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DISCLAIMER

Low Intensity Beam Monitoring Witn An Image-Intensified Scintillator Detector*

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Abstract

We describe a compact, light-weight, image-intensified scintillator detector with video output developed for low-intensity ($< 10^{10}$ particles cm^{-2} sec^{-1}) beam monitoring.

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*Work under the auspices of the U.S. Atomic Energy Commission.

1. INTRODUCTION

Relativistic beams of heavy ions have been accelerated on an improvised basis at the Berkeley Bevatron since 1971. Thus far, moderately intense beams of fully-ionized Carbon, Nitrogen, Oxygen and Neon have been accelerated and extracted. A vigorous program of physics, chemistry, and biomedical experimentation utilizing heavy-ion beams has been initiated. The presently available beam intensities of 10^3 particles cm^{-2} sec^{-1} for Neon to 5×10^7 particles cm^{-2} sec^{-1} for Carbon present a monitoring problem which is not resolved with the system employed in routine high-intensity proton operation in which focussing and steering monitoring is accomplished with zinc sulfide and plastic scintillator detectors. The scintillators are inserted into the beam, viewed by vidicon cameras, and displayed at the main control room console. The scintillator-vidicon system requires a minimum intensity of 10^{10} particles cm^{-2} sec^{-1} for visual detection and is inadequate for heavy-ion beam intensities. Alternatively, monitoring with Polaroid film exposures in the beam line is time-consuming and cumbersome.

The problem was adequately resolved with an image-intensified scintillator-vidicon system originally developed for use at the 184 inch-cyclotron where it replaced a more expensive, less sensitive image orthicon and scintillator system. The light produced by a charged-particle beam incident on a plastic scintillator is imaged on the input faceplate of a commerical three-stage electrostatic image intensifier. The intensifier selected for this application is an RCA 8606 which has 40 mm diameter fiber-optic faceplates.[1] Originally developed for the military, these devices of compact, rugged design provide luminance gains of 5×10^4 and are available at reasonable cost. With image intensification, proton beam intensities as low as 10^5 particles cm^{-2} sec^{-1} are readily detected. Even lower intensities of heavy ion beams are detectable due to their higher charged states. The addition of a variable aperture extends the useful range of this apparatus over six decades of beam intensity.

2. DESCRIPTION

Referring to Figure 1, the beam is incident from the left and passes through a 1 cm thick plastic scintillator which is mounted on the side of a light-tight box. A 10 cm x 8 cm graticule is etched onto the surface of the scintillator and illuminated by four - 4 milliwatt tungstem lamps, one in each corner. Graticule light intensity is variable and adjusted for each aperture setting. The image of the light from the graticule and the beam spot on the scintillator is reflected by a 45° front-surface glass mirror (3 mm thick), minimizing the length of the apparatus in the beam direction and removing the electronic components from the beam line and away from magnetic fields produced by beam optical elements. The image intensifier tube is encased in a 0.6 mm mu-metal shield to further reduce the effects of stray magnetic fields. For applications at the Bevatron where heavy ion beam energies range between 250 MeV/nucleon and 2.1 GeV/nucleon, the scintillator, mirror, and light-tight box have a minimal effect on the beam optical properties. The surplus optics lens system images the scintillator onto the input faceplate of the RCA 8606 image intensifier. An over-all magnification of 0.20 limits the graticule image-size to less than two-thirds of the useful intensifier faceplate diameter. In this manner the intensifier pin-cushion distortion, which is a power function of the image height from the central axis, is reduced. No significant loss of system resolution results because the resolution of the intensifier (900 TV lines) is much higher than that of the vidicon tube (500 TV lines). The lens and aperture system has been designed to compensate the moderate residual pin-cushion distortion. A variable aperture in front of the lens system is powered by a miniature dc gear motor which may be either remotely or manually operated.

The intensifier input face is fiber-optically coupled to the photocathode of the first stage. Each of the three-stages of electrostatic amplification requires 15 kV which is provided by the built-in voltage multiplying network of the tube and a 2800 V - 3 kHz oscillator. The oscillator derives its 6.5 Vdc input from a battery pack of twenty-four 1-1/2 volt cells located at one side of the box. Regulation of the oscillator input voltage is maintained by a Zener diode. The graticule lights are also powered by the battery pack. With the image-intensifier tube and the graticule lights operating at full intensity, battery lifetime is estimated to be approximately 500 hours.

