HIGH CURRENT AND HIGH ENERGY AIRIX INDUCTION ACCELERATOR DEVELOPMENT

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Abstract

Development of AIRIX induction accelerator (16-20 MeV, 3.5 kA, 60 ns) is now in the PIVAIR prototype phase wich is a validation step for AIRIX at 8 MeV. PIVAIR installation designed at CESTA, comprises at present an injector (4 MeV; 3.5kA; 60 ns) and 8 induction cells (250 keV per cell) supplied by specially designed high voltage generators. In this experiment different cell technologies have been tested and two of them have shown a good electric response on resistive load. Technologies and results are presented. We have tested, with an electron beam, four cells of each type. Time resolved spectrum analysis has demonstrated that the increase in beam energy corresponds to the supplied high voltage, although some broadening of the spectrum appeared. The optimization of beam transport will be described as well as the beginning of the BBU instabilities studies.

1 INTRODUCTION

The AIRIX induction LINAC is designed to accelerate a high current electron beam (3.5 kA, 60 ns) from 4 up to 20 MeV, for flash X-ray radiography applications. The PIVAIR prototype, wich is a 8 MeV validation step, carried out at CESTA, will be composed by an injector, that generates a 4 MeV electron beam, and 16 induction cells.

A first 4-cells block, with Rexolite insulator, had been installed and tested last year on PIVAIR line [1]. Recently, two other blocks of different technologies have been added and tested separately (figure 1). The aim of this procedure is to make a technologic choice for the AIRIX induction cells.

After a brief description of the characteristics of the injector and HV generators, we describe the design of each type of cells and the several tests which have been performed to improve each technology. We will discuss also about the beam transport problems and present the BBU experiment we are preparing.

2 INJECTOR

The PIVAIR injector, designed by PSI and LANL [2], produces a 4 MeV, 3.5 kA electron beam, with an energy spread less than 1 % during 60 ns. The jitter of this machine is less than 0.5 ns, and the voltage reproducibility is about 0.60 % over 1000 shots. The emittance of the beam is 1200 ± 400 π mm mrad [3].

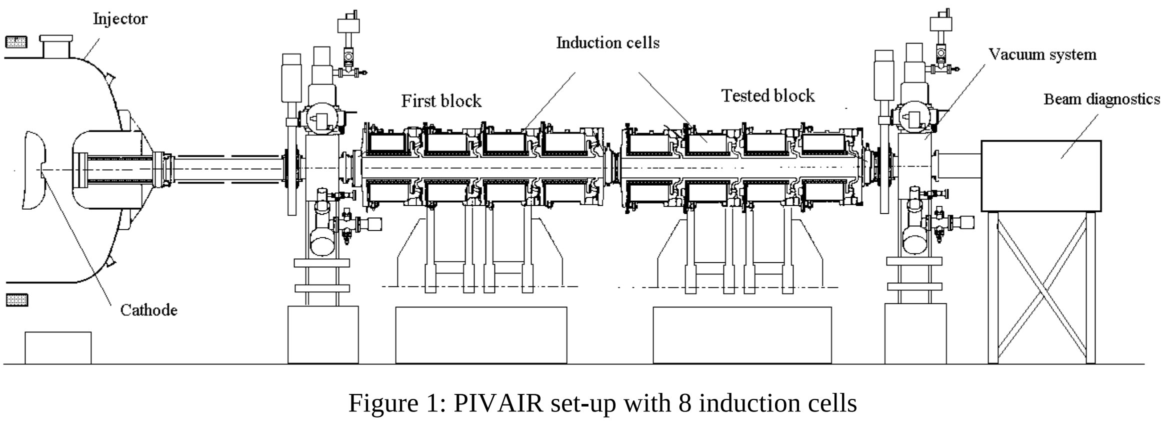


Figure 1: PIVAIR set-up with 8 induction cells

3 HIGH VOLTAGE GENERATORS

In the AIRIX LINAC, induction cells are driven by specially developed HV generators [4]. Each generator drives two cells via four 50 Ω cables, and gives a 250 kV / 75 ns HV pulse with a high accuracy and low jitter (<2ns). Seven out of eigth generators constructed for PIVAIR have been tested, and installed on the machine.

