STATUS OF THE AIRIX INDUCTION ACCELERATOR

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Abstract

AIRIX Induction Accelerator (16-20 Mev, 3.5 kA, 60 ns) has been designed at CESTA for flash X-ray application. After two years of experimental studies on prototype cells and High Voltage Generators we started in 1994 the PIVAIR milestone which is a validation step at 8 MeV for AIRIX. The PIVAIR injector has been assembled and tested; it produces a 3.5 kA electron beam at 4 MeV with good voltage flatness (±0.35 %) and low emittance. An accelerating module of eight induction cells has been constructed and four cells have been first connected with the injector.The other ones will be added this year and will use ferrite cores with high magnetic flux variation specially developed by CEA for this application. First results on beam characteristics will be given in this paper as well as progress achieved in diagnostic technologies, cell alignment and beam transport studies.

I - INTRODUCTION

Dedicated to flash X-ray radiography application AIRIX induction accelerator has been designed to produce a 16-20 MeV, 3.5 kA, 60 ns electron beam. Development of this machine started at CESTA in 1992 with the construction of two prototypes: an induction cell and a high voltage generator. After testing we decided to construct PIVAIR accelerator which is a validation step of AIRIX up to 8 Mev; it will permit to check the different technologies involved on AIRIX but also to study the beam transport and focusing.

PIVAIR installation will consist of a 4 MeV injector , sixteen 250 keV induction cells and a focusing solenoid. In march 1994 injector acceptance tests have been successfully performed at CESTA and by the end of the same year we tested four induction cells loaded with the 3.5 kA electron beam generated by this apparatus.

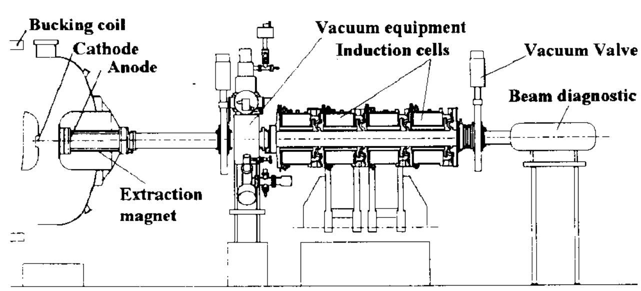


Figure 1 : PIVAIR setup

In the following sections we describe the existing PIVAIR equipments (fig.1) and we present the experimental results obtained.

II - INJECTOR

The injector used on PIVAIR was designed by PSI for the pulse generator and by LANL for the diode. It comprises a 1.5 MV glycol-insulated Blumlein which is pulse charged by a step-up transformer and switched out by four laser-triggered spark gaps. A series of increasing impedance transmission lines is used to transform the Blumlein output voltage to 4 MV at the diode.

The beam is generated by a 7.62 cm diameter rayon-velvet cathode surrounded by a non-emitting anodized aluminum field shaper; the distance between the re-entrant anode and cathode is 17.5cm.

During acceptance tests beam characteristics were measured using diagnostics developed by CESTA [1][2]. A summary of the results are given in table 1. It appears that measured performances are in good agreement with AIRIX specifications except for emittance. We suspect that the value obtained for this parameter is higher than expected because data processing does not take into account diagnostic perturbations due to metallic mask focussing.

Table 1 . AIRIX injector characteristics

	Specifications	Measured
Diode voltage	$\geq$ 4 MV	4029 kV $\pm$ 4 kV
Voltage flatness	< $\pm$ 1 % in 60 ns	< $\pm$ 1 % in 60 ns $\pm$ 0.35 % in 50 ns
Voltage reproductibility	$\pm$ 1%	$\pm$ 0.60 % over 1000 shots
Beam current	$\geq$ 3.5 kA	3.8 kA
Normalized rms emittance (π . mm. mrad)	$\leq$ 1200	1600 at 3.77 kA
Jitter (1σ)	$\leq$ 1.5 ns	$\leq$ 0.5 ns

III- HIGH VOLTAGE GENERATORS

A high voltage pulse gnerator has been developed to drive two induction cells with 250 kV / 75 ns flat top pulses with voltage variation smaller than $\pm$ 1% .

A prototype described in a previous paper [3] was tested in 1993 and gave good results . On this base a series of four generators has been constructed last year to feed the first eight PIVAIR induction cells. They are now operating.

