STATUS OF AIRIX ALIGNMENT AND HIGH CURRENT ELECTRON BEAM DIAGNOSTICS

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ABSTRACT

The AIRIX Induction accelerator (16-20MeV, 3.5kA, 60ns) has been designed at CESTA for Flash X-ray Radiography application. The PIVAIR test stand (4-8MeV, 3.5kA, 60ns) is now being operated to study, in particular, alignment techniques and electron beam diagnostics. We present here the use of the Hydrostatic Levelling System (HLS) and the Wire Positioning System (WPS) developed by ESRF to ensure the whole accelerator alignment accuracy. We describe the optical and destructive diagnostics of electron beam which use a CCD gated camera. Among these diagnostics, we present the emittance measurements with the pepper-pot or the three gradient method. We also present the beam size and position measurements with Cerenkov or OTR (Optical Transition Radiation) radiators. An electrical and non destructive Beam Position Monitor (BPM), using Bθ loops, has been developed and is discussed. Correlation has been experimentally studied between optical and electrical beam position diagnostics

1 INTRODUCTION

In the AIRIX project, a high current electron beam (3.5 kA) is generated by a 4 MeV PIVAIR injector. The beam is accelerated up to 16-20 MeV by passing through 64 induction cells [1] and then focused for high performance single shot X-ray radiographic experiments. The AIRIX accelerator is designed to obtain a 2mm focal spot size. This high focus quality requires small emittance and low energy spread ($\Delta E/E \leq 1\%$) but also low transverse beam instabilities along the accelerator to minimize emittance increase ($\Delta\varepsilon \leq 10\%$). The objective is to study in particular, on the PIVAIR facility, the chromatic effects (corkscrew motion) due to the energy spread coupled with the cell magnetic misalignment and the Beam Break Up motion generated by the accelerating gap in the cells.

This paper presents alignment techniques to reduce chromatic effects and time resolved diagnostics to measure emittance and beam position.

2 ALIGNMENT TECHNIQUES

The 50m length AIRIX accelerator contains 16 cell-blocks with 4 cells per block. The goal, to reduce chromatic effects, is to enclose all the cell magnetic axes in a 250µm diameter cylinder with an angle spread lower than 500µrad around the reference beam axis.

Simple calculations show the earth curvature influence which lead to a discrepancy level between the accelerator extremities up to 200µm. We can also mention the expansion structure (25µm/°) due to temperature gradient.

To control accelerator aligment between two shots without breaking vacuum, we define a new reference outside the cells (external reference), by a vertical and a horizontal plane (figure 1). Two WPS (Wire Positioning System) and three HLS (Hydrostatic Levelling System) detectors studied by ESRF [2] and developed by Fogale company, are necessary to ajust these two planes.

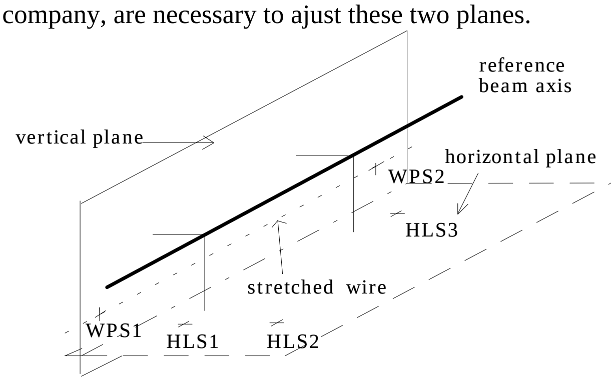

figure 1 : external reference

2.1 Alignment techniques

The HLS and WPS are both capacitive detectors characterized by a high accuracy and reliability. Table 1 presents their main specifications.

	HLS	WPS
accuracy	5µm	1µm
resolution	0.25µm	0.3µm
bandwith	0-10Hz	80Hz
range	2.5mm	±2mm

table 1

The method used to ajust the HLS is based on the communicating vessel principle (figure 2).

