The progress of AIRIX at CESTA

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Abstract

The new AIRIX accelerator dedicated to Flash Radiographic applications is in progress at CESTA. It will consist of a pulsed electron injector (4 MeV - 3.5 kA - 60 ns) and a series of 64 induction cells supplied by 32 high voltage pulse generators operated at 250 kV. The output electron beam, at 20 MeV, is designed to be focused on a 2 mm spot for X-ray conversion into a target. The injector is now being completed and will be connected during next months with a first block of four induction cells in order to start the PIVAIR milestone which is designed as a validation step of AIRIX up to 8 MeV. Moreover numerical studies and experimental tests are being carried through on the cell and high voltage technology, the physics of beam transport and the diagnostics.

1. INTRODUCTION

AIRIX facility is designed to produce a high brightness and high intensity electron beam for Flash X-ray Radiography Application [1]. A 4 MeV injector is now operating at CESTA; beam characterization began by the end of march 94 with time resolved diagnostics developed for this program.
A first induction accelerating module is under assembly, taking into account mechanical and magnetic alignment which are key topic for beam transport and emittance conservation along the accelerator. We plan to couple the first four induction cells with the injector by the end of the year. In this paper we present first results and future development.

2. PULSED GENERATOR

A high voltage generator has been designed to drive two induction cells with 250 Kv square pulses; the voltage variations must be less than ± 1% over 70 ns and the command fire jitter must be less than 2 ns (1 σ).
A prototype has been tested; it mainly comprises:

- a 12.5 Ω water filled blumlein as Pulse Forming Line
- a coaxial structure SF6 spark gap
- a blumlein charging system comprising a step-up transformer and 2 thyratrons
- a spark gap triggering system

The most complex system is the spark gap triggering circuit because of hard specifications recquired: high peak amplitude and rise time, good reproducibility are needed to obtain low command fire jitter. After some difficulties with CX2607 thyratrons (reproducibility and jitter problems), the whole generator has been successfully tested with CX1725x thyratrons. Connected with four (50 Ω)H.V. cables it is now operating in the 250 kV range (fig. 1) to test induction cells.

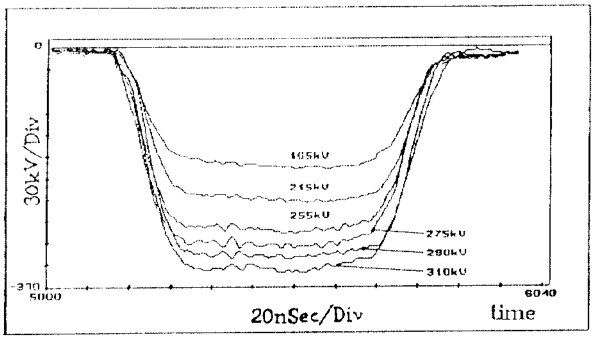

Figure 1: blumlein output

Four generators are under assembly to feed the first eight induction cells of PIVAIR LINAC by september.

3. INDUCTION CELL DESIGN

Each cell comprises 11 ferrite cores (250 mm I.D., 500 mm O.D. and 25.4 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 accelerating gap is 19 mm width. On the first prototype design, oil is used as dielectric surrounding the ferrites and a solid insulator provides the vacuum oil interface (fig. 2).