IV - INDUCTIONS CELLS

Each induction cells use 11 ferrite cores (250 mm I.D., 500 mm O.D. and 25 mm thick) housed in a non magnetic stainless steel body, a 4 layers bifilar-wound solenoïd magnet and 2 printed circuit dipole trim coils.The 19 mm width accelerating gap has been shaped in order to minimize the beam coupling with the gap cavity and reduce the BBU instability (fig.2)

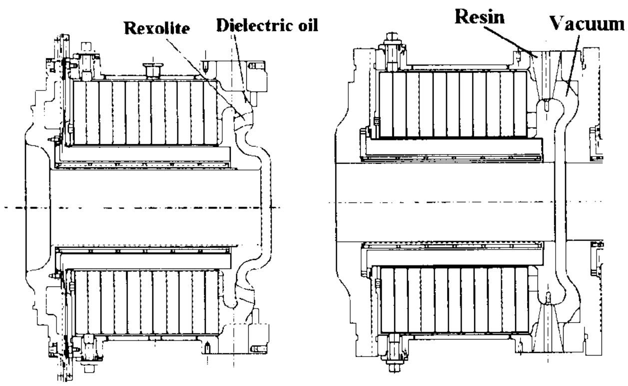


Figure 2 : PIVAIR induction cells

IV.a - High voltage testing

Three gap insulator technologies have been tested on the prototype cell. An alumina insulator brazed on cell body was first experienced. A good vacuum tightness was obtain (10^{-8} torr) but the cell exhibited numerous flashovers at voltage levels higher than 200 kV.Modifications of gap shape and alumina-field angle did not give best results.Consequently this technology was not choosen for AIRIX.

The second insulator tested was made of reticulated polystyrene (Rexolite) and used viton O-ring seals to ensure vacuum tightness. The gap geometry was choosen so that an angle of 40° was maintened between insulator surface and E-field.With this configuration the vacuum reached 10^{-6} torr in the cell and the high voltage strength was tested up to 300 kV without any flashovers. From these results we decided to construct four PIVAIR cells with Rexolite insulator.

In the third technology gap insulator is suppressed and dielectric oil surrounding the ferrite cores is replaced by vacuum. This technology is attractive for two reasons First the vacuum interface and high voltage insulation are transferred on HV cable heads which is more convenient for accelerator maintenance in case of flashover. On the other hand BBU calculations shows that transverse impedance is lower for such a cell.

Tested on prototype cell this configuration needed several months of experiment to be qualified for PIVAIR. At the begining we observed a decrease in cell impedance for voltage pulse higher than 210 kV.We found that the default originated in current leakage along ferrite cores due to a too short distance between cores and metallic housing. Once this problem solved the cell was tested sucessfully with pulses up to 300 kV.

At present four induction cells without ring insulator are under construction and will be mounted on PIVAIR sooner.

IV.b - Ferrite improvements

TDK PE11B ferrite used on the first cells are not sufficient to maintain 75 ns flat top with 250 kV pulses because cores saturation occured too early. In order to increase the magnetic flux swing available on ferrite we decided to test two other compositions : TDK PE 16 and a CEA ferrite specially developed for AIRIX application. The best result was obtained with the last one which offers a 15 % increase in magnetic flux swing . So AIRIX and PIVAIR cells will be furnished with CEA ferrite cores.

V - DIAGNOSTIC DEVELOPMENT

Because electron beam characteristics are essential in providing high quality radiographic flashes, time resolved electron beam diagnostics have been developed at CESTA.They are described in details in a companion paper elsewhere in this conference [5]. A summary of their performances are given below.

Spectrometer: a magnetic spectrometer has been built to measure on a single shot, electron energy versus time ranging from 1 to 10 MeV. In this apparatus the beam is bended as it enters between poles of a semi-circular magnet. After deviation electrons are intercepted by a linear fiber optic array.The interaction between fibers and beam produces Cerenkov radiation which is analized with a streak camera. Time resolution of 1 ns and energy resolution $\Delta E/E$ of 0.1 % are currently obtained.

Emittance measurement: this diagnostic is based on the pepper-pot technique. It uses 3 mm thick tantalum plate with an array of 1 mm diam.holes. The beam first passes through the mask and is then intercepted by a plastic film scintillator. Image obtained is recorded on a gated CCD camera. With this equipment time resolved emittance can be measured in two transverse directions with 5 ns resolution.

Beam position and current monitors: to evaluate beam transport conditions (BBU perturbations and chromatic aberrations) beam position monitors have been developed. Each one comprises four pickup loops that measure the magnetic field associated with the beam. The resolution we need is ± 5 % for current and ± 100 µm for position in the 1 GHz bandwidth. To reach this objective we have improved the loop mechanical construction (accuracy , reproducibility) and the quality of data acquisition system (oscilloscopes , cables ...)

At present one monitor has been calibrated and is used on PIVAIR accelerator; its performances are under test.