The amplified image is fiber-optically coupled to the rear output faceplate of the RCA 8606. A GE-TE33 video camera with a 25 mm f/1.4 lens views the image, using a 8 mm extension tube.

The complete light-tight portable assembly is depicted in Figures 2 and 3 with the latch-top removed. The system weighs 16 kg, with an overall length of 106 cm and is encased in a wooden box. The vidicon output of a 2.10 GeV/nucleon Carbon beam is shown in Figure 4. Approximate intensity of the beam is 5 x 10^5 particles cm^{-2} sec^{-1}.

3. USES

The original system was developed at the 184 inch cyclotron, but has found diverse uses in the Bevatron heavy-ion facility. The monitor may be positioned horizontally or vertically in the beam line, space permitting. External dimensions have been minimized to permit access into crowded beam lines. The monitor is frequently moved from point-to-point along the beam line as tuning proceeds. Only ac power for the camera and a video output signal cable need be provided.

Biomedical experiments with heavy ion beams often require short exposures with beam spots of various sizes. Rapid changes in quadrupole tuning are achieved with minimum beam time utilizing the image-intensified scintillator.

Besides heavy ion beams, low intensity ($< 10^{10}$ particles cm^{-2} sec^{-1}) beams of protons, deuterons and alphas are frequently requested for experimental investigation. Monitoring and tuning of these beams are similarly facilitated with the image-intensified scintillator.

An alternate use of the intensifier is depicted in Figure 5. With the mirror relocated and with the appropriate mechanical modifications, the monitor is attached to the bezel of a Tektronix 519 oscilloscope. With this arrangement the Accelerator Development group at this laboratory is able to intensify and display single-sweep oscilloscope traces at 500 picoseconds/cm.

REFERENCES

1. RCA Image Tube Marketing, Lancaster, PA.

FIGURE CAPTIONS

Fig. 1 Schematic view of the Apparatus.

Fig. 2 and Fig. 3 Views of the Apparatus with the latch-top removed.

Fig. 4 Vidicon output of ∿ 5 x 10^5 Carbon ions cm^{-2} sec^{-1}. 1 cm x 1 cm graticule scale.

Fig. 5 Alternate use of Apparatus as CRT trace intensifier.

