Beam Structure and Transverse Emittance Studies of High-Energy Ion Beams*

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Abstract

A visual diagnostic technique has been developed to monitor and study ion-beam structure, shape, and size along a transport line. In this technique, a commercially available fluorescent screen is used in conjunction with a video camera. The visual representation of the beam structure is digitized, enhanced through false-color coding, and displayed on a TV monitor for on-line viewing. The digitized information is stored for further off-line processing (e.g., extraction of beam profiles). An optional wire grid placed upstream of the fluor screen adds the capability of measuring transverse emittance (or angular spread). This technique allows real-time observation of the beam response to parameter changes (e.g., evolution of the beam structure, shifts in the beam intensity at various spatial locations within the beam perimeter, and shifts in the beam center and position).

I. INTRODUCTION

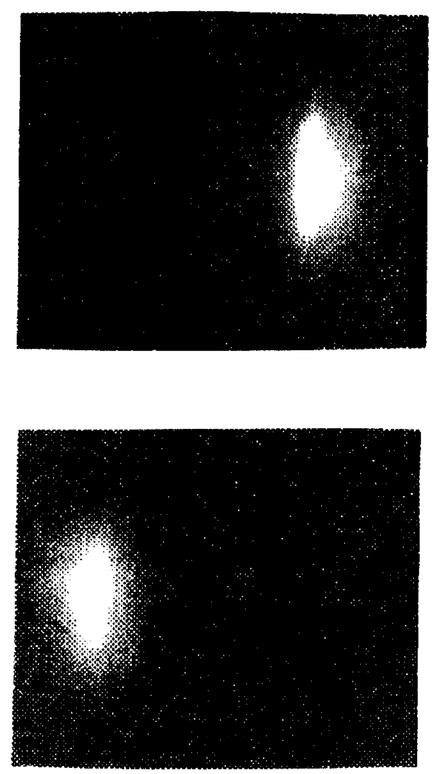
In order to demonstrate the effectiveness of this visual diagnostic technique, the system was placed at the output of the Accelerator Test Stand (ATS) funnel experiment [1,2,3]. The 425-MHz, 5-MeV H^- beam from the ATS drift-tube linac (DTL) was guided through four bunchers, two bends in the horizontal plane, an rf deflector, and a dipole sweep magnet. The diagnostic fluor was placed downstream of the rf deflector and the sweep magnet. Since the power density of the full 25-mA, 5-MeV H^- beam of was too high for direct observation, a laser pulse of 50- to 100-ns width was initially used to neutralize a segment of the beam upstream of the sweep magnet, while the remaining H^- beam was deflected into a Faraday cup. Thus, only the neutralized portion of the beam would reach the fluor for observation.

II. DESCRIPTION OF THE EXPERIMENT

We used a CCD Cohu camera (model # 4800) in conjunction with a 200-mm Nikkor lens to monitor the emitted light. The output of the video camera was digitized and stored in the computer for detailed analysis.

A laser pulse of 50-ns width was used to neutralize a segment of the beam upstream of the sweep magnet. However, since we could not trigger the camera externally, light was collected for the entire 50 μs of ATS beam pulse length. As a result, the laser-neutralized beam signal (50-ns duration) was completely washed out by the background neutrals. If these background neutrals originated in the localized drift region between the rf deflector and the bending magnet, one would expect them to carry the full signature of the output beam. This assumption is based on the fact that the ion beam (along with its associated neutrals) reaches the rf deflector at a steep angle, so that the neutrals strike the deflector housing and disperse while the ions are bent into the deflector by a quadrupole magnet at its entrance. For this reason, we decided to investigate the background neutrals that gave us a strong signal when integrated over the 50-μs ATS pulse duration.

Figure 1 shows the background neutral beam spot with the deflector off and with it on. The well-confined background neutral beam spot supports the assumption that these neutrals are created only in the last segment of the beam path, during the free drift from the deflector to the dipole magnet. Figure 1 also indicates a 2.7 ± 0.4-cm movement of the beam (the error comes from the uncertainty in locating the center of the beam spot). This movement is consistent with the data from the slit and collector that showed H^- beam deflection angle of 36 ± 2 mrad [2]. This deflection angle leads to a 2.9 ± 0.1-cm



(a)

(b)

5 cm

Figure 1. Horizontal beam spot movement with the deflector (a) off and (b) on

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spatial movement of the beam after axial travel of 80 cm between the deflector and the fluor. The good agreement between these two independent measurements, confirms that the observed neutrals have originated in the drift region between the rf deflector and the fluor.

To continue our studies, we placed a wire grid 5 cm upstream of the fluor to measure the beam emittance [4]. Figure 2 shows the beam spot with the superimposed wire shadows. However, because of insufficient spatial resolution resulting from the wide camera field of view, these data could not be further analyzed to extract the emittance information. We continued the experiment by studying the effects of the rf phase of the deflector on the beam. Figure 3 is the optimized beam shape, which was achieved by varying the rf phase of the deflector by 53° with respect to the settings that resulted in the beam spot shown in figure 2. This simple test demonstrates how easily this visual technique can be used to optimize the parameter settings.

