BEAM TRANSPORT AND CHARACTERIZATION ON AIRIX PROTOTYPE AT CESTA

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Abstract

Designed to produce an X-ray dose of 500rads @ 1m, AIRIX flash X-Ray Radiographic facility will consist of 4 MeV/3.5 kA pulsed electron injector and 16 MeV induction accelerator powered by 32 H.V. generators. Construction of PIVAIR accelerator (8 MeV AIRIX prototype) is now ended at CESTA.The injector has been connected with 16 accelerating cells in order to study beam transport and centering procedures. Accurate,time resolved diagnostics have been used to measure beam characteristics and a tickler experiment has been planned to estimate BBU instabilities. In this paper all experimental data recently obtained will be discussed and first conclusions for AIRIX will be given.

1 INTRODUCTION

After four years of experiments on PIVAIR prototype at CESTA,AIRIX flash X-ray radiographic machine is now under construction and will be commissionned by CEA at Moronvilliers in 1999.This installation will generate an intense bremsstrahlung X-ray pulse of 500 rads @ 1m using an electron beam of 3.5 kA/4 MeV produced by a pulsed diode injector and accelerated up to 20 MeV by 64 induction cells driven by 32 H.V. generators.

Final design of AIRIX has been decided this year on the base of performances obtained with PIVAIR accelerator after a series of experiments involving electron beam. At first, high voltage tests performed on this facility have permitted to choose generators and induction cell technologies: the results of this work are presented in a companion paper elsewhere in this conference[1].

Then, electron beam delivered by PIVAIR has been extensively characterized by using time resolved diagnostic equipments in order to measure beam position, energy and emittance. During these experiments, a beam transport and centering procedure has been defined and tested with success along the accelerator.

Finally, a tickler experiment has been carried out with 8 induction cells in order to estimate the BBU predictive capability of numerical models.

All experimental measurements made to date on PIVAIR will be summarized and discussed in the following sections of this paper. Section 2 will describe the facility and sections 3 to 7 will discuss the beam experiment results.

2 PIVAIR FACILITY DESCRIPTION

The construction of PIVAIR installation started at CESTA in 1994 with the injector assembly and testing. Using a velvet cathode as electron source this generator is able to produce in routine 4 MeV/3.5 kA beam with an energy spread less than ± 1 % over 60 ns pulse duration. By the end of 1995 eight induction cells were connected to the diode and last year another module of eight cells was added. All PIVAIR cells are designed to deliver the same acceleration to the beam (250 keV) but they differ by the insulation technology used in the high voltage region: eight cells use an oil-insulated ferrite core and a reticulated polystyrene as accelerating gap insulator, the other cells use vacuum to insulate ferrite and consequently no gap insulator[1][2].

Influence of these configurations on beam characteristics will be discussed below.

3 BEAM MONITORING

Beam transport along the accelerator is controlled by seven Beam Position Monitors (BPM). Three BPM are placed at the injector output on the drift tube and one BPM after each block of four cells. Specially developed for this application,they use four electrical loops to determine centroid position by measuring B_Θ field associated with the beam .

Tests performed on PIVAIR have demonstrated a resolution of ±200 µm and a sensitivity of 20 µm .The bandwidth was limited to 400 MHz by the integrator technology but was considered sufficient for AIRIX. However, we have observed a decrease of electron pulse rise time as beam progresses through the accelerator. As shown on figure 1 rise time was 25 ns at the injector exit and 10 ns after 16 accelerating cells. We think that this effect is due to the loss of low energy electrons during transport. If this phenomena grows with the number of cells on AIRIX accelerator, BPM bandwidth will have to be improved in order to maintain the same resolution.

An optical diagnostic is also used on PIVAIR to monitor beam position and help beam centering. It is based on measurement of Cerenkov light generated

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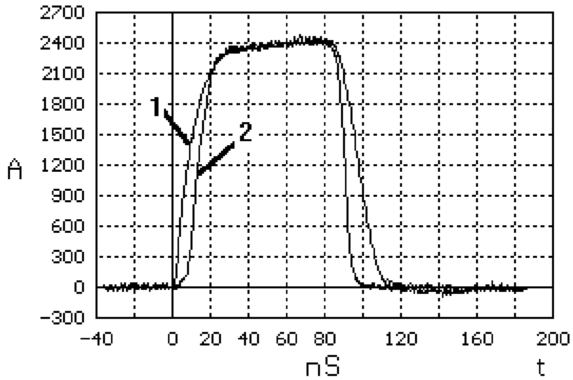

Figure 1: Beam profile at injector output (1) and accelerator output (2).

by interaction of electrons with an aluminized PET plastic foil. In this diagnostic the light is imaged with a streak camera to get a time resolved measurement.