VI - PIVAIR RESULTS

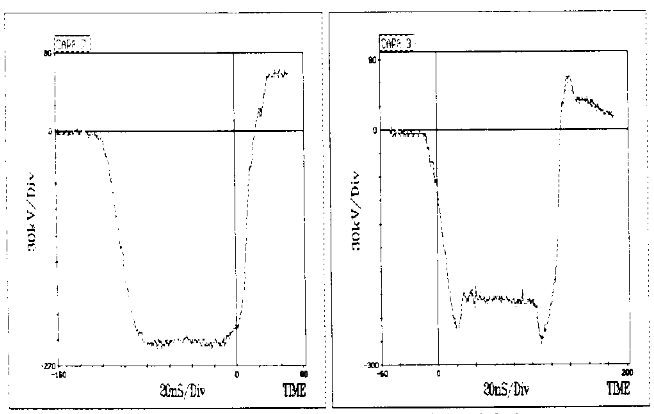
Alignment: by the end of 1994 four induction cells with Rexolite insulator were assembled in one block on a mounting stand using a laser beam for alignment. Then the cell block was aligned with a theodolite on a reference axis normal to the cathode.Accuracy obtained between cell and reference axis was ±190µm for offset and ± 210 mrad for tilt angle [4].

Synchronization: high voltage generators spark gap triggering was controled by a Standford pulse delay generator which offers a very high accuracy and a low jitter. Synchronization of HV generators was first tuned on a resistive load and then applied to the cells. This system was very satisfying.

Beam transport: to simulate beam transport conditions and determine axial magnetic field along accelerator we used the envelope code ENV developed at CESTA. This code was experimentally validated on LELIA accelerator [5] last year. On PIVAIR we first calibrated the guiding magnets by measuring ,with a Hall probe, axial magnetic fields versus coil currents.

Then initial beam characteristics were obtained by evaluating the mean quadratic radius with an optical diagnostic placed just behind the extraction coil.

Beam acceleration: pulses up to 210 kV have beeen successfully applied to the cells loaded with 3.5 kA beam issued from the injector (fig.3). At this voltage level no flashovers was observed. For higher voltages, saturation of TDK PE 11 ferrite cores generates a peak of current which after reflection on HV cables produces an inverse voltage pulse on gap cell. This pulse appears 440 ns after the main pulse and induces flashover on the gap insulator. So with current ferrite cores accelerating pulses are limited to 210 kV



(a) without beam (b) with beam

Figure 3 : PIVAIR cells response

Beam characteristics: an energy of 4.8 MeV has been measured with the spectrometer at the accelerator output (fig.4). This result confirms an energy gain of approximatively 210 kV by cell. Figure 4 -a and 4 -b show that energy spread obtained at injector output (± 1 %) is not affected by acceleration. Emittance measured at the accelerator end was about 1600 π.mm.mrad ; this value agrees well with emittance predicted by ENV code. In order to complete code evaluation we must now perform beam radius measurements inside the accelerator tube.

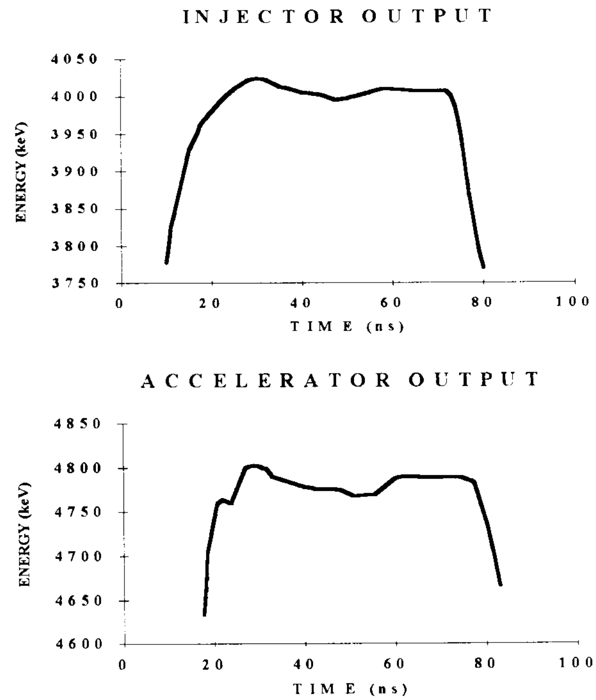


Figure 4 : Beam energy

VII - PIVAIR SCHEDULE

Eight inductions cells (4 vacuum cells and 4 Rexolite cells) are under construction and will be connected to the accelerator during summer 1995. After HV testing we plan to measure energy gain and start BBU experiment with 7 MeV / 3.5 kA beam.

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