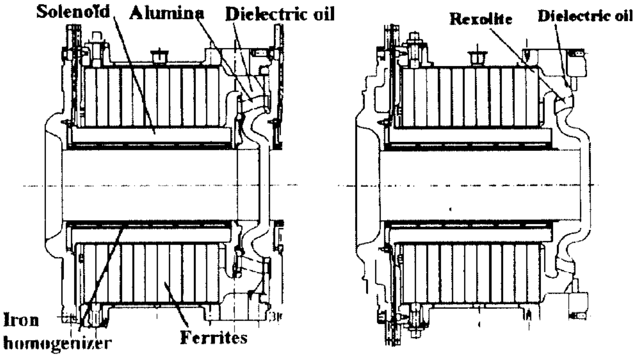

Figure2: induction cells

3.1 High voltage testing

This first prototype allowed to explore different ways:
a) gap insulator: alumina brazed on the cell body is the best way to obtain vacuum tightness but the prototype exhibited some flashovers during experiments in the 230 kV range. An alternative solution, Rexolite insulator, has been tested: its ability to hold high voltage drastically depends on gap geometry (angle θ between equipotential lines and the insulator surface) and we had to change gap geometry to reach 300 kV without any flashover.
b) gap geometry: FLUX-2D electrostatic code has been used to study voltage distribution, particularly in the gap but the initial calculations didn't take into account the θ parameter sensitivity experimentaly observed.
c) Ferrites studies: as TDK PE 11 B first tested seemed to be not sufficient to perform recquired 250 kV - 75 ns flat top pulse (saturation began at 240 kV), we tried TDK PE 16 (best result measured) and then CEA prototype ferrites (fig. 3): continuous progress have been demonstrated and we expect soon a very good ferrite from another CEA team .

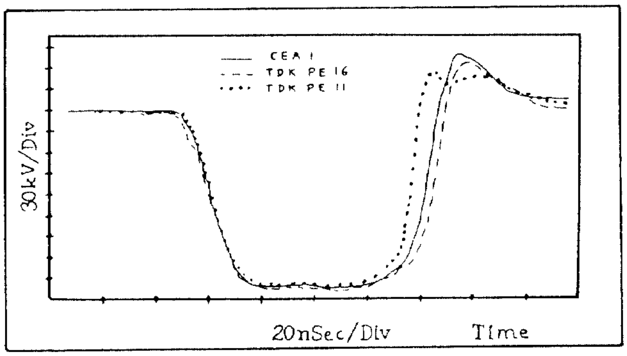

Figure 3: Cell response with different ferrites

3.2 Next design: all vacuum technology

Because of low repetition rate, oil is not needed and we are studying a ferrite under vacuum geometry where gap insulator is useless; vacum interface and high voltage insulation are then transfered on H.V. cable interface (fig. 4). Such a cable inteface has been tested under 300 kV.

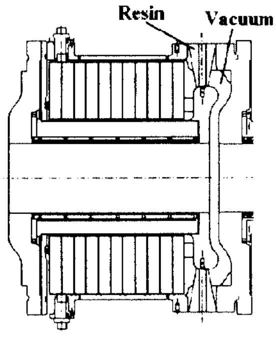

Figure 4: all vacuum cell

3.3 Transverse impedance studies

The BBU instability results in high frequency transverse oscillations of the electron beam; growth factor depends on transverse impedance which is a function of gap geometry and material dielectric constant. Transverse impedance measurements of a gap cavity mock up have been performed and compared with PALAS numerical calculations (fig 5) in order to minimize the beam coupling with the gap cavity.

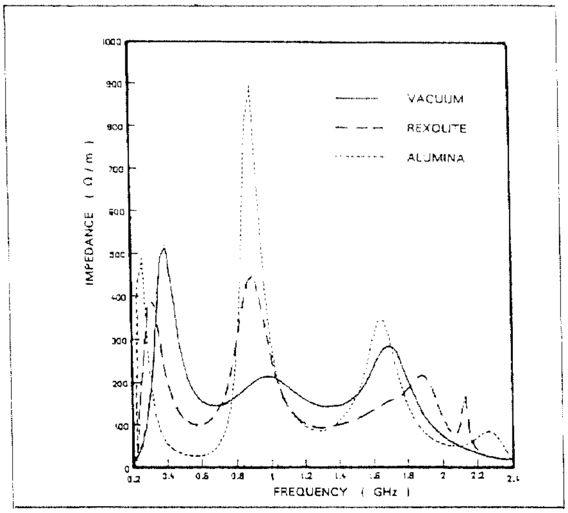

Figure 5: Transverse impedance calculation

3.4 Alignment specifications

A first block of four cells is now under assembly. Special care has been taken with the solenoid design and construction. Each solenoid comprises iron homogenizer rings in order to fix magnetic axis with geometric axis with a large accuracy: less than 1 mrad for tilt error and ±100 μm for off-axis error.

4. DIAGNOSTIC STUDIES

Low energy spread and small emittance are needed to optimize beam transport and final focus. Time resolved diagnostics have been developed to reach experimental requirements.

4.1 Spectrometer

A magnetic spectrometer has been designed and built to analyse electron energy versus time from 1 to 10 MeV (Fig). After 180° deviation, the electron interaction with a 100 optical fiber sheet (Cerenkow radiation) allows a continuous time analysis with a 1 nsec resolution and an energy resolution $\Delta E/E = 0.1\%$ over a 0.1 E energy range [2].