We have compared results given for beam position by Cerenkov diagnostic and BPM. Currently a ± 1.5 mm discrepancy was observed between the two methods; but due to calibration difficulties, it was impossible to evaluate independently the Cerenkov method accuracy.

As this diagnostic is not suitable at energy higher than 10 MeV,we have developed for AIRIX another optical diagnostic using Optical Transition Radiation (OTR),phenomena which occurs when a charged particle crosses the interface between two medium having different dielectric indices.Tests performed on PIVAIR with the same PET foil were very satisfying.

Unfortunatly,optical diagnostics are interruptive and their absolute accuracies are not known so they are only utilized for rough beam centering. However, they allow measurement of beam profile which is of a great interest for emittance evaluation.

4 BEAM TRANSPORT AND CENTERING

PIVAIR beam transport and centering is carried out with an iterative method that involves both experimental measurements and calculations made with an envelope code knows as ENV.

The procedure begins with optical measurements of beam radius at the injector output for different sets of anode magnet currents.The results permit to deduce numerically initial beam characteristics (diameter,envelope slope,emittance) which are used as data entry for ENV calculations of cell guiding magnet currents.These values are choosen in order to transport the beam at constant diameter. Typical beam diameters on PIVAIR are 72 mm at the cathode and 40 mm in the accelerator.

Beam centering is realized every block of 4 cells using ENV calculations and BPM measurements.Electron beam is first centered at entrance of block n°1 with the help of dipole trim coils placed on the drift tube.Then beam position is measured at the output of the same block for different sets of cell trim magnet currents.From these measurements ENV code determines current values that allow centering at the block exit.The same procedure is applied to the next block.

This step by step tuning method has been tested with success on PIVAIR giving a centering accuracy of ± 200 µm. It will serve as a basic procedure for AIRIX beam transport.

5 BEAM ENERGY MEASUREMENTS

Beam energy has been measured with a time resolved spectrometer placed at different locations along the accelerator.This apparatus described in a previous paper [3] is able to measure energy spectrum with a very high resolution (0.2 %) by means of an electromagnet coupled with an array of optic fibers and a streak camera.

Maximum energy measured at the output of the sixteen PIVAIR induction cells was 7.2 MeV; this value is less than the design value of 8 MeV because accelerating pulses on Rexolite cells were limited to 200 kV to avoid high voltage flashovers.

The spectrum profile has been compared with spectrum obtained at the injector exit (figure 2). Both exhibit an energy spread around ± 1% peak to peak over 60 ns beam duration. Nevertheless, we observe on the accelerator spectrum a slight broadening of the trace which is not yet explained.

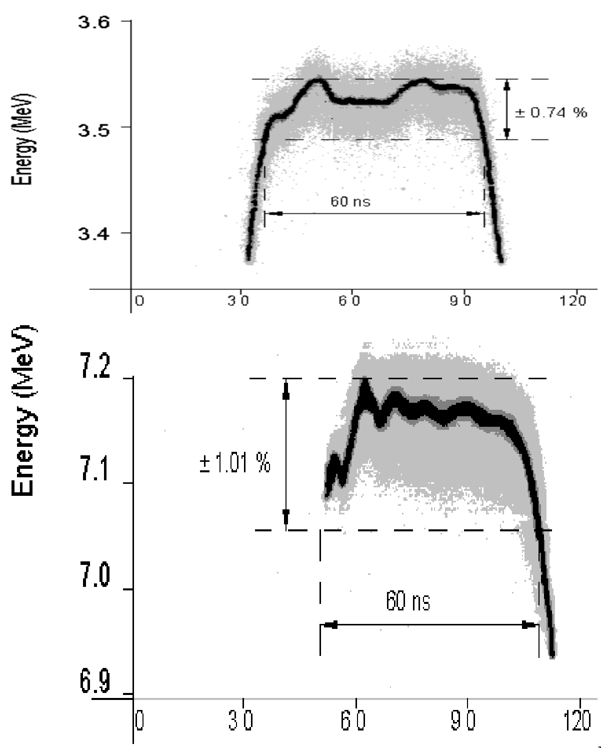

Figure 2: Beam energy spectrums at injector output (3.55 MeV) and 16 cells accelerator output (7.2 MeV).

Another series of experiments have been performed at 5.5 MeV in order to compare spectrums measured after acceleration with Rexolite cells and vacuum cells.No significant difference was noted between the two technologies(figure3).

