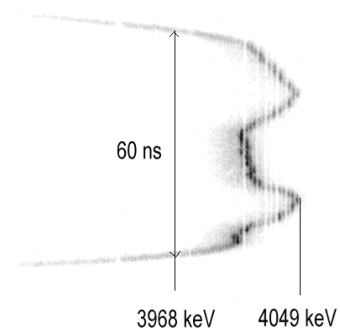


Figure 1: energy spectrum of the AIRIX injector

The next table gathers the results of the acceptance test of the AIRIX and PIVAIR injectors. The essential difference is the cathode configuration.

Table 1: injectors acceptance test results

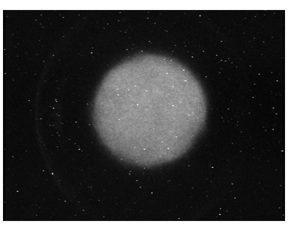
Injector	PIVAIR	AIRIX
Diode voltage (spectrometry)	4029keV± 4 keV	4027keV± 4 keV
Voltage flatness	< ± 1% over 60ns	< ± 1% over 60ns
Voltage reproducibility	1%	1%
jitter	< 1 ns	< 1 ns
Cathode diam.	76 mm	89 mm
Velvet recess	2.8 mm	6.1 mm
Beam current	3.5 kA	3.5 kA
Normalized RMS emittance	1650 Π.mm.mrad	1900 Π.mm.mrad

We have been obliged to increase the cathode diameter and the velvet recess in order to hold the 3.5kA current value and to have the smaller emittance value as possible. The beam normalized RMS emittance has been measured with the Pepper-pot method [5]. Nevertheless, the differences we observe (table 2) in the measurement of this parameter, for similar cathode configuration between the two injectors aren't yet explained.

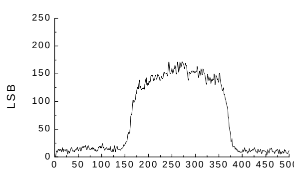
Table 2: RMS emittance comparison between AIRIX and PIVAIR with: cathode diameter=76mm, recess=2.8mm

	ε rms (π mm mrad)
PIVAIR	1600 ± 100
AIRIX	2100 ± 100

The determination of the initial parameters of the beam, (Ro=beam diameter, R'o=beam envelope slope at the origin) is made with the three gradient method [5]. Images of the beam are made by an intensified and gated camera, observing Cerenkov radiation (CR) or Optical Transition Radiation (OTR) created when the beam passes through a 5μm thin aluminized mylar foil. The analysis of the beam profile, with a 5ns gate placed at different temporal position of the pulse, has shown important differences. More precisely, at the end of the pulse, we observe an abnormal and centered peak (figures 2-5).

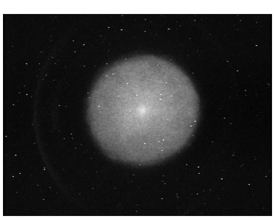


2

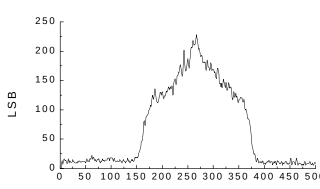


3

Figure 2: image of the beam observed with a gate of 5ns placed in the firts 10 ns of the flat-top of the pulse
Figure 3: the associated and centered beam profile



4



5

Figure 4: image of the beam observed with a gate of 5ns in the last 10 ns of the flat-top of the pulse
Figure 5: the associated and centered beam profile

Those images have been made when we used the 89mm diameter and 5.7mm recess cathode. We have obtained equivalent results with the 76mm diameter cathode and a recess of 4, 5 and 6mm by observing in the same way OTR or CR. We have experimentally demonstrated that the importance of the phenomenon is coupled to the value of the recess. When we use the 76mm diameter cathode, and a recess of 2.8 or 3.2 mm, the beam profiles are quiet different to those obtained with big recess, and the peak seems to be less important but the emittance is higher. In that configuration, the beam profiles are very similar to those obtained on the PIVAIR injector with the same apparatus.

However, the peak apparition is perhaps produced by combined effects between cathode emission and the optical diagnostic that visualizes the beam. Future experiments for optical diagnostic studies will check if there is a diagnostic effect or no.
We are now continuing tests on the injector to find the best configuration of the cathode (lower emittance, stable beam profile during the pulse) before determining the initial parameters of the beam.

3 H.V. GENERATOR

The AIRIX high voltage pulsed generator have been designed to drive two induction cells with a 250 kV, 75 ns pulse (flat top deviation less than ± 1%).
Some improvements have been necessary in order to reach specifications and reliability:
- the spark gap geometry has been corrected and a polarization added;
- thyratron command unit: initially built by EEV, a new one designed by EUROPULSE has been successfully tested.
- minor modifications on magnetic switch reset circuit and H.V. delay line.