4 INDUCTION CELLS

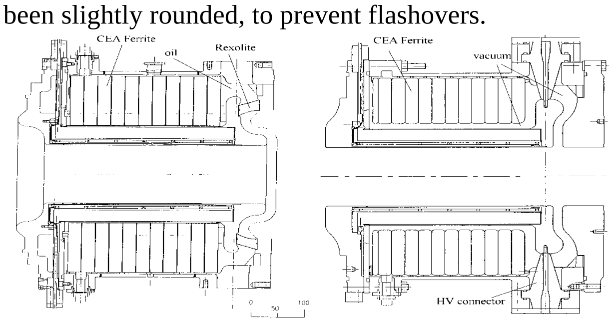
4.1 Cell design

Induction cells have been designed to accelerate the beam using a HV pulse of 250 kV. Two four-cells blocks of different technologies have been tested separately in addition to the first one already installed on the machine. In one case, we have used four cells with Rexolite insulators. Subsequently, we have replaced this block by another one, where the ferrite are under vacuum (no Rexolite insulator in the gap).

In both technologies, we use ferrite cores, specially developed by CEA. They exhibit higher magnetic flux swing than TDK PE 11 ones. The first four PIVAIR cells, which contain TDK cores, can operate only at 220 kV [1].

The designs of the two types of cells are quite different although the non-magnetic stainless-steel body, housing the ferrite cores, has the same dimensions.

For the Rexolite technology cells, eleven ferrite cores (250 mm I.D., 500 mm O.D. and 25 mm thick) are used. In the case of vacuum technology cells, our first design used ferrite cores having same dimensions of those previously mentionned. During tests, several flashovers occured between ferrite and internal cylinder of the cell's body. The design that procures satisfactory electrical tests requires different dimensions for the 11 cores (270 mm I.D., 500 mm O.D., 25 mm thick). To adjust the magnetic material section, to be able to operate at 250 kV, we have placed a twelfth thin core (10 mm thick). Moreover, the edges of each core have been slightly rounded, to prevent flashovers.



Rexolite technology vacuum technology

Figure 2: Design of the induction cells.

On the figure 2 we can compare the design of these two types of cells. In the vacuum technology cells we remark that annular gap insulator is suppressed and vacuum-oil interface is transfered on HV electrical connectors.

4.2 Acceptance test

A good vacuum tightness (10^{-7} Torr) was obtain for each technology. This value is easily reached with Rexolite technology cells, but in case of vacuum technology, we need to bake the ferrite cores and cell's housing.

Each cell has been tested with an identical high voltage generator to those installed on the accelerator. We decide that a cell has a good electrical behaviour when it produces a 250 kV pulse of 60 ns width with no flashovers for 250 shots. Both technologies have demonstrated good electrical results.

4.3 Beam accelerating tests

The second part of the cell testing consists in characterizing them on the machine, when accelerating the electron beam. The cells are grouped by 4 to make an accelerating block, which is then aligned on the machine axis [3].

The best way to visualize the acceleration is to use a time resolved energy spectrometer [3], that can measure the energy spectrum with high resolution (0.2%). We obtained in both cases, a maximum energy of 5.8 ± 0.058 MeV during 60 ns. This shows that the two technologies are acceptable for PIVAIR accelerating modules.

At this point there is no fundamental argument in favor of one of the two types of cells although the vacuum technology is more convenient for insulator maintenance because of easier accessibility.

However, there is a point where vacuum technology is preferable. The generator pulse duration exceeds the beam pulse duration. This implies, near the nominal HV value (250 kV), a ferrite cores saturation and generate a peak of current. This surge, after reflections on HV cables produces an inverse voltage on the accelerating gap 440 ns after the main pulse. This reverse pulse induces flashovers along the Rexolite insulator when the HV exceeds 200 kV. After many shots with this phenomenon, we have observed some flashovers during the main pulse, which have caused damages in the gap.

With vacuum technology cells, we haven't observed this phenomenon and any flashovers.