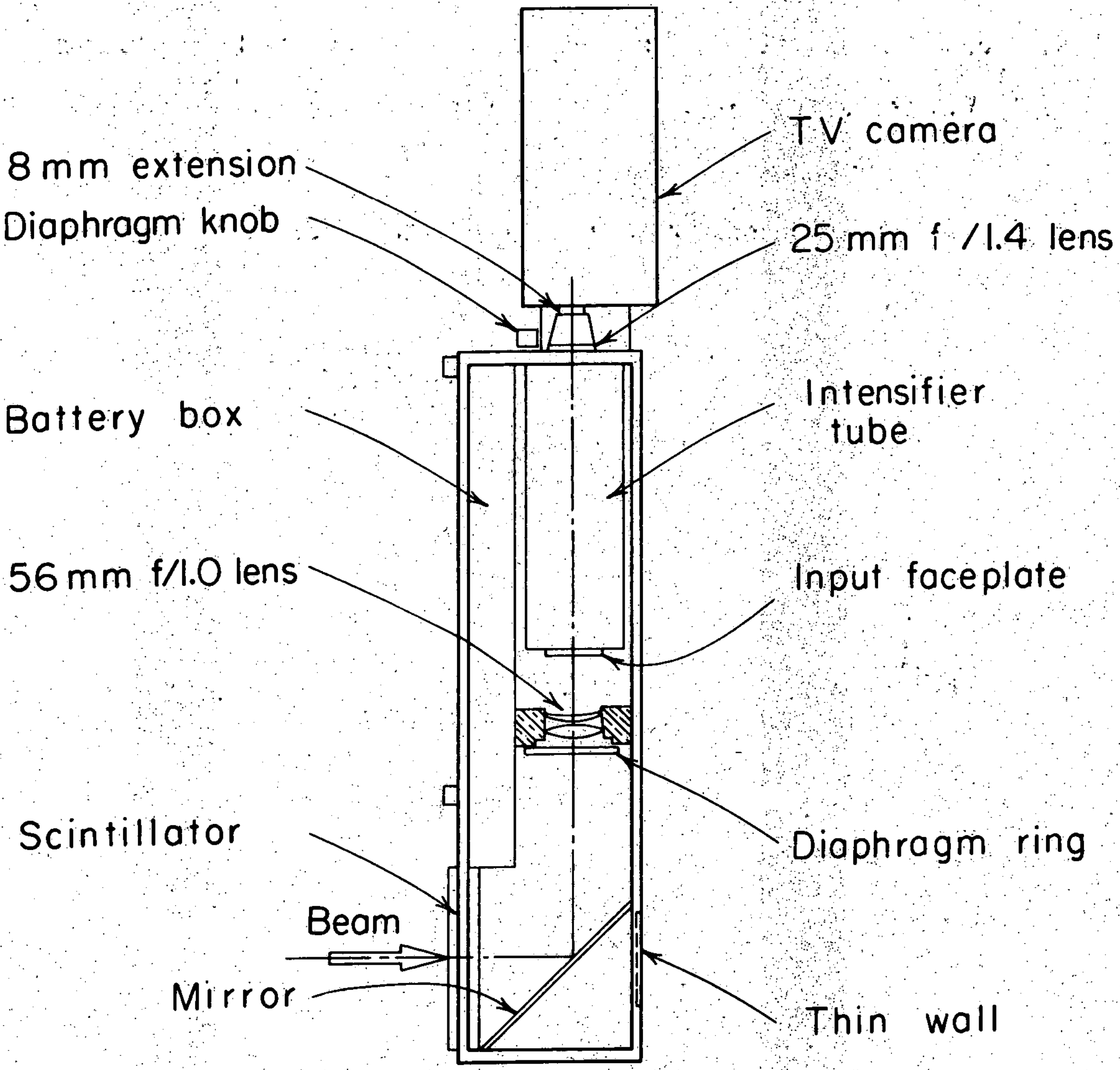

Fig. 1.

