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A New Electron Mirror Design

The electron-mirror microscope is a recent addition to the list of laboratory instruments available for magnetics studies. The device is not new. For several years it has been used to view surface irregularities, charges, and contact potentials;[1-3] it is only in the past year that its ability to reveal magnetic phenomena has been discovered and exploited.[4]

The original instrument used for experimental work in this area is an in-line system in which the impinging and returning electron beam remains on the same axis throughout its travel.[1] This system is still in use. The off-axis system, which is the subject of this short communication, will be explained, and micrographs of very high recording densities resolved with this instrument will be presented.

Principle of Operation

If an electron beam passes close to a magnetic surface, any magnetic field above the surface, such as that of a bit of recorded information, will influence the path of the beam.

In any axially symmetric system (e.g., a cathode-ray tube) an electron mirror can be formed if an axial electrode (the faceplate) is held at a negative potential with respect to the cathode. The electric field so produced results in a surface of zero potential which extends across the tube axis at a distance from the mirror electrode, the exact distance depending on the mirror potential.

An electron beam, upon entering the mirror area, penetrates the mirror field to this zero-potential surface. Here its axial velocity approaches zero, and it is reaccelerated in the opposite direction. The exit path will be a function of the incoming trajectory and the electric-field configuration. If the zero-potential or turn-around point is adjusted so that the beam traverses a magnetic fringe-field of sufficient intensity near the object surface, the returning electron paths will be modified and a representation of the magnetic field can be seen by viewing a phosphor screen excited by the beam.

Description of the Mirror

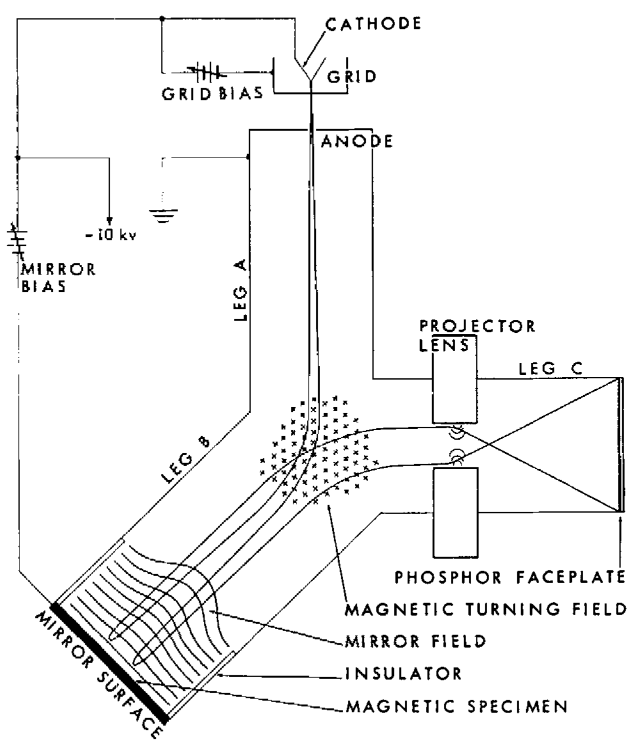
Consider the apparatus shown in Fig. 1. In the center of the device is a uniform magnetic field of the direction shown. As the beam travels down the tube center (Leg A), it traverses a magnetic field which is of sufficient magnitude to turn the beam as shown. The electrons entering the mirror area (Leg B) are reflected back and then traverse the turning field in the opposite direction. Because of the reversal in the direction, the beam is deflected into Leg C, where it strikes a phosphor faceplate for viewing. A short-focal-length focus magnet is placed in the path of the returning beam to provide variable, electron-optical image magnification.

