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TITLE: IMAGESCOPE TO PHOTODIODE BEAM-PROFILE IMAGING SYSTEM

AUTHOR(S): D. D. Chamberlin, J. S. Hollabaugh, and C. J. Stump

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Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

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IMAGESCOPE TO PHOTODIODE BEAM-PROFILE IMAGING SYSTEM*

D. D. Chamberlin,† J. S. Hollabaugh,†† and C. J. Stump, Jr.,†† AT-4, MS H821
Los Alamos National Laboratory, Los Alamos, NM 87545

Summary

Transverse beam-distribution measurements of high-current cw accelerators must be obtained from noninterceptive sensors. For the 100-mA H_2 or D beam of the Fusion Materials Irradiation Test (FMIT)[1,2] accelerator, these transverse properties may be obtained by detecting the visible radiation resulting from beam interactions with residual gas. A system of mirrors, intensified TV cameras, digitizers, and tomographic reconstruction codes has been reported previously.[3,4] This report describes a new technique for sensing and digitizing the light projected transversely from the beam of the FMIT accelerator at Los Alamos National Laboratory.

Figure 1 is a sketch of the main components of the Imagescope to photodiode beam-imaging system. An input lens focuses the beam-profile image onto a bundle of optical fibers that are spatially coherent from end to end. The output end gathers the fibers from the four input legs into a small double-row format. Thus, four different beam-profile images are transferred from this fiber-optic bundle (Imagescope) through a microchannel-plate (MCP) image intensifier with a format arranged so that two linear photodiode arrays (Reticons) receive the intensified images. The photodiode arrays have 512 elements each; thus, each beam profile has a 256-element resolution. An electronic package accepts the electric signal from the photodiodes, digitizes the contribution of each sensitive element, and transmits the digitized profile information over a fiber-optic data link to a memory unit accessible by the CAMAC data-acquisition and processing system. Details of this new beam-profile imaging and digitizing system are presented in the following sections.

Physical Arrangement

Figure 2 shows the prototypic assembly from input lens to digital transmitter. Each of the four input legs is 122 cm long with a bend radius of less than 10 cm. The input ends are shown in various stages of assembly, from exposed fiber ends through lens coupler and inserted lens and on to a stripped lens mounted in the final beamline holder. The final holder is then mounted outside a narrow window on the beampipe within a 3.3-cm axial dimension. The inexpensive commercial lenses were disassembled to remove unnecessary materials and reduce the installed size. Custom-built lenses could allow still further reduction of the installation space requirements. The active area of the fiber bundle in each leg is 7 by 3 mm, with 6-μm individual fiber diameters. The output end of the Imagescope gathers the images from the four legs into two rows of two images each with an active region of 14 by 3 mm for each row.

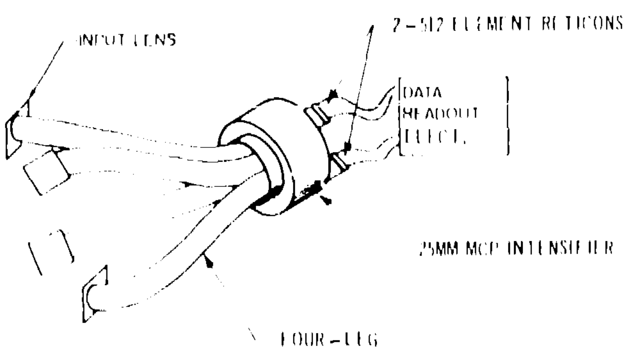

Fig. 1. Sketch of system components showing the coherent bundle fiber optic Imagescope, MCP image intesifier, linear photodiode arrays, and digitizing electronics package.

The output format of the Imagescope was chosen to fit in the active area of the 25-mm MCP intensifier. The MCP intensifier has a gain of up to 30 000, adjustable by the external voltage applied. The resolution of 25 line pairs/mm is the system's limiting resolution. The MCP intensifier is enclosed in the light-tight assembly between the output end of the Imagescope and the two photodiode arrays (Fig. 2). This assembly has provisions for aligning the photodiode arrays with the image regions on the intensifier's exit face. All these units use fiber-optic coupling for maximum efficiency in light transfer.

The linear photodiode arrays were chosen to maximize the active area and are referred to by their commercial name, Reticon. Each has an active area of 12.8 by 2.5 mm, separated into 512 elements along the long dimension. With two beam profiles imaged onto each Reticon, the resolution for each profile is 256 elements corresponding to a beam-view region of roughly 3 cm for this particular application. As seen in Fig. 2, the Reticons are attached to the read-out electronics with ribbon cables, although future versions will use sockets on the circuit boards for the Reticons, to reduce the unamplified signal transmission distance. The use of photodiodes to image a beam has been reported at Chalk River.[5]

The size of the electronic package is unnecessarily large for the version pictured in Fig. 2. Future versions will reduce the package size to roughly 10 by 15 by 20 cm. The Reticons may be cooled by installing them on thermoelectric cooling pads. Voltage control for the gain of the MCP intensifier is accomplished through this electronics package. The digitized output is transmitted over a fiber-optic data link. Note that powering this system with a small battery pack would imply complete electrical isolation with the attendant noise immunity. The overall system now being constructed will encompass four of these units to be placed at longitudinally separated positions on the beamline. This system then will provide input for tomographic reconstruction of the transverse beam-density distribution at any of the four positions or of the transverse emittance distribution in either horizontal or vertical planes.