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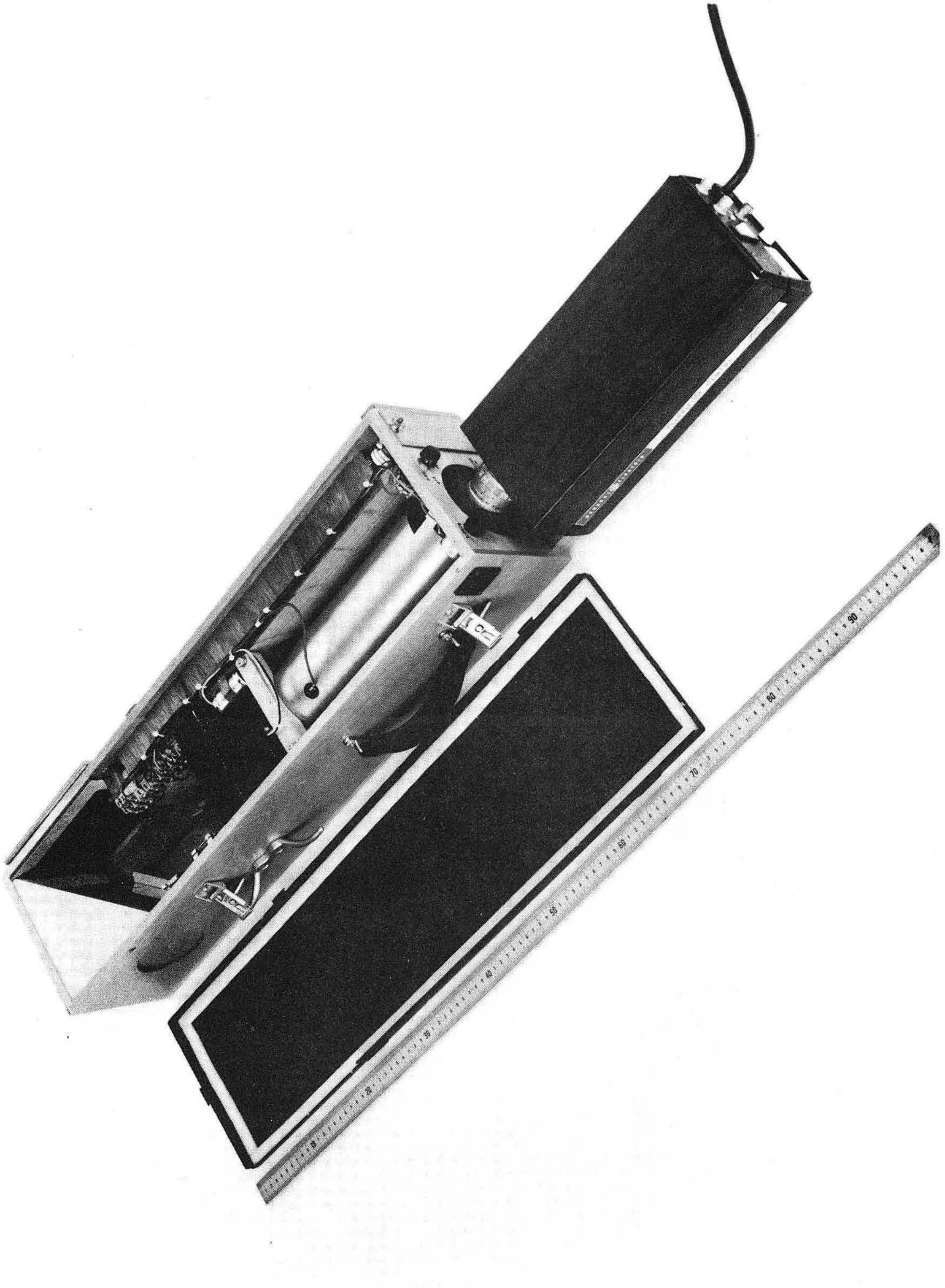