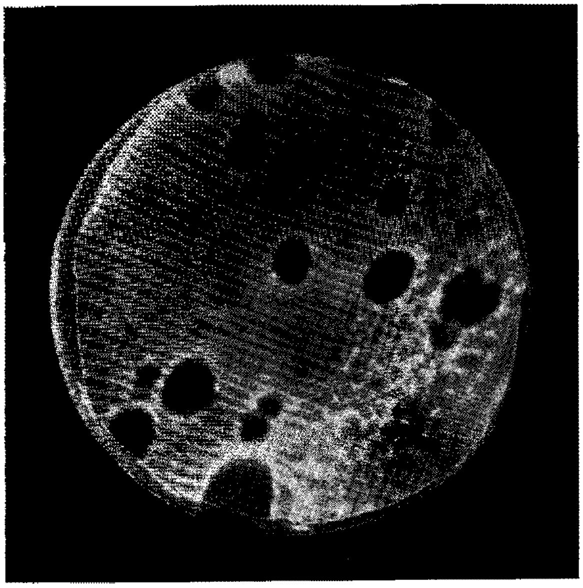
The configuration of the equipotentials forming the mirror field is a result of the system geometry. These equipotentials are the optical equivalent of a plano-concave lens and yield a desirable divergent beam. Initial beam collimation is attained simply by grid focusing.

Experimental Results

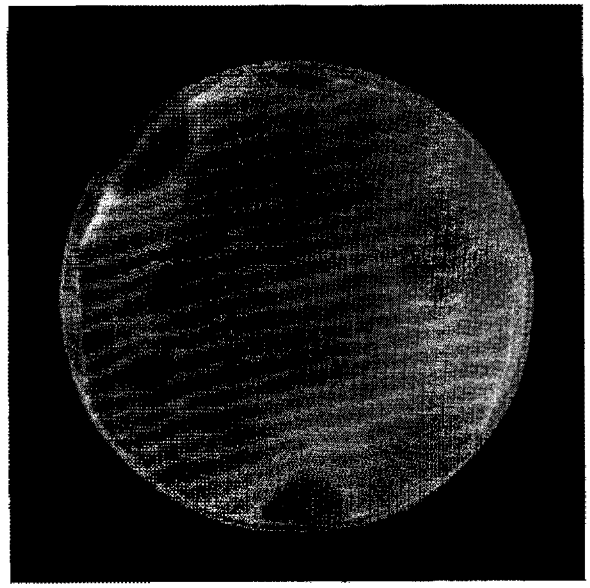
For a demonstration of the excellent resolution capabilities of the mirror, a super-calendered tape was used.

Figure 1 **Schematic diagram of electron mirror microscope.**





(a) 3000 bits/in., 90×



(b) 3000 bits/in., 190×

Figure 2 **Recording on magnetic tape.**

Varying densities of repeated ONES (NRZI) were recorded on separate tracks across the width of the tape. The results of this experiment are shown in Figs. 2 and 3. Figures 2a and 2b are successive magnifications of 3,000 reversals per inch. The disrupted patterns on the right side of Fig. 2a represent the unswitched area between tracks.

Figure 3 is a mirror micrograph of 8,000 reversals per inch. The black areas in this and the preceding figure are not magnetic-field discontinuities but result from the specimen preparation. To ensure a uniform surface of zero potential, the objective must be conductive. This tape was rendered conductive by an over-coating of evaporated gold (less than 1000 A). Because of the mirror microscope's sensitivity to electric-field perturbations, any pinholes in the coating are manifested as disturbances in the image; if they acquire an electrostatic charge as a result of light ion bombardment, they will appear as black holes.

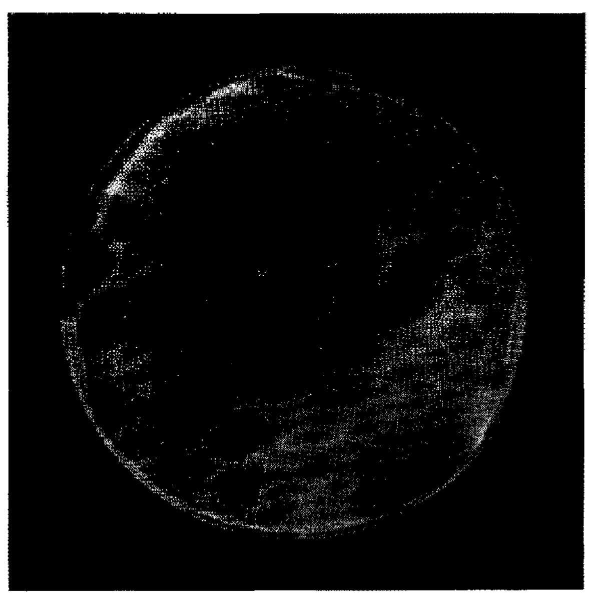
Figures 4a and 4b are successive magnifications of a recording on a thin evaporated film. The film was of a thickness of approximately 9000 A and an H_c of 150 oersteds. Here the advantage of a smooth conductive surface becomes apparent, for the contrast obtained on thin films is excellent.