4.2 *Emittance measurements*

Using the pepper pot technique, with a plastic film scintillator and a CCD camera (gated from 3 nsec to 300 msec), this diagnostic measures time resolved electron beam transverse emittance. As the pepper pot consits in a tantalum plate holding a set of regularly spaced holes along the 2 transverse directions of the beam axis, emittance is simultaneous measured in the 2 transverse directions [2].

These diagnostics have first been used and validated on ITS facility at Los Alamos before being employed at PSI site for AIRIX injector technical acceptance test.

5. INJECTOR

The injector is the same type as the one used at Los Alamos on the ITS facility for the DARHT program; it comprises a 4 MV pulsed generator designed by PSI [3] and a diode designed by LANL .

After a one month assembly at CESTA, first operation and beam caracterization began by the end of March 94. The diode consists of a 17.5 cm anode cathode gap and a 7.62 cm diameter rayon-velvet cathode recessed 2.8 mm from the cathode shroud surface. A comparison of specifications with measured results is given in table 1.

Table 1
Injector specifications and results at CESTA

	Specifications	Measured
Diode voltage	≥ 4 MV	4029 kV ± 4 kV
Voltage flatness	< ± 1%	< ± 1% in 60 ns
Pulsewidth	> 60 ns (flat top)	± 1% in 60.5 ns
Beam current	≥ 3.5 kA	3.6 kA
Voltage reproducibility	± 1%	0.077 % (1 σ)
jitter	< 1.5 ns	0.66 ns
Shot rate	1 per minute	

Fig 6 shows the high resolution spectrometer result, with a good voltage flatness: less than ± 0.35% spread over 52 ns First emittance measurements, performed in a 5 nsec window centered on pulse flat top, provided a normalised emittance at 4 MeV from 1500 to 1600 π mm mrad.

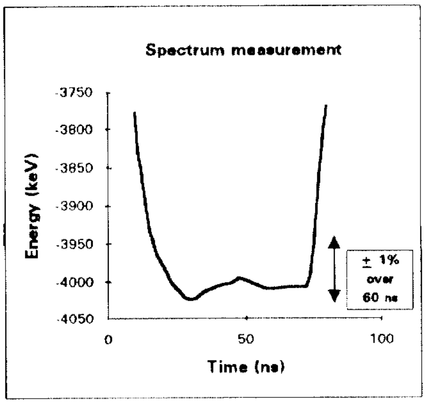

Figure 6: Injector energy spectrum

6 PIVAIR MILESTONE

A first 2 MeV accelerating module is under construction. It will be connected with the injector by the end of the year to experiment induction cell technology (alumina and rexolite insulator, alignment...).

This first step will also allow to measure the energy gain and spread after induction acceleration.

A second accelerating module will be added in 1995 in order to reach 8 MeV. At that time, the PIVAIR set up (fig. 7) will be the test bed for AIRIX validation: induction cell and HV generator technology, alignment, beam transport and focusing, X-ray generation.

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[3] Pulse Science Inc. 600 Mc Cormick street - San Leandro CA 94577

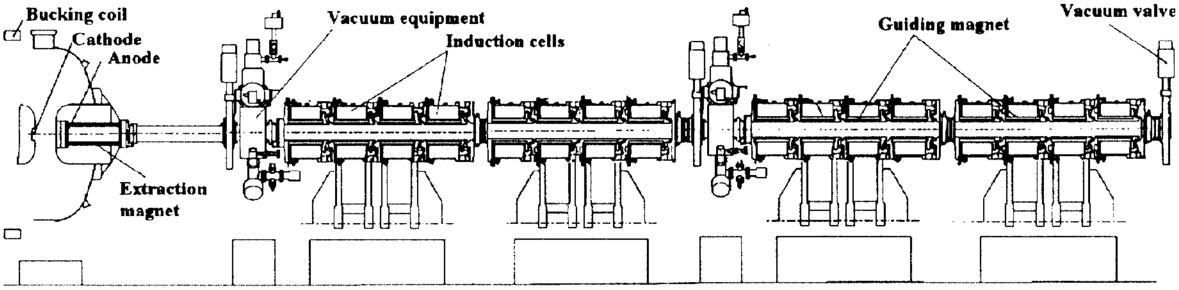

Figure 7: PIVAIR set up