AIRIX PROTOTYPE TECHNOLOGICAL RESULTS AT CESTA

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Abstract

AIRIX Flash X-ray Radiographic facility is based on a 4 MeV - 3,5 kA pulsed electron injector and a 16 MeV induction accelerator. The accelerator will consist of 64 induction cells powered by 32 H.V. generators operated at 250 kV. The final 20 MeV electron beam will be focused on a target designed for X -ray conversion. At CESTA, PIVAIR is a testbed designed as a validation step of AIRIX up to 8 MeV. The injector has been connected with 16 accelerating cells, increasing electron beam energy to 7.2 MeV. Two kinds of induction cells have been developed and tested .A focusing experiment is planned for electron beam spot diameter measurements. After this step, beam focusing on a target will be experimented for X-ray source characterization.

1 INTRODUCTION

AIRIX induction accelerator has been designed to produce a 16-20 MeV, 3.5 kA, 60 ns high brightness electron beam for flash X-ray radiography application. Obtaining the final 2 mm focal spot size requires a low energy spread ($\Delta E/E \leq 1\%$) and a small emittance electron beam. These objectives have governed each component design: pulse power sources (injector and H.V. generators), induction cells (magnetic alignment and H.F. response) in order to minimize emittance growth ($\Delta\varepsilon \leq 10$ %) along the accelerator.

The first studies began at CESTA in 1992 with the development of two prototypes: a 250 kV pulsed generator and a versatile induction accelerating cell.

PIVAIR facility (Fig 1) is a validation step of AIRIX up to 8 MeV and consists of a 4 MeV pulsed electron injector, sixteen induction cells powered by eight H.V. generators, and a beam focusing section.

In the following sections, we shall describe the experimental set up and results which lead to the technological choices for AIRIX accelerator.

2 INJECTOR

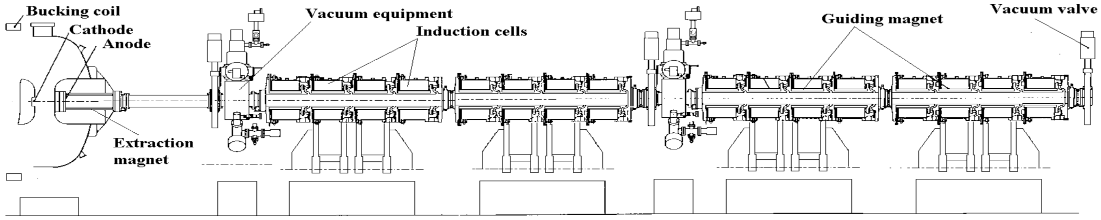
The injector consists of a 4 MV good flatness pulsed generator developed by PSI [1] and a vacuum diode designed by LANL for the DARHT project. Acceptance tests at CESTA in early 1994 have demonstrated a 4 MeV-3.5 kA beam with a low energy spread (± 1% over 60 ns). The beam normalized emittance was measured at 1600 ± 300 π.mm.mrad with the pepper pot method. The injector has exhibited an excellent reproducibility and a low command fire jitter (0.5 ns at 1σ) over more than 8000 shots performed in the 3 to 4 MeV range.

3 HIGH VOLTAGE GENERATORS

A high voltage pulsed generator has been designed to drive two induction cells with 250 kV, 75 ns pulses with less than ± 1% flat top deviation. Eight generators are currently operating on PIVAIR induction LINAC with the rated specifications according to the beam energy spectrum measured.

4 INDUCTION CELLS

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



Figur 1 : PIVAIR set-up

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4.1 Cell design and H.V.testing

The first induction prototype cell was operated with the prototype H.V. pulse generator and pure resistive loads in the 200 to 300 kV range [2] in order to test different set-up (gap geometry and insulators, fe rrite types,...). Two types of cell were finally selected to be tested with a 3.5 kA beam on PIVAIR test bed (Fig 2):