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Fig. 2.

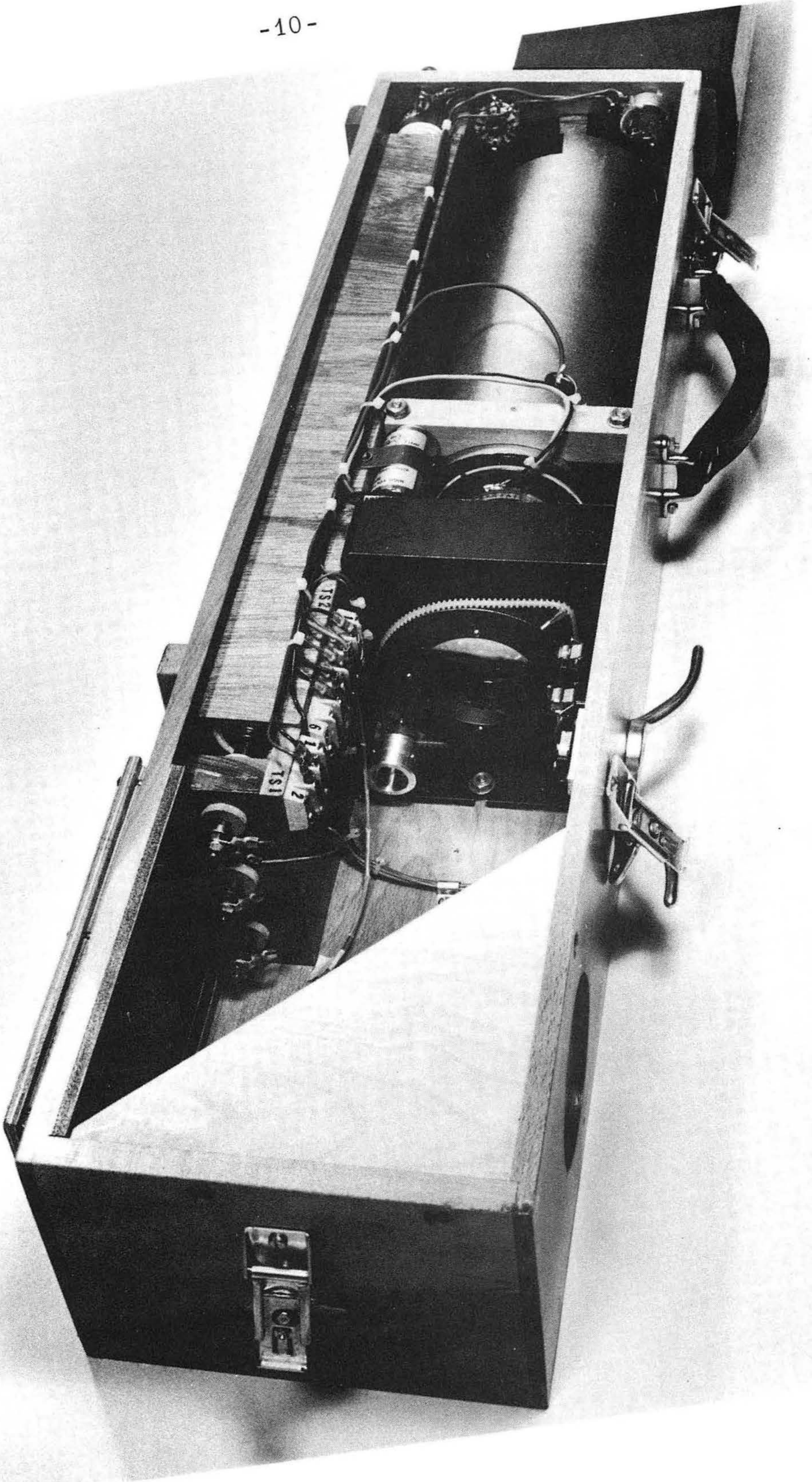

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Fig. 3.

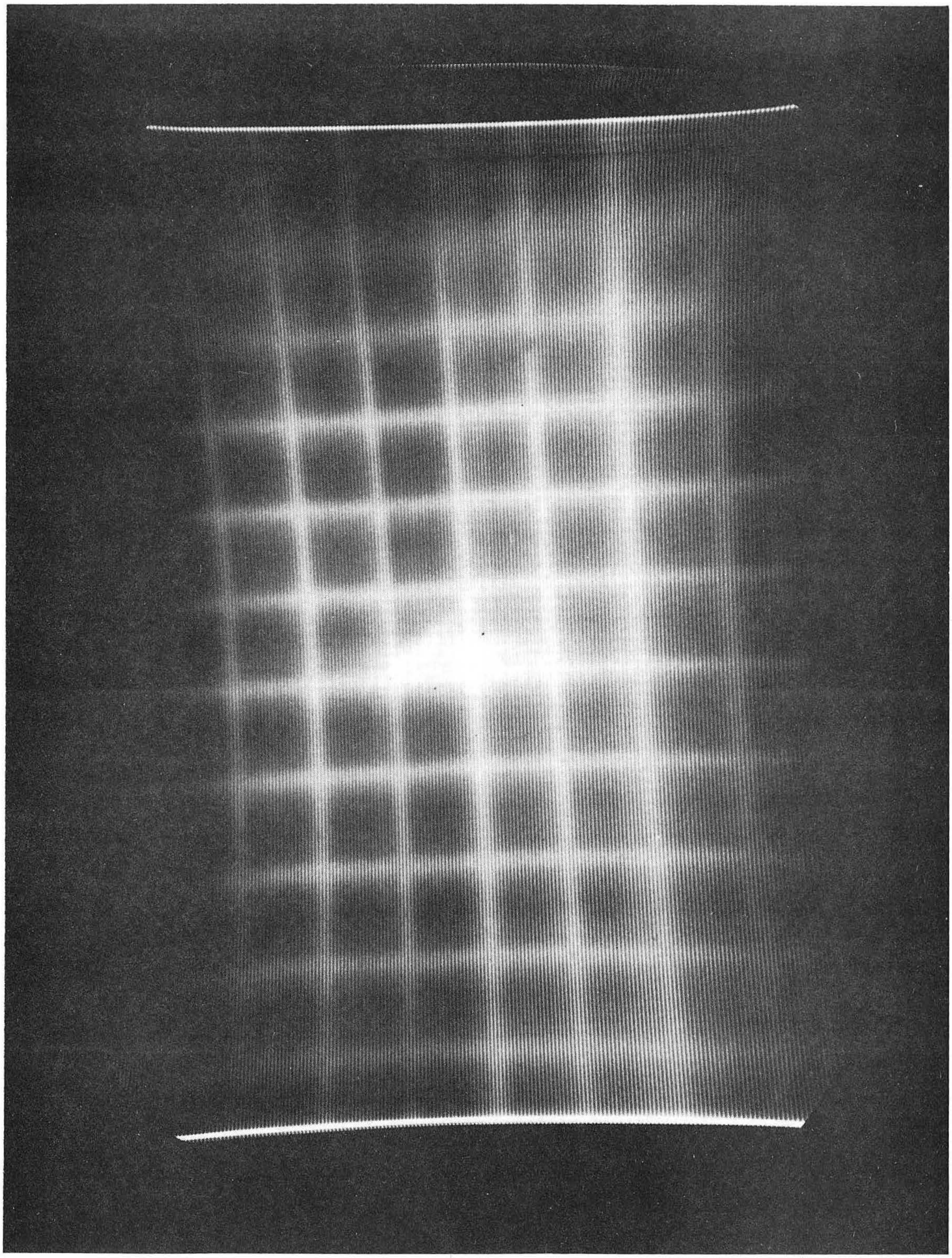

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Fig. 4.

