

UPGRADE OF THE ESRF FLUORESCENT SCREEN MONITORS

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Abstract

The ESRF injector system contains 23 Fluorescent Screen monitors: 4 in the TL-1 transferline (200MeV), 8 in the Booster, and 11 in the TL-2 transferline (6GeV). They are based on Chromium doped Alumina screens that are pneumatically inserted in the beam path with an optical system collecting and focusing the emitted light onto a low-cost CCD camera with standard 75ohm video output. Serving mainly alignment purposes in the past 10 years, the upgrade now aims at a 200um fwhm resolution for beam-size and profile measurements. This while preserving the main existing design components, notably the mechanics and the video & timing network.

The particularity of the Alumina screen not in vacuum but in atmosphere will be explained. Details of the mechanics, the optic system and the way of light flux adjustment will be given. An analysis of the factors determining the spatial resolution as well as the results obtained with different screen material will be presented.

BASIC PRINCIPLE

The fluorescent screen is mounted on a support that itself slides into a steel tube of 40mm inside diameter. With a simple steel finger this support is pushed against the very end of the tube, at the other end this finger is attached by a screw to a cf-63 flange. By means of a bellows and a pneumatic drive the assembly can be translated over 50mm at 90° angle to the electron beam path. When inserted the centre of the screen, at 45° angle to the beam path, is at the theoretical centre of the beam.

Light emitted from the screen surface is collected with an effective opening angle of only 1° determined by the lens opening of about 7mm at 400mm distance from the screen. A simple mirror deflects the light 90° at the tube's end towards the camera. The latter is so kept outside the direct view of the screen for better and long lasting protection against radiation damage. (see fig.1)

The camera and lens are housed in an immobile 2mm lead case with a lead-glass window. Only the mirror that is attached to assembly with tube and cf-63 flange moves when inserting & extracting the screen.

SCREEN OUTSIDE BEAM VACUUM

The screen is in ambient atmosphere and not in the UH Vacuum environment of the beam. The electron beam will first traverse the steel tube before hitting the screen surface about 20mm further down. At the beam energies of the ESRF of 200MeV and 6GeV the electrons will completely traverse the device and not cause any problem of excessive activation at this point. However, at 200MeV the scattering induced by the presently 0.5mm thick steel tube limits the spatial resolution, this is discussed further below. For practical reasons and limited costs of the upgrade, the old mechanics is maintained but may be

modified for a small number of TL-1 stations where the high resolution is essential.

A paper mask with 10lines/mm targets in the four corners is stuck directly to the screen, leaving a +/-10mm region free in the centre. It allows precise calibration and easy focussing adjustment at time of installation.

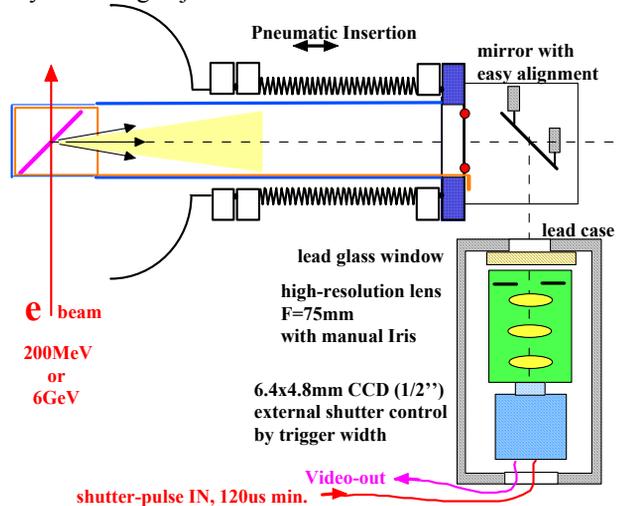


Fig. 1: Set-Up: screen in air and light collection optics.

