MEASUREMENT OF RAY DEVIATIONS IN AN OPTICALLY INHOMOGENEOUS FIELD*

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Horman (1) has suggested that holograms can be used for making schlieren photographs. This has been demonstrated experimentally by Tanner (2), by Chau and Horman (3), and by Story, Ballard and Gibbons (4). These authors have pointed out that a transient phenomenon can be captured in hologram form using a pulsed laser and reconstructed at leisure. A large amount of information can be extracted from it by making a variety of adjustments.

It has not been previously pointed out that the hologram can be used to measure the angles through which particular rays are deviated in passing through an optically inhomogeneous field. Without the use of holography it would be possible to make this measurement only for static systems. Thus, laser holography can be combined with shadowgraphic, schlieren and interferometric techniques to provide a more detailed study of the field than has ever before been possible.

The method treated here utilizes an image hologram; i. e., the image of the field is formed on a photographic plate which is also illuminated with a reference beam as in standard holography (5,6,7). Reconstruction of the hologram provides a readout in which one can select a particular element of area on the image of the field and determine both the angle and the direction of deviation of rays passing through the corresponding portion of the field.

The experimental apparatus for recording a hologram of the optically inhomogeneous field in shown in Fig. 1. For the purpose of testing the feasibility of the technique, the dynamic system was replaced by a static object, O. The object used was a microscope slide that previously had been melted enough to cause the deviation of light rays passing through it. The perforated screen, S, was used to produce a number of pencils of light that could be used to identify particular elements of area of the object. This screen was an opaque plate in which a square matrix of 1 mm holes was drilled. The parallel laser light, I, illuminated this screen. Some of the pencils of light thus created were refracted by the object, O. Others were allowed to miss the object in order to define a coordinate system. The imaging lens, L, brought the pencils of light back to their original relative position in forming the image of the field on the film plate, H. The image had unit magnification. A carrier beam, C, intercepted the information beam, I, on the photographic emulsion. The film plate was mounted such that (after developing) it could be returned exactly to its original position so that the relationship between the imaging lens and hologram could be maintained.

The optical system used for reconstruction of the hologram made use of the principle of reversibility to eliminate the effect of the lens. The system is shown in Fig. 2. The hologram, H, is illuminated from the back by coherent light, P, which is parallel to the original carrier beam. The hologram splits the light into a zero order beam, Z, which is trapped at the light trap, T, a virtual first order image which is not used, and a real first order image, R, which is used in making the reconstruction. The rays associated with the real image follow (in reverse) the path of the rays that produced the hologram. Because of the reversibility of light rays and the fixed relationship between P, H, and L, these rays retrace the path of the original rays through the system and form a real image of the object at the position at which the object existed originally.

In making this measurement it is convenient to use a mirror, M, to intercept the reconstructed rays and direct them along an unobstructed path such that a long lever arm is produced. This lever arm increases the accuracy of measuring the deflection at the readout film plate, F.

The measurement of the deflection was made by the use of a reference diagram. The reference diagram was prepared using only the parallel laser light, I, the screen, S, and the object, O, of Fig. 1, together with a piece of paper which was placed at the proper distance from the object. The marks representing the pencils of light that missed the object were superimposed on the corresponding spots on the film plate. These marks established the coordinate system with reference to which the deviations (both holographic and nonholographic) were measured. The angular deviations are calculated directly from these measured distances and the distance from the object (or its image) to the reference diagram (or film plate).

The unsophisticated apparatus used for this preliminary study gave results that were in error by an average of about 5%. Work is continuing on the development of more sophisticated apparatus and on methods of utilizing ray-deviation data.

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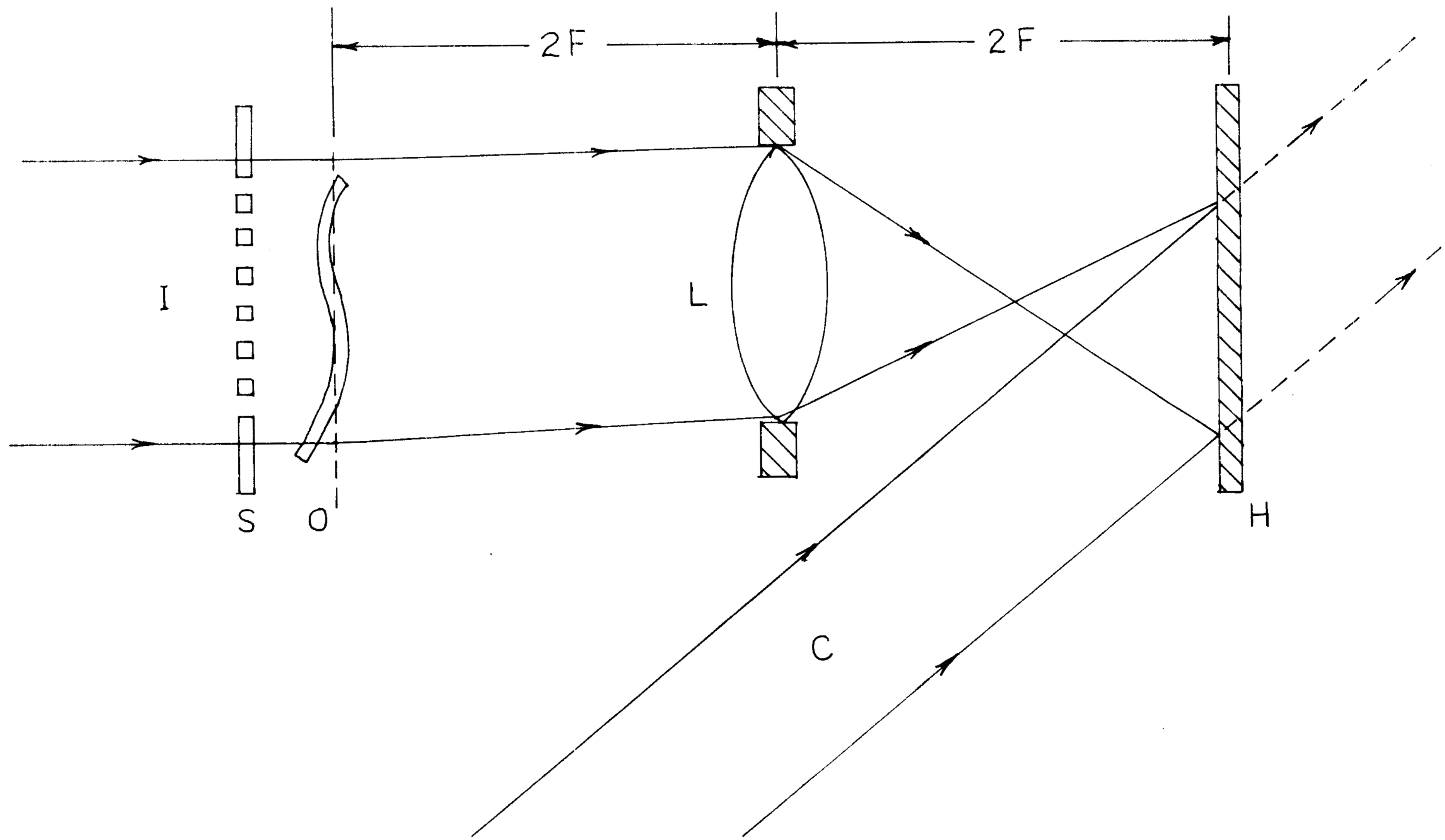