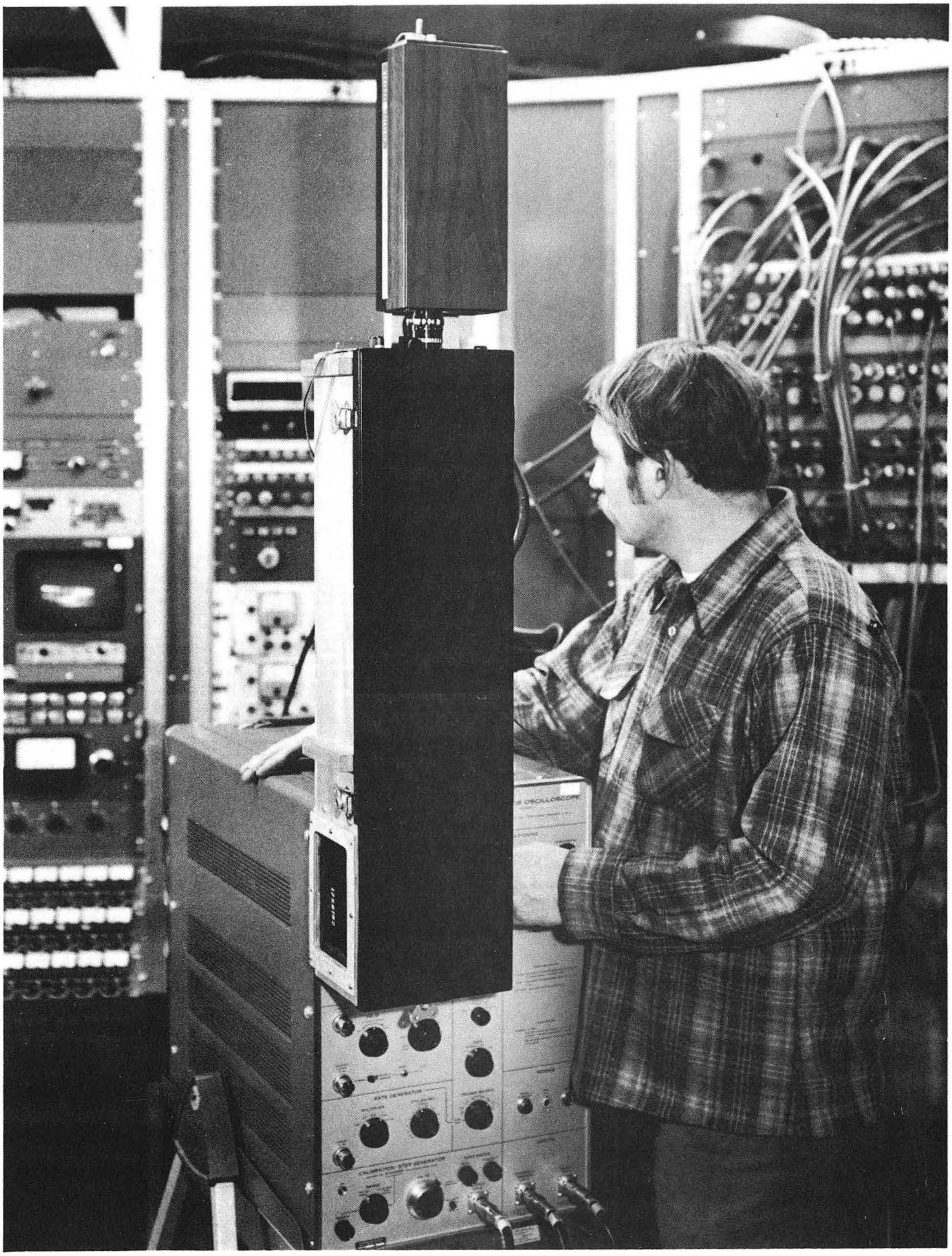

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Fig. 5.

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