CHOICE OF COMPONENTS

For the screen material a Chromium doped Alumina with reference AF-995R is used [1,2]. This product offers a strong resistance to radiation induced damage, was specifically developed for particle's viewing screen applications and is available at a price of 50Euros for a 50x50x1mm plate. This material has good luminosity properties and for our applications the amount of light flux is abundant and needs reduction. This is obtained with an electronic shutter in the Sony ST-50CE CCD [3]. With a few millisecc luminosity decay time of AF-995R and the shortest shutter time of 130us the right amount of beamspot intensity is obtained by adjustment of timing between the two as illustrated below in figure 2. The 75mm macro imaging lens offering >20lp/mm resolution in object space is from Edmund Optics [4].

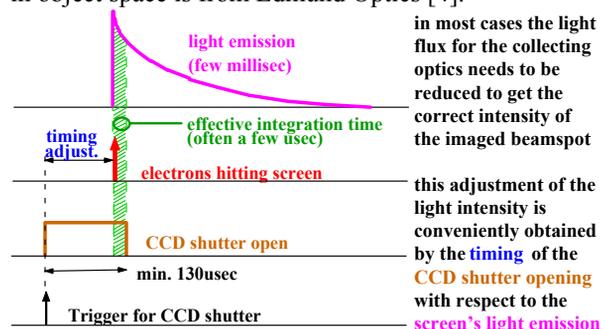


Fig.2: adjustment of light intensity with CCD shutter.

For the transport of the camera signal an extensive network of coaxial 75ohm cabling and video multiplexing was already in place since the original installation. The reuse of this determined the choice of a CCIR video standard for the cameras. A total of 23 signals are routed to one single National Instruments 1409 product for the image acquisition. The above-mentioned trigger for the camera's shutter is send over a separate cabling network with all cameras in series.

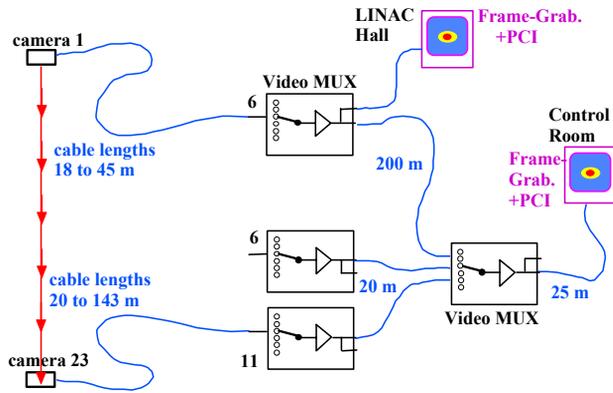


Fig.3: Video Network distribution for 23 stations.

SPATIAL RESOLUTION

Scattering in metal tube

For the 200MeV electrons the scattering caused by the present 0.5mm thick Steel wall is producing a limitation of nearly 600um. This effect, negligible at 6GeV, can be reduced by thinning the wall and/or using Aluminium.

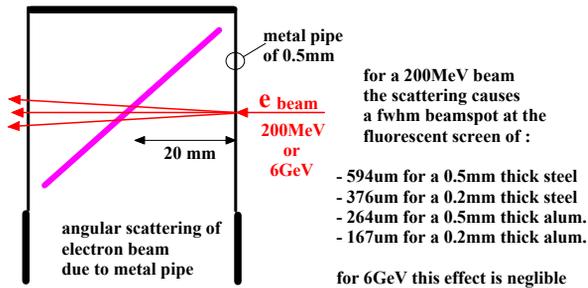


Fig.4: electron scattering limits spatial resolution.

Screen Characteristics

The screen itself limits the spatial resolution due to the combination of three characteristics : finite thickness of the screen, limited opacity of the screen material, and light scattering inside the screen. The electron beam creates a line of light emitters points inside the screen. The light coming from these points is not strongly attenuated, while it is scattered before it reaches the screen surface. The consequent blurring of the spot on the screen is simulated for a given light attenuation coefficient as in fig. 5 (top-left). For the same 1mm thickness but for opacity (or transparency) values a factor 10 and 100 stronger than AF-995R the fwhm beamspot blurring is a factor 0.67 and 0.5 smaller. The strong non-symmetry is explained by the 45° inclination angle. The

theoretical results are fully confirmed by measurements in which the AF-995R material was compared with Alumina screens of ~100 times stronger opacity. This was done in identical beam conditions in TL-2, at 6GeV so without suffering the resolution limitation due to the scattering effect. Both the factor 2 in spatial resolution improvement and the non-symmetric response are obtained.