Data Processing

The integration time for light input to the photodiode elements is selectable, with a tradeoff being made between dark current in the photodiodes, the gain voltage of the MCP intensifier, and the light stop of the input lens. Present usage has a 13-ms integration time and a well-stopped lens for incrased depth of field. Figure 3 outlines the data flow from raw

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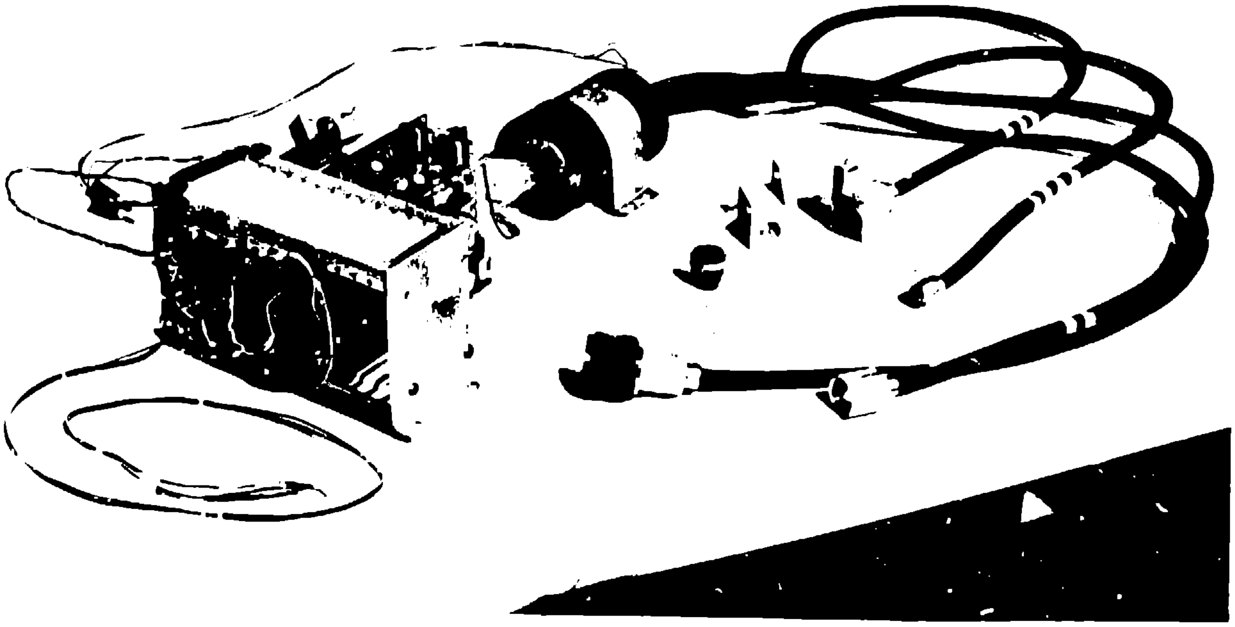

Fig. 2. Photograph of system components. The input ends (with varied lenses and holders) are in the right foreground with the Imagescope legs curving back to the light-tight enclosure of the MCP intensifier. Two ribbon cables emerge from the Reticons at the lower left of that enclosure and connect to the prototypic circuit boards of the readout and digitizing electronics package.