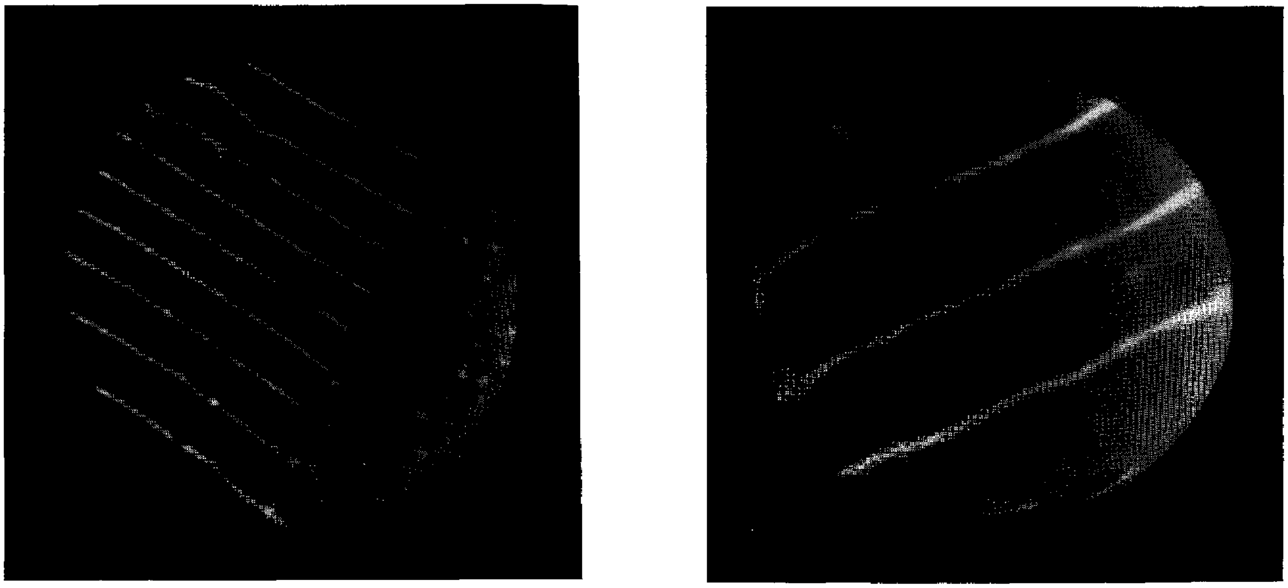
Conclusions

It is intended that the device described will become a useful tool in magnetics research. However, to suggest that the electron mirror will be as efficient as several more conventional methods now available[5-9] would be premature.

The device presently in operation is the third that we have constructed. The first two were in-line versions similar to one mentioned in the literature. The in-line system presents two primary difficulties. First, the visual image is provided by the phosphor coating on the front face of the last accelerating anode. Hence, the final image will be obstructed by the hole in the center of the anode.

Figure 3 **Recording on magnetic tape.** *8000 bits/in., 295×*





(a) 700 bits/in., 80× *(b) 700 bits/in., 220×*

Figure 4 **Recording on Ni-Co evaporated surface.**

Second, variable magnification is complicated because the impinging and returning beams must traverse the same optics.

The off-axis version of the mirror allows easy viewing and photography and a straightforward means of obtaining high magnification. The primary disadvantage of this system is that the introduction of the magnetic turning field entails the introduction of several unwelcome aberrations, because a completely uniform magnetic field is not obtainable. Consequently, this system may have a lower ultimate resolving power than the in-line version. But even the introduction of the magnetic turning field is not without advantages, for it provides a built-in method of positioning the electron beam which makes for greater general flexibility.

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