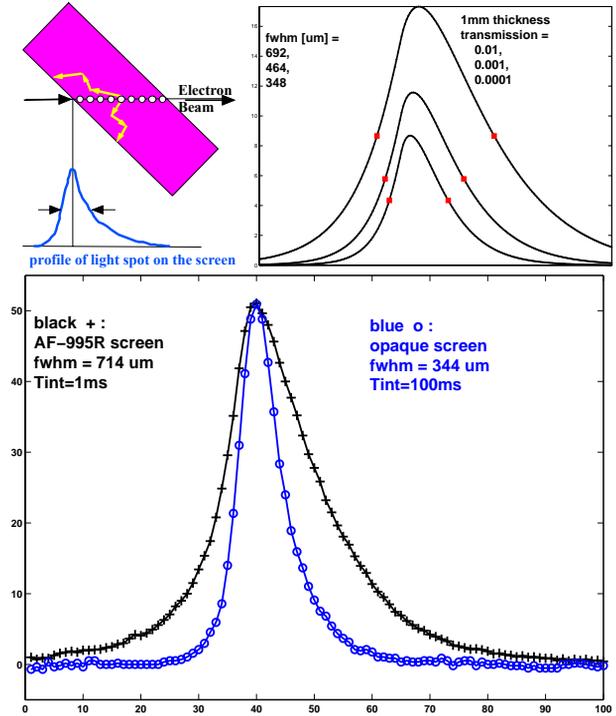


Fig.5: spatial resolution limit due to screen characteristics.

Optical Imaging System

Three factors determine the resolution of the optical system : diffraction ($\lambda=600\text{nm}$, $\alpha\sim 1^\circ$), depth-of-field (screen at 45°), and the system's pixel resolution. In electronic shutter mode the ST-50CE camera (due to CCIR interlaced standard) produces only 240 lines (i.e. a factor 2 less than normal) vertical resolution. Fig.6 shows the total resolution : even with only 240 lines the total resolution is less than 100um for 5-10mm diaphragm (at 400mm) at any part of the screen (range +/- 10mm).

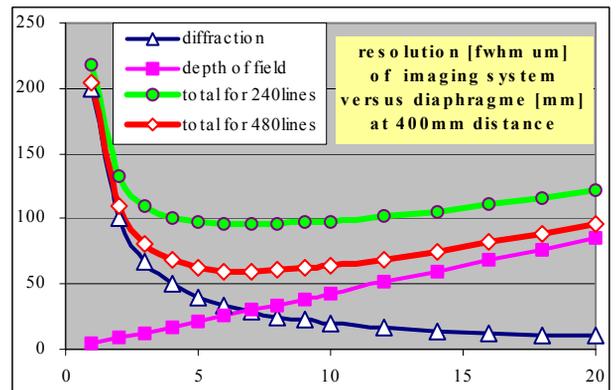


Fig.6: spatial resolution of optical imaging system.

RESULTS

The upgrade is so far installed in the 4 TL-1 screens and 2 screens in TL-2. The images acquired are first treated by Labview in which some symmetry operations are applied (rotation, left-right inversion) to correct effects introduced by mirrors and rotation of camera. After that the image matrix is treated by simple Matlab functions that determine the centre of gravity and the beamsizes of the spot at the maximum repetition rate of 10Hz.