Figure 1

Experimental Apparatus

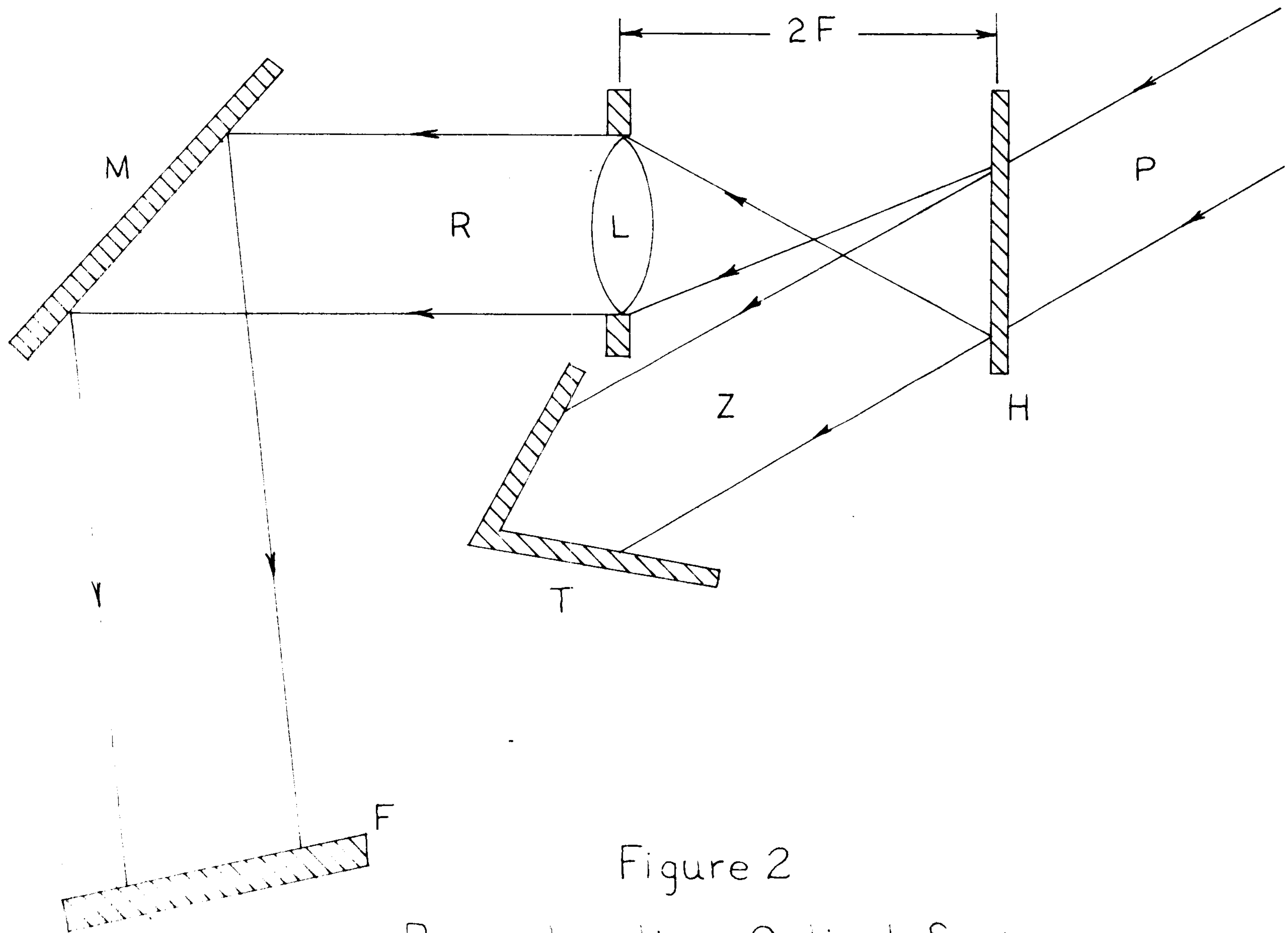

Figure 2

Reconstruction Optical System