We have also observed, for both technologies, a problem of ferrite cores resetting. The demagnetization is necessary to put the ferrite material in an optimum magnetic state (lowest level on the hysteresis curve). It is realized by a reset pre-pulse (2 µs, 20 kV) delivered by the HV generator before the main pulse (250 kV, 75 ns). Because of electrical reflections or different couplings between cells, the initial magnetic state of the ferrite isn't always the optimum. This implies an earlier saturation of ferrite material, and then the flat-top duration is smaller.

Although this phenomenon isn't presently critical for good acceleration, we are continuing studies and try to solve this problem.

We can see in figure 3 the different time duration of HV pulses measured on 4 different cells during the same shot. We remark, for the two types of technologies, that although flat-top of the pulses is not affected, there exists a difference of 15 ns between the pulse widths.

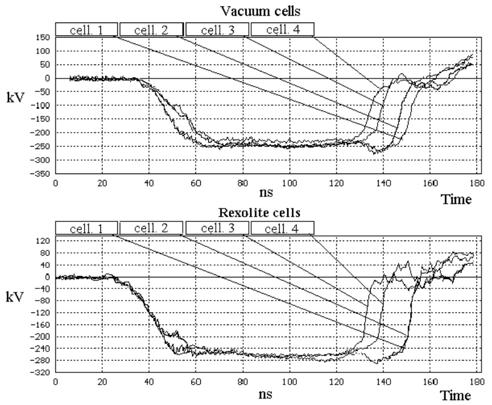


Figure 3: HV pulse measurement on 4 cells for vacuum technology and Rexolite technology

5 BEAM TRANSPORT

For the PIVAIR transport calculations we use the ENV envelope code [5] developed at CESTA. The results of this code have been experimentally validated at the exit of the anode, and after each block of four cells. The experimental data used in the code are initial conditions for beam parameters, determined by beam diameter measurements [3] for different axial magnetic field values. The code also needs experimental magnetic field calibration of each solenoïd of the accelerator.

Beam transport has a direct incidence on the spectrum. We have measured different spectra, with identical HV characteristics, but with different values of beam transport parameters. This measurements show that beam transport, (i.e. beam diameter) affects the instantaneous energy dispersion of the beam. We will do new experiments to confirm this result and to try to understand it.

We emphasize also the beam centering procedure which is under development. This will determine the currents in the steering magnets, needed to transport the beam on the axis, by measuring the position of the centroid with BPM (Beam Positionning Monitors) [3].

6 BBU EXPERIMENT

To complete the study of cell technology, we are developing a BBU experiment. First, we begin the studies with a "tickler" cavity placed between the injector and the accelerator, and measure, after 8 Rexolite cells, the amplification of the initial transverse motion produced by the cavity.

Calculations have shown that transverse impedance is lower for vacuum technology cells. They have been confirmed by measurements (figure 4) made with the two-wire method [6] in the 200-2000 MHz range

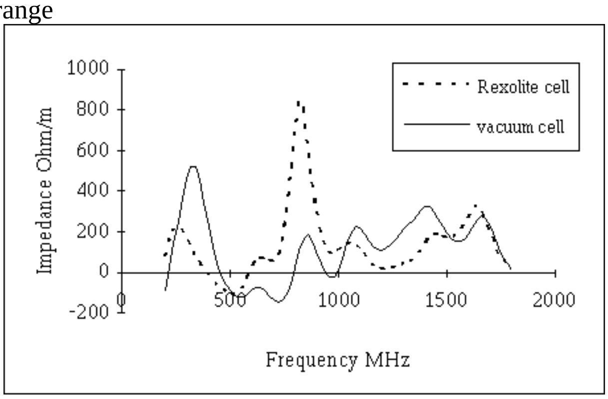


Figure 4: tranverse impedance measurement:
a:Rexolite technology cell; b:vacuum technology cell

7 CONCLUSION

PIVAIR accelerator development is a crucial milestone for the AIRIX project. Research on cells of different technologies and optimization of the beam transport, are important points that gives experience on high intensity electron beam acceleration and will permit an extrapolation for AIRIX beam transport. After the first BBU experiment with 8 cells, we plan to install 8 vacuum technology cells during next summer, and to thereby obtain the complete PIVAIR set-up.

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