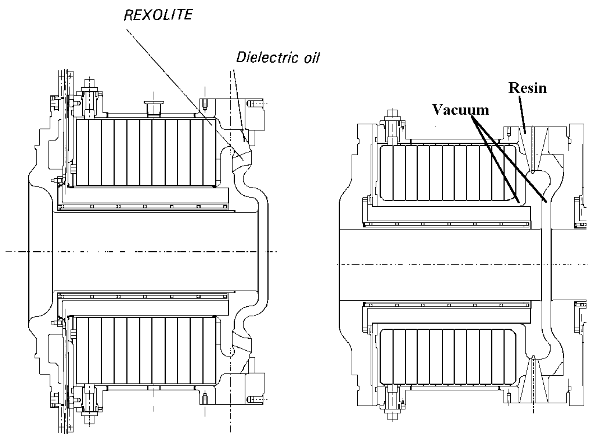

Figure 2: PIVAIR induction cells

4.1.1 Rexolite cell

In this technology, the ferrite cores are insulated with oil and the gap insulator is made of reticulated polystyrene (Rexolite) ; viton O-rings provide vacuum tightness (10^{-6} Torr).

4.1.2 Ferrite under vacuum cell

In such a cell, gap insulator is suppressed and dielectric oil is replaced by vacuum. The vacuum interface and high voltage insulation are transferred on cable heads.

4.2 Ferrite improvement

The first tests performed with TDK PE 11 B ferrite pointed out the need for increasing available flux swing in order to maintain a 75 ns flat top at 250 kV. TDK PE 16 ferrite were tested but the specific ferrite developed by CEA-LR exhibited a 15% flux swing gain. They were successfully tested on PIVAIR and choosen to furnish AIRIX induction cells cores.

5 DIAGNOSTICS

Specific, accurate and time resolved diagnostics have been developed in order to monitor (BPM) and to characterize (spectometer, emittancemeter, beam imaging using OTR or Cerenkov) the electron beam; they are more detailed in a companion paper [3]

6 PIVAIR RESULTS

6.1 Alignment

The 50 meters lenght AIRIX accelerator will consist of sixteen cell blocks (each block is a four induction cell assembly) completed by a drift pipe and a focusing magnet.The cell magnetic misalignement must be minimized in order to reduce chromatic effects.The objective is to enclose all the cell magnetic axes into a 250 µm diameter cylinder with an angle spread lower than 500 µrad around the reference beam axis. Moreover we want to be able to control the accelerator alignement between two shots without using the beam axis (i.e without breaking vacuum), so a new external reference must be defined .

A first procedure, using a prism technique and four lasers [4] has been abandonned for accuracy problems.

In the new procedure, the beam axis reference is defined with respect to a vertical plane and an horizontal plane (Fig 3). Two WPS (Wire Positioning System) and three HLS (Hydrostatic Levelling System) detectors are necessary to ajust these two planes [5]. Both detectors use capacitive probes and were studied by ESRF.

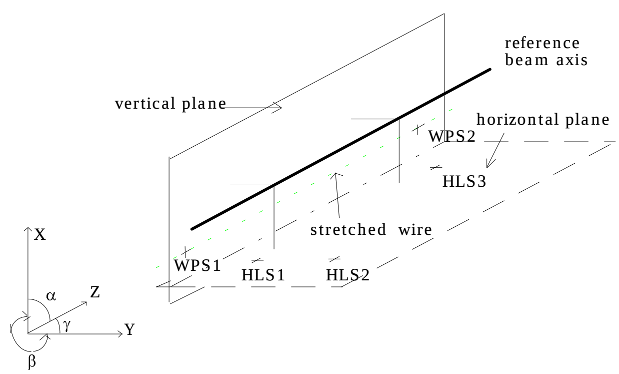

Figure 3: external reference

The alignment procedure consists of 3 steps:
- the reference beam axis is defined into the accelerator building and two standard references are set up to materialize this axis.
- each block ,which consits of 4 cells mechanically aligned and assembled on a Standard Mounting Bench (SMB), is aligned with respect to the SMB standard references (fig 4) by means of the WPS and HLS detectors. The third HLS is replaced by a bank indicator.
The detector values are recorded in a block data file
- the cell block previously aligned on the SMB reference axis is then transported on the accelerator line in order to be aligned on the beam reference axis. The final alignment is obtained when the HLS and WPS detectors reproduce the block data specifications previously recorded on the SMB.