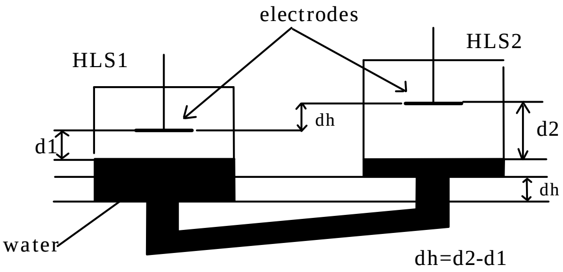

figure 2: HLS detectors

The one used for WPS consists in positioning the stretched wire with respect to the electrodes located at the accelerator extremities (figure 3).

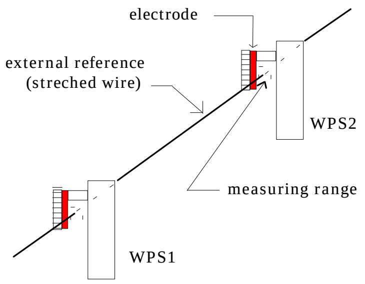

figure 3: WPS detectors

2.2 Cell-block alignment procedure

The cell-blocks are previously connected by a mechanical or a magnetic [3] technique on a Standard Mounting Bench (SMB). This block is then aligned with respect to two standard references (figure 4) by means of the WPS and HLS dectectors. The third HLS is replaced by a bank indicator.

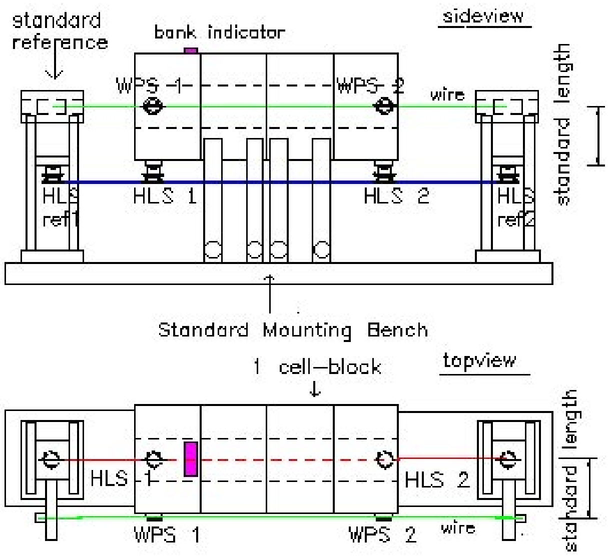

figure 4: cell-block alignment on the bench

The detector values, are recorded in a block-data file. The cell-block alignment procedure along the accelerator, is performed by using a theodolite previously aligned on the normal of the injector cathode.

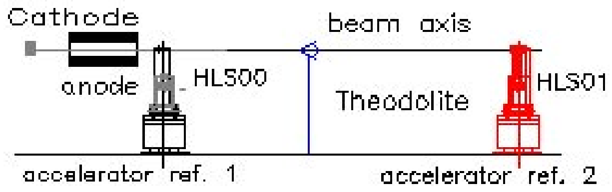

figure 5

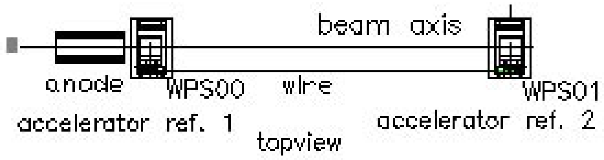

figure 6

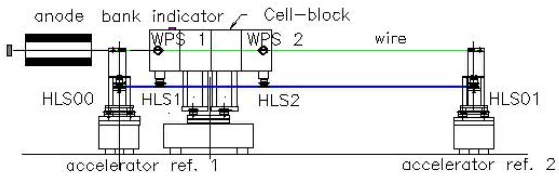

figure 7

We can distinguish three steps :

1-alignment of the anode and the two accelerator references previously ajusted on the SMB bench (figure 5) with the theodolite

2-wire positioning (figure 6)

3-alignment of a cell-block with HLS and WPS detectors to reproduce block-data specifications (figure7).

3 BEAM DIAGNOSTICS

3.1 Optical diagnostics

The normalized root mean square emittance measurement $\varepsilon_{n,rms}$ is performed by using the pepper-pot [4] and the "advanced three gradients" methods. In both cases we used an intensified gated camera (with gating down to 5ns) to record the beam image on a radiator (fast scintillator for the pepper-pot diagnostic and Cerenkov or Optical Transition Radiation (OTR) for the other).

