

BEAM PROFILE MONITORS IN THE NLCTA*

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Abstract

The transverse current profile in the Next Linear Collider Test Accelerator (NLCTA) electron beam can be monitored at several locations along the beam line by means of profile monitors. These consist of insertable phosphor screens, light collection and transport systems, CID cameras, a frame-grabber, and PC and VAX based image analysis software. In addition to their usefulness in tuning and steering the accelerator, the profile monitors are utilized for emittance measurement. A description of these systems and their performance is presented.

I. INTRODUCTION

Among the devices which comprise the beam instrumentation system of the Next Linear Collider Test Accelerator [1] at SLAC are eight beam profile monitors: one near the gun, one between the injector sections, one each before, in the middle of, and after the chicane, one after the main accelerator, and one at each of the two dumps. Along with four wire scanners, these profile monitors allow us to view the transverse charge distribution of the electron beam at various positions along the beam line. They are of great utility for monitoring beam shape, verifying transmission, and, in the high dispersion region of the chicane and spectrometer, measuring energy spread in the long bunch train [2],[3]. In addition, they are employed in data acquisition for beam emittance and TWISS parameter measurement.

II. SCREEN

The screens used in our profile monitors are of the same type used in the SLC [4]. They are fabricated from aluminum, to which is bound a fine-grained surface layer of $Gd_2O_3S:Tb$. This coating phosphoresces with a decay time of about a millisecond where the incident electron beam deposits energy. The light emitted per unit area is proportional to the charge passing through the screen. They are supported on pneumatic vacuum feedthroughs which allow them to be retracted from the beam pipe volume when not in use.

When a screen is inserted, its surface makes an angle of 45° with the beam line axis so that it can be viewed through a vertical view port. A pattern of holes drilled in the screen allows for image dimensions to be calibrated. For most screens, this is a rectangular frame with seven

holes horizontally and five vertically. The horizontal and projected vertical hole spacing is 1.5 mm. The last three profile monitors have larger screens with a different hole pattern.

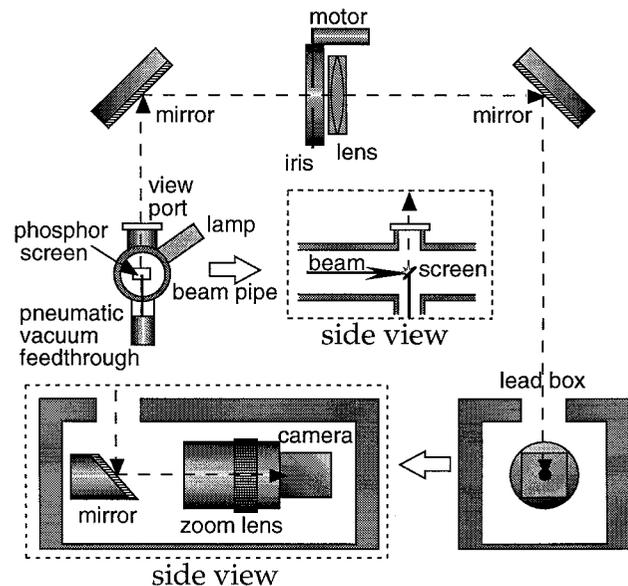


Figure 1. Profile monitor optics diagram.

III. OPTICS

An optical system is employed to distance the camera from the high radiation levels produced by the beam, particularly when incident on the screen. The layout of our optical elements is illustrated in Figure 1. They include three flat optical mirrors, an adjustable iris, and a three-inch, 350 mm focal length imaging lens. The image magnification is set close to unity to minimize aberration. The camera is placed a couple of feet off to the side of and below the beamline and is shielded by an enclosure of lead bricks supported by a steel frame. The amount of light entering the camera is adjusted by means of a remotely controlled motor connected to the iris. Also remotely controllable is a lamp aimed through a second window in the vacuum chamber. This allows us to illuminate the screen in order to view the hole pattern and calibrate the x and y scales of the received image. Illumination is also needed while manually aligning the optical elements and focusing the image.