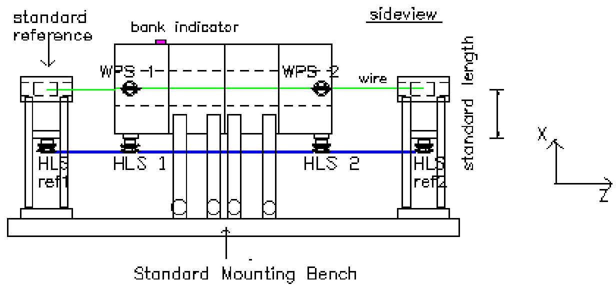

Figure 4: cell block alignment on the bench

The SMB, very sensitive to thermal or vibration perturbations, has been entirely automatised for each cell alignment and could be operated by night to avoid human work perturbations.

The first HLS network is going to be tested in the PIVAIR accelerator set up and environment by the end of this year. As the WPS wire can't be installed before the end of AIRIX accelerator assembly, the full scale alignment system will not be set up and tested before the end of next year.

6.2 Induction cell characterization

6.2.1 Rexolite cells

The first 4 cells, using TDK PE 11 ferrites, demonstrated a 210 kV per cell "routine" accelerating level with a 4 MeV-3.5 kA injected electron beam. For higher accelerating voltages, ferrite saturation occured and a reverse peak voltage appeared accross cell gap, leading to a flashover. Thanks to the magnetic flux gain obtained with CEA-LR ferrites, the next 4 cells exhibited a 250 kV working voltage (1 MeV energy gain per block measured with the time resolved spectrometer) over a few hundreds shots, but a growing number of flashovers occured during reverse and direct voltage. Even after carefull cleaning and refurbishing, a durable and reliable working hasn't been reached. We suspect a bad vacuum thightness on some of the Rexolite insulator vacuum O rings but didn't manage to fix it.

6.2.2 Ferrite under vacuum cells

Two blocks of four cells have been constructed in order to test on PIVAIR facility two different gap shapes , designed to minimize transverse impedance .
The first H.V tests exhibited current leakage between ferrite cores and the internal diameter of the metallic housing. This led to increase the ferrite core internal diameter to 270 mm in order to improve HV insulation . Consequently the ferrite section and available magnetic flux were lowered. This was partly balanced by adding a 12^{th} core (only 12 mm thick). These cells were successfully tested at 300 kV on the HV testbed before being assembled on PIVAIR accelerator line. To obtain the right vacuum level in the beam pipe (10^{-7} Torr),this technology recquired 2 days heating at 70 °C in order to dehydrate ferrites .The tests with a 3.5 kA beam demonstrated a 250 kV working voltage for the two kinds of cell. This value was confirmed by energy spectrum measurements but the available voltage flat top accros the accelerating gap was 7% shorter (compared to Rexolite cell) which necessitated to carefully synchronize injector and pulse generators. Reliability testing (1000 shots at 250 kV) revealed no flashovers for the "flat gap" cells during the main voltage pulse and a few flashovers during the main pulse and reverse polarity postpulses for the "curved gap" cells. This led to choose the ferrite under vacuum technology with flat gap for the AIRIX accelerator.

After disassembling the "curved gap"cell block, we carefully inspected gap and ferrite surface and we found that some plastic shims (used to maintain insulation distance beetween the first ferrite toroïd and the gap electrode) were certainly involved into the flashovers occurence. Removing these shims resulted in a noticeable reliability improvement demonstrated over 400 shots.

In order to delay the ferrite saturation and decrease overvoltages stresses we decided to add a 13^{th} ferrite core: each AIRIX cell will consist of thirteen 24 mm thick ferrite cores. This, partially balanced by some mechanical changes, will imply a 1.2 meter lenght increase for the final AIRIX accelerator.

7 PIVAIR AND AIRIX SCHEDULE

PIVAIR focusing section is now under construction. A focusing experiment at 7 MeV and electron beam spot characterization are planned before summer. Then it will be necessary to extend PIVAIR building before begining the first radiography experiment and X-ray spot characterization.

At Moronvillier site, AIRIX building is quite finished. AIRIX injector has been assembled by the end of february and is now under acceptance test.

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