Table 3: H.V. pulsed generators characteristics

	PIVAIR gen.	**AIRIX gen.**
Blumlein operating range	100 to 270 kV	100 to 270 kV
Main switch polarization	none	V/3
SF6 nominal pressure	3 bars	1 bar
Thyratron command unit	EEV (gas switch)	EUROPULSE (solid state switch)
jitter peak-peak jitter rms (1 σ)	18. 9 ns 3 ns	12 ns 2,6 ns

4 INDUCTION CELLS

Each induction cell comprises:
- 13 ferrite cores (270 mm I.D., 500 mm O.D., 24 mm thick) housed in a non magnetic stainless steel body
- a guiding solenoid magnet
- two printed circuit dipoles coils for beam centering
- two quadrupoles to correct possible transverse beam dissymmetry.

The 19 mm width accelerating gap has been shaped in order to give good high voltage behavior and minimize the beam coupling with the gap cavity to reduce BBU instability.

Compare to PIVAIR cells, the ferrite section has been increased by 9% in order to delay ferrite saturation and to optimize the timing of the acceleration.

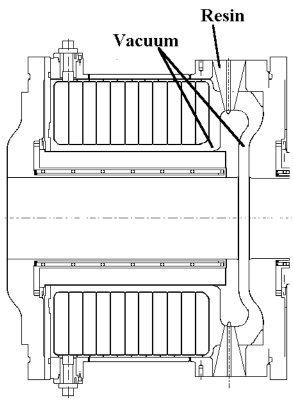


Figure 6: AIRIX induction cell

The H.V. test performed on the 16 first cells loaded with resistors confirmed the flux gain.

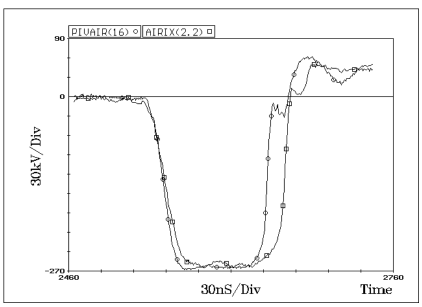


Figure 7: PIVAIR and AIRIX cells H.V. response on resistive loads

The next table shows the cell changes from PIVAIR to AIRIX design.

Table 4 : induction cells characteristics

	PIVAIR cell	AIRIX cell
ferrite length	12 x 25 mm	13 x 24 mm
available flux	24.4 mV.s	26 mV.s
gap spacing	19 mm	19 mm
flat top duration at 250 kV	65 ns	75 ns
Quadrupole coil	none	2

This should lead to a better behavior after beam loading, according to PSPICE calculations

5 CELLS ASSEMBLY

After vacuum and high voltage tests, the cells are aligned and assembled 4 by 4 [8]. We consider after this step only the block of four cells with his alignment references.

To minimize chromatic effects, the specific criteria impose that all the cell magnetic axes have to be enclosed in a 250 µm diameter cylinder with an angle spread lower than 500 µrad around the reference beam axis. In order to install only cells which have consistent magnetic axes with the criteria, we characterize magnetic defaults with the pulsed wire field technique.

6 ‘‘AIRIX 16 CELLS’’ EXPERIMENT

To make a comparison with PIVAIR, and to improve industrial realization, we are preparing different experiments with the electron beam accelerated by 16 cells. In a first step, we will characterize the acceleration with the time-resolved spectrometer. This diagnostic will confirm also the good machine timing [6].

We will measure the emittance with the Pepper-pot method. We will improve also the beam transport calculation code ENV [7] with CR beam imaging, and the beam centering procedure with the use of new Beam Position Monitors.

We plan to make experiments during 6 weeks at the end of this year to well characterize the electron beam and then validate the AIRIX technological choices.

7 CONCLUSION

Today 19 H.V. voltage generator have been assembled and tested at PEM. Three blocks of 4 cells have already been installed.

The accelerator will be completely assembled in march 99. After the final alignment of the machine with HLS and WPS technology [8], we will test the entire accelerator. The complete machine is planed to be operational for the radiographic experiments at the beginning of 2000.

REFERENCES

[1] E. Merle et al., ‘‘AIRIX prototype technological results at CESTA’’, Proceedings of PAC 97.

[2] Ph. Eyharts et al., ‘‘Beam transport and characterization on AIRIX prototype at CESTA’’, Proceedings of PAC’97.

[3] Pulse Sciences Inc., 600 Mc Cornick street, San Leandro, CA 94577, USA.

[4] D. Villate et al., ‘‘AIRIX alignment and high current beam diagnostics’’, Proceedings of PAC 95.

[5] C. Bonnafond et al., ‘‘Optical and time-resolved diagnostics for the AIRIX high current electron beam’’, Proceedings of DIPAC 97.

[6] Ph. Anthouard et al. ‘‘AIRIX and PIVAIR accelerator status’’, Proceedings of Power Modulator Conference 98.

[7] J. Bardy, ENV ‘‘Envelop electron beam transport code’’, Private communication.

[8] C. Bonnafond et al., ‘‘Status of AIRIX alignment and high intensity electron beam diagnostics’’, Proceedings of EPAC 96.