IV. CAMERA

The camera used in our profile monitors is the

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VI. SOFTWARE

In conjunction with the Fidelity 200 frame-grabber card, we use Data Translation's GLOBAL LAB Image software, running in Microsoft Windows for Workgroups. This image processing and analysis package has many features. It configures the frame-grabber for our camera model. It displays live video or captures single frames, which can be saved as TIFF format image files. It can plot the pixel values along any slice of an image selected by dragging a line. It also allows the user to program scripts to perform desired sequences of operations.

Unfortunately, GLOBAL LAB Image seems not to have been designed with beam physicists in mind. It cannot readily do such things as projections, curve fits, and contour plots. One can expand its capabilities by writing additional C-code. However, for our purposes, it was preferable to FTP beam images to the SLC VAX and analyze them there, when desired, with our own code written in MATLAB. This code subtracts the baseline from the image array, displays 2-D contour plots, projects the pixel values onto the x and/or y axis, and fits gaussian curves to determine the beam sigmas. An example beam spot is shown in Figure 5. Its projections, along with gaussian fits, are shown in Figure 6.



Figure 5. Beamspot image.

VII. EMITTANCE MEASUREMENT

The beam physics program of the NLCTA makes it desirable to be able to measure the beam emittance, as well as how well matched the beam is to the lattice. This is done with our profile monitors using the general procedure described by Ross, *et al.* [5].

To measure horizontal beam phase space, for example, the CORRELATIONS PLOT program in our controls software is used to step a horizontally focusing quadrupole magnet upstream of the chosen profile monitor through seven field strengths about the nominal value. At each step, a trigger is sent to our frame-grabber, and GLOBAL LAB Image stores the beam image to disk.

These images are then transferred from PC to VAX, and their gaussian spacial distribution sigmas in the

relevant dimension are determined. These are related to the beam sigma matrix at the screen by $\sigma_{11} = \sigma_x^2$. MATLAB

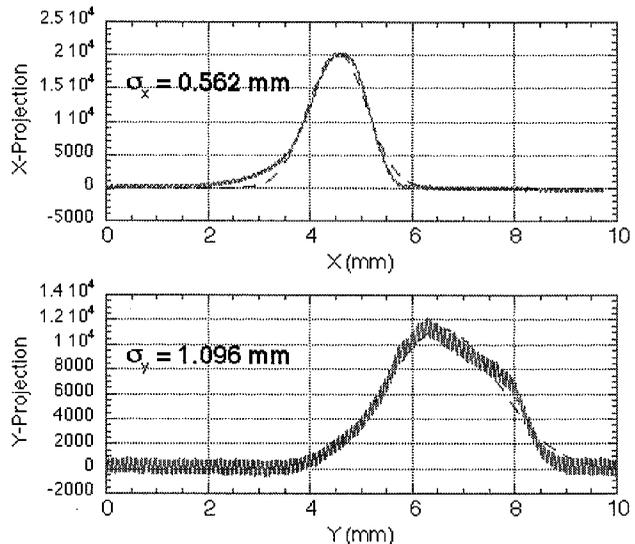


Figure 6. Projections and gaussian fits (dashed).

then reads in the quadrupole name and field values from the CORRELATIONS PLOT output and gets the transfer matrix between the quadrupole and the profile monitor from the online database, as well as the beam energy. A parabola is fit to a plot of σ_x^2 vs. quadrupole strength. From its three coefficients and the transfer matrix, we can determine the 2×2 sigma matrix at the quadrupole. The emittance and TWISS parameters then follow from $\epsilon = \sqrt{\det \sigma}$, $\beta = \sigma_{11} / \sqrt{\det \sigma}$, and $\alpha = -\sigma_{12} / \sqrt{\det \sigma}$. Using further transfer matrix information from our model, we can "swim" this beam ellipse upstream and calculate the mismatch at the accelerator input, characterized by

$$B_{\text{mag}} = \frac{1}{2} \left[\frac{\beta^*}{\beta} + \frac{\beta}{\beta^*} + \left(\alpha \sqrt{\frac{\beta^*}{\beta}} - \alpha^* \sqrt{\frac{\beta}{\beta^*}} \right)^2 \right],$$

where the asterisked parameters are the measured values and the others the design values.

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