We have experimentally shown in the pepper-pot method, that the presence of the mask leads to double the $\varepsilon_{n,rms}$ value. The foil focusing effect [5] due to the cancellation of the self electrical field of the beam inside the mask, produces a non linear beam focusing and thus an increase of the rms emittance. The value measured after the injector and the first accelerator cell-block, is typically, 1600 and 840 π.mm.mrad with and without deformation. This behaviour is confirmed by calculations done by the M2V code. We have also noticed that $\varepsilon_{n,rms}$ is not very sensitive to the mask resistivity. A 5% emittance increase is observed when the mask resistivity decrease from stainless steel to copper value.

The "advanced three gradients" method is quite different. The evolution of the rms beam radius versus the focusing coil current (figure 8), may be fitted by a curve calculated from an envelope equation, which depends on the following parameters: $\varepsilon_{n,rms}$, the initial rms beam divergence and radius (α_{rms},r_{rms}).

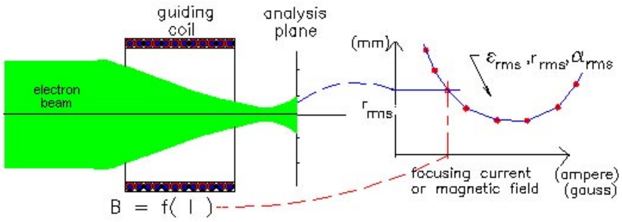

figure 8: three gradients method

The value of $\varepsilon_{n,rms}$ is, in this method, very sensitive to the beam radius. A small increase of this parameter leads to a higher increase of the emittance: $\Delta\varepsilon/\varepsilon \propto 5(\Delta r/r)$
The beam radius is measured by using Cerenkov or OTR radiators. The accuracy of these methods is currently being studied. For the Cerenkov radiation, the light is emitted inside the radiator and depends on the electron diffusion process. Thin radiators (~10µm) are used to minimize this effect. The phenomenon is different for the OTR radiation. It occurs when a charged particle crosses the interface between two mediums having different dielectric indices. The backward radiation is emitted in narrow lobes oriented on both sides of the specular direction. Their orientation depends strongly on the angular trajectory of the electron beam. Special attention is necessary for angular aperture choice of the camera lens. We measure at 4 MeV and 3.5kA:

$\varepsilon_{n,rms}$(Cerenkov)= 1300 π.mm.mrad
$\varepsilon_{n,rms}$(OTR)= 900π.mm.mrad

The higher value obtained for Cerenkov radiation is not yet understood. These values are obtained at different shots. A single shot experiment will be soon performed to measure at once OTR and Cerenkov radiations.

3.2 Electrical diagnostic

Beam transport along the accelerator is controlled by Beam Position Monitors (BPM) using four loops to measure the B_Θ field generated by the beam. In addition to guiding, this non destructive diagnostic will be able to analyse corkscrew and BBU effects. Table 2 presents the main specifications for this two instabilities.

	corkscrew	BBU
range	±5mm	±5mm
accuracy	±0.1mm	±0.1mm
sensitivity	±0.1mm	±0.02mm
bandwith	60-80MHz	1GHz(SCD 1000)

table 2

An experiment has been performed to analyse the correlation between the Cerenkov diagnostic, using a 0.5mm width silica plate, and the BPM diagnostic. Due to experimental calibration problems, it was not possible to decrease the discrepancy between these two methods. Currently, a ±1.5mm maximum discrepancy is measured with a standard deviation σ of 0.6mm.

4 CONCLUSIONS

These alignment techniques and diagnostics appear directly connected with the development of the AIRIX program. The severe alignment specifications lead to use the HLS and WPS detectors studied by ESRF. This choice is justified by their high accuracy, quality and reliability. The optimization of the electron beam is been performed by means of destructive or non destructive diagnostics. Further experiments are requested to improve their understanding.

5 REFERENCES

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[2] : MARTIN D. & ROUX D., Real Time Altimetric Control By a Hydrostatic Levelling System, Second International Workshop On Accelerator Alignment, Sept. 10-12 1990 (DESY GERMANY).

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[5]: R.J. ADLER Image-field focusing of intense ultra-relativistic electron beam, Particle Accelerator 1982 Vol.12 (39-44).