In another attempt to obtain emittance measurements, the camera optic was modified to reduce the field of view. The beam spot is shown in figures 4 with the deflector and all the bunchers on, and in figure 5 with them off. Notice the dramatic changes in the beam-spot size and shape. When the bunchers are off, the beam-spot size in the horizontal plane is increased due to beam debunching and dispersion in the bend plane of the funnel. Further analysis was hampered by poor spatial resolution, even though the resolution was significantly improved. Nevertheless, these data further

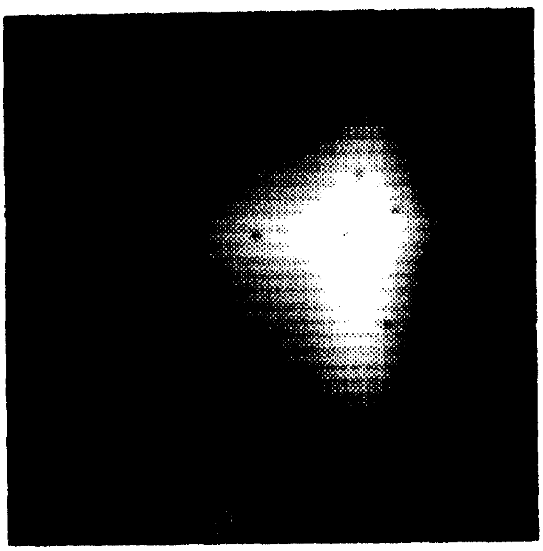

Figure 2. Beam spot and superimposed wire shadows.

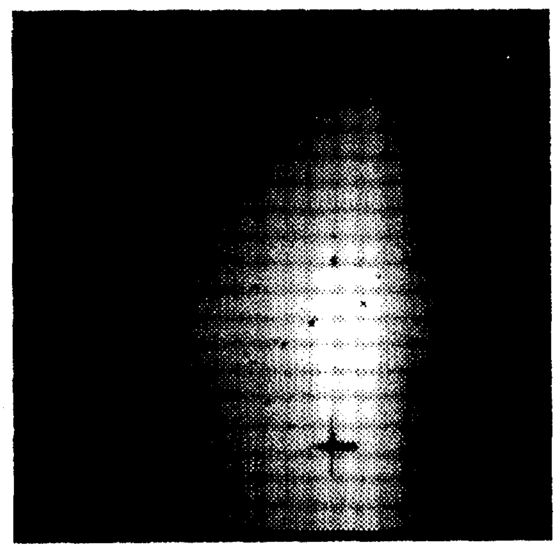

Figure 4. Beam spot with the deflector and all the bunchers on.

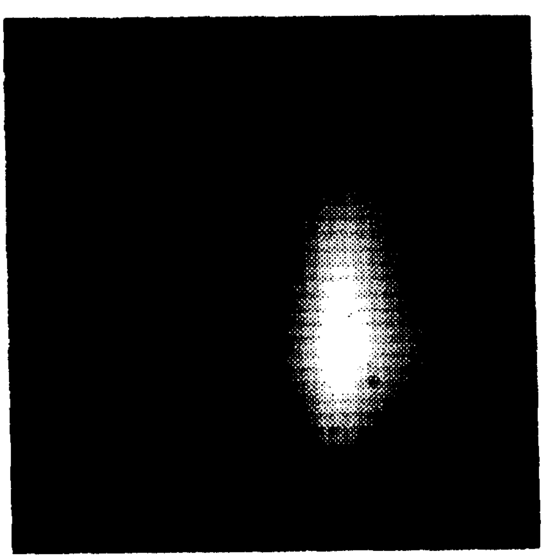

Figure 3. Beam spot at optimized rf phase of the deflector.

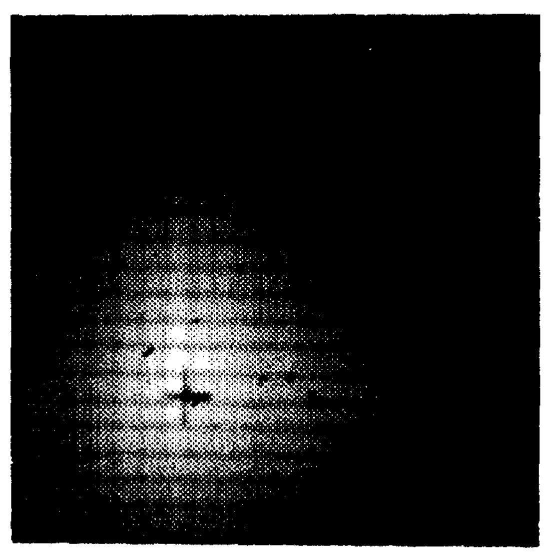

Figure 5. Beam spot with the deflector and all the bunchers off.

emphasize the effectiveness of this diagnostic in detecting the effects of accelerator parameter changes on the beam.

III. FUTURE WORK

We are tailoring our diagnostic technique to measure transverse emittance and beam profile at the output of the 2.5-MeV Ground Test Accelerator Radio-Frequency Quadrupole (GTA RFQ). Unlike the ATS funnel beamline, the GTA beamline is straight and the background neutrals cannot be used to determine H^- beam phase-space. However, the background gas pressure in GTA is at least an order of magnitude lower than that in the ATS and the background neutral signal is expected to be reduced accordingly. Thus, we can laser-neutralize the beam to enhance the signal in the lower-background environment of GTA.

To achieve this objective, we must utilize fast-gated cameras (having external triggering capability) that provide 50-ns beam viewing time (laser neutralization time). In addition, we want to improve the spatial resolution of the experiment. We hope to achieve both goals by acquiring a more sophisticated camera and optic system, that also allows remote control of both focus and aperture. This remote control capability is necessary to operate in the GTA environment.

IV. ACKNOWLEDGEMENT

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V. REFERENCES

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