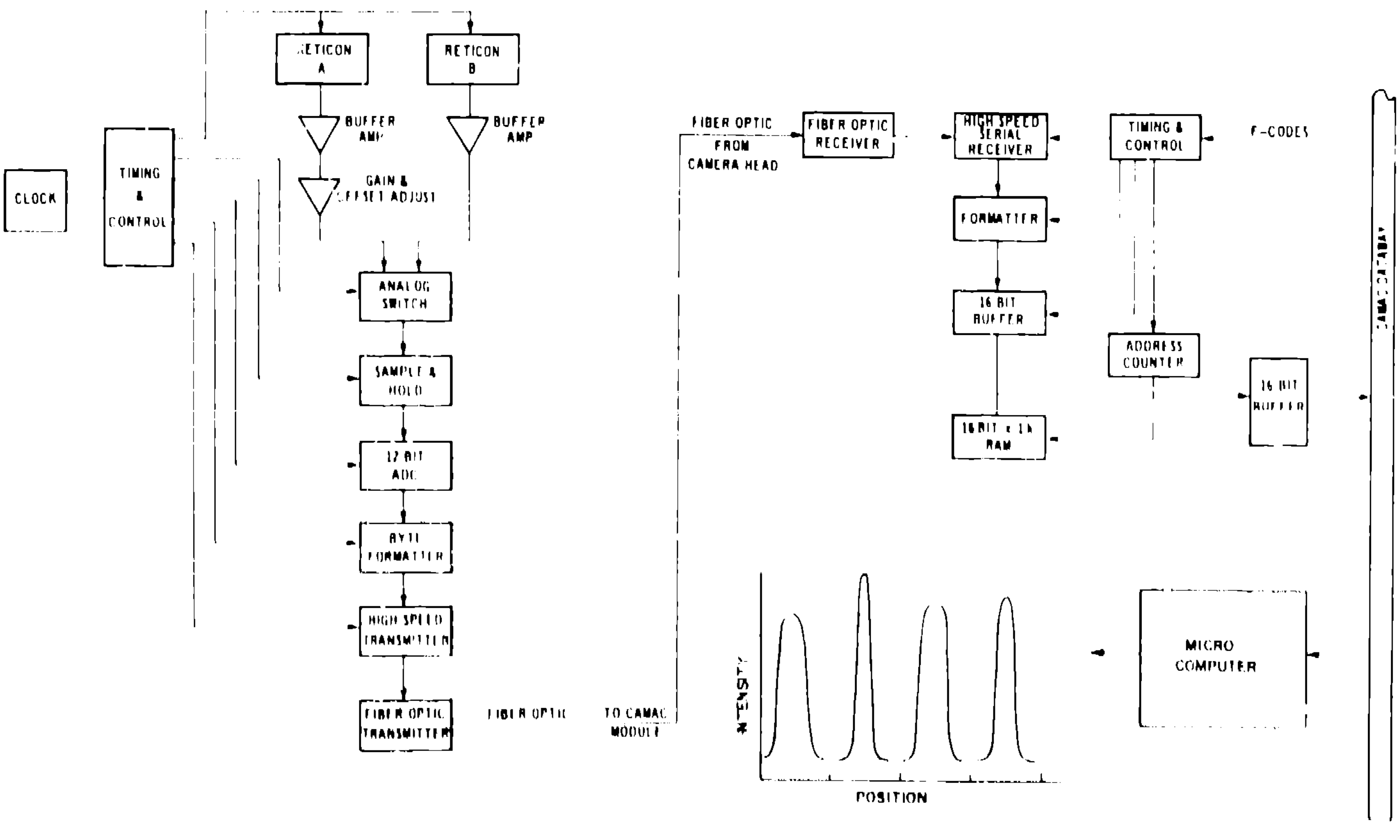

Fig. 3. Block diagram of the data flow and electronics. The left-hand section is physically located on the beamline and connects to the CAMAC module, drawn at the upper right, over the fiber optic link. Also shown is the CAMAC-based microcomputer and a sketch of the output data array.

photodiode current to profile display. Signals from the photodiodes are multiplexed into a 12-bit analogue-to-digital converter (ADC) and then transmitted in serial format over a fiber-optic transmission link. The receiver for this link is mounted in a CAMAC module with a 1024-element memory that is accessible from the CAMAC control system. The data are passed to the CAMAC-resident LSI 11/23 microcomputer that stores them on a magnetic disk. The profiles then may be plotted as shown in Fig. 3 or processed through the tomographic reconstruction coding to provide either transverse spatial or emittance distributions. Not shown in the figure is a digital-to-analogue converter (DAC) located in the CAMAC module that allows real-time presentation of the raw profiles on an oscilloscope as an aid to operator tuning of the beam.

Immediate plans for upgrading the system include mounting the Reticons on the read-out circuit board, adding a clock and microprocessor to the board, and providing an incoming fiber-optic link for control messages. The incoming link with the on-board processor will allow remote control of the MCP gain voltage, of the Reticon integration time, and of the sequencing of read-outs from the several Reticons of the completed system. These increased capabilities include timing of the Reticon light-integration period to correspond with the passage of a 10-ms beam pulse, an operating mode to be used for initial start up of the accelerator.

Conclusion

The system described here is now in use on the FMIT accelerator beamline at Los Alamos. It is working well and is sufficiently flexible in its application to be chosen for making new measurements of the beam at new positions. The cost of the optical components appears to be steadily decreasing. The data quality is expected to be superior to that of the competing TV camera system. The noise immunity also is expected to be a preferred feature of this noninterceptive beam imaging system.

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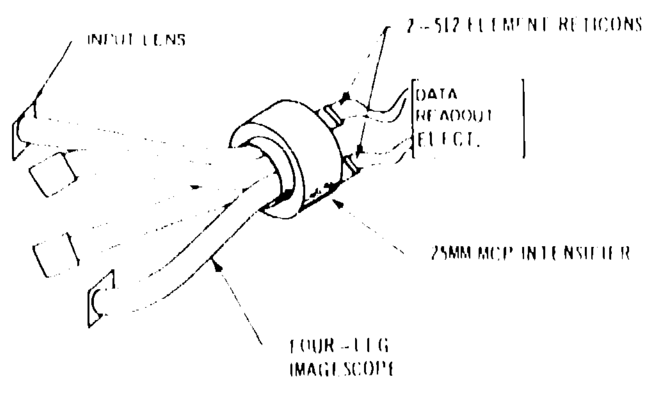

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