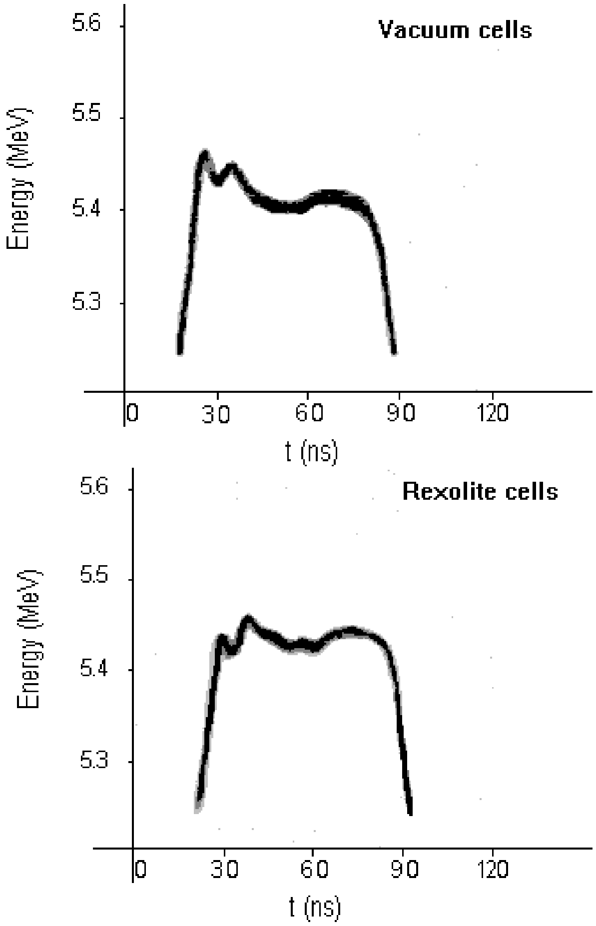

Figure 3: Energy spectrums obtained after acceleration with Rexolite or vacuum cells.

6 EMITTANCE MEASUREMENTS

Emittance has been determined using the three gradient method by measuring the beam radius at the injector output for different sets of extraction magnet current.The data have been fitted with ENV envelope code to obtain normalized rms emittance.

Experimental results show that emittance value depends on the optical diagnostic (Cerenkov or OTR) used to measure the beam radius. For a 3 kA/3.6 MeV electron beam we have extracted the following emittances:

$\varepsilon_{n,rms}$(Cerenkov)= 780 π.mm.mrad

$\varepsilon_{n,rms}$(OTR)= 700 π.mm.mrad

The same experiment was conducted at the accelerator exit but varying the guiding magnet current on the sixteenth induction cell.In this case beam energy was 6.2 MeV and measurements have given the results mentioned above:

$\varepsilon_{n,rms}$(Cerenkov)= 1300 π.mm.mrad

$\varepsilon_{n,rms}$(OTR)= 700 π.mm.mrad

Although the difference between emittances measured by the two diagnostics are not yet explained we note that in both cases the emittance is low.This result agrees well with calculations made for PIVAIR cells.

7 BBU EXPERIMENTS

Design of PIVAIR cells have been made in order to limit development of BBU instabilities by minimizing the transverse impedance of the accelerating gap.

First series of experiments using the two wires method have confirmed the transverse impedance predicted by PALAS code for both technologies used on PIVAIR.

The goal of this new experiment was to validate the BBU calculation code SITAIR by measuring, at the exit of eight Rexolite cells, the amplification of beam transverse oscillation initiated by a tunable tickler cavity.

Typically we have measured initial oscillations of 0.06-0.1 mm for frequencies ranging from 700 to 900 MHz.The cavity was excited by a 3 kA /3.6 MeV beam and driven by an external 23 W rf source.The magnetic guiding field was set around 300 Gauss.In these conditions we have observed a maximum BBU gain of 8 at 780 MHz. To date the best agreement ($\pm$15%) with SITAIR code was obtained for a transverse impedance real part of 800 Ω/m.

To complete this work we must now calculate the imaginary part of transverse impedance that will optimize the fitting of experimental data with code calculations.

CONCLUSIONS

Thousands of tests realized on PIVAIR since 1994 have demonstred that technologies of accelerator sub-systems are adequate for AIRIX. Electron beam characteristics predicted by the numerical codes have been obtained; but we must verify that they are sufficient to achieve a small radiographic source size after focussing on tantalum target.This work is in progress at CESTA and will be ended this summer.

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