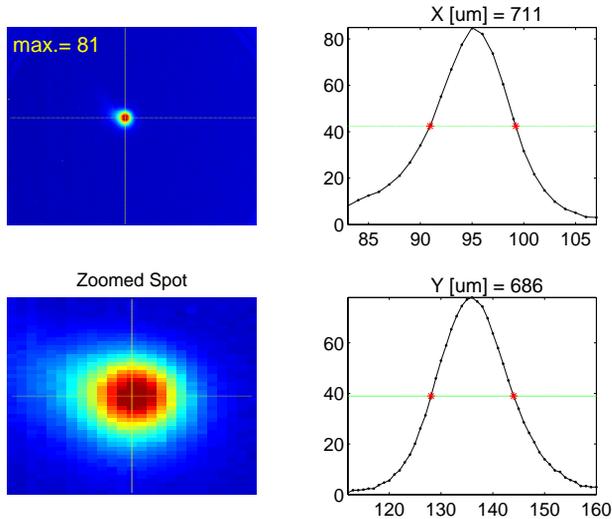


Fig.7: typical output result after Matlab treatment.

A series of measurements on the 2nd TL-1 screen were performed to determine the emittance. A preliminary result of 400nm.rad was obtained but needs a revision once the spatial resolution has been improved and the LINAC beam is better conditioned.

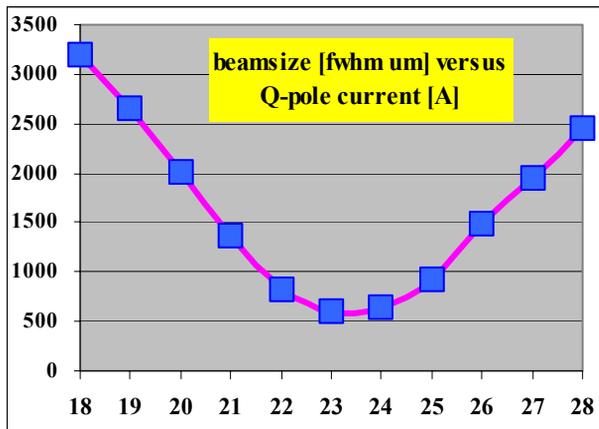


Fig.8: emittance measurements in TL-1.

CONCLUSION & FUTURE WORK

The upgrade of the screen monitors has been carried-out in a cost effective way while preserving a major part of the existing system. It can be summarised as follows :

- Optimised spatial resolution.
- Easier adjustment of light spot intensity.
- Easier and more precise focussing and calibration.
- Relieved motion mechanics.

- Higher quality screen material.
- Better protection against radiation damage for CCD.
- Availability of numeric results at 10Hz rate.

However, in today's configuration the aim of 200um fwhm spatial resolution is not yet achieved due to scattering produced by the system and certain screen characteristics. These limitations affect TL-1 and TL-2 to different extents, it can be stated that the spatial resolution today is in the 300 to 700um range.

While this is acceptable for the 8 stations in the Booster and for a number of other stations (see the nominal beamsizes at the TL-1 & TL-2 stations in fig.9), it would limit the precision of certain studies like the emittance measurement. In the near future the possibility to suppress or reduce the scattering effect will be considered by using a screen inside UHV or thinning the tube. Also, an improvement of the screen material characteristics is sought for which several possibilities will be examined soon : Thinning the AF-995R (230um has been achieved), using 'dark' (opaque) version Alumina, using thin Phosphor coatings [5] or thin YAG:CE scintillators [6].

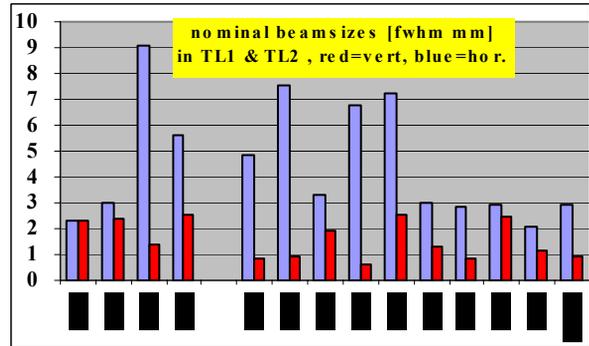


Fig.9: beamsizes in TL-1 and TL-2.

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