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FOUR EXPOSURE HOLOGRAPHY SYSTEM

L. P. Mix
R. W. Kessler

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FOUR EXPOSURE HOLOGRAPHY SYSTEM*

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L. P. Mix and R. W. Kessler
Sandia Laboratories, Albuquerque, New Mexico 87115

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ABSTRACT

A four exposure holographic interferometry system, designed for studying transient phenomena occurring on nanosecond time scales and particularly those associated with relativistic electron beams, is described. This system permits four holographic exposures of a single transient event to be made with independently adjustable interpulse spacings of from 6 to 28 nsec. The system is portable, allows for a wide range of image magnifications, features colinear scene beams to facilitate alignment and large aperture imaging lenses to minimize refraction phenomena. The various design parameters are discussed and typical holograms presented to indicate the types of data which may be obtained.

INTRODUCTION

The development of Q-switched lasers with pulse lengths of a few nanoseconds has permitted holographic interferometry to be applied to the study of a number of transient phenomena. These include measurements of plasma formation and motion in high current field emission diodes,¹ plasma phenomena associated with exploding wires,^{1,2,3} energy deposition profile of electrons in materials,⁴ shock propagation in solids⁵ and the development of instabilities in solids.⁶ In most of these applications only a single measurement during a particular event was possible; to obtain the time development of the phenomena under investigation, exposures had to be made at different times on successive events. In this paper a system is described for making four holographic exposures during a single transient event. Although other systems have been designed which permit four holographic exposures,^{3,7,8} this system has a number of features which make it particularly well suited for pulsed relativistic electron beam (REB) phenomena. These features include a large aperture imaging system to minimize refraction phenomena (probably the single most important feature), colinear scene beams for ease in alignment, easily adjustable interpulse spacings of from 6 to 28 nsec, a wide range of image magnifications, and portability and rapid adaptability to a number of different types of measurements.

SYSTEM DESCRIPTION

To facilitate its use on a number of different experiments, the holographic system is constructed as an easily transported module. The entire system is mounted on a 91 cm x 244 cm (3 ft. x 8 ft) table which rests on a castered support. Along one edge of the table is space for mounting optical rails to support the laser. The remainder of the table is covered by an

enclosure which serves as a camera housing to protect the holographic film from fogging due to surrounding room lights, and to partially shield the enclosed optics from the harsh environment which is typical in REB accelerator facilities.

A schematic of the optical system is shown in Fig. 1. A Korad PTM laser is used for the holographic exposures. The oscillator is operated near threshold with transverse and longitudinal mode selectors. A single K-6 amplifier is operated at sufficient gain to produce ~ 50 mJ in the 4 nsec FWHM output pulse. Since Agfa-Gevaert Scientia 10E75 plates are typically used to record the exposures, satisfactory results could probably be obtained without the amplifier especially if the image size was reduced to some fraction of the total holographic plate area or if pre-exposure or postexposure⁹ were employed.

The laser output is directed into the camera through an aperture and split into scene and reference beams. The reference beam is passed through a delay, D_0 , which accounts for the scene beam excursion from the camera as well as for variations in the length of the folded optics in the imaging system, D_4 . The temporal spacing between exposures is provided by the time-of-flight delays, D_1 , D_2 , and D_3 each of which can range from about 6 to 28 nsec. To facilitate changing these delays, the scene and reference beams are brought near one another following the delay, D_0 , to permit the use of a common mount for both beams. Thus any change in the interpulse spacing is automatically made simultaneously in both the scene and reference beams. The four reference beams, after passing through appropriate delays, are split and expanded onto the film at an angle of 20° to the normal to the film and at an azimuth angle of 45° with respect to adjacent beams thus insuring no interference between the real and vertical images of different exposures.³

FIGURE 1

Schematic of four exposure holography system.

The relation between the scene and reference beams can be visualized more clearly in the photograph of the holographic system shown in Fig. 2. The sliding doors have been removed for clarity. The four mirrors (R) which direct the reference beams to the film can be seen arranged in an arc about the scene beam mirror (S). The reference mirrors are positioned such that the angle between the scene mirror and each of the reference mirrors from the film is 20° . The film is mounted in a holder on the end of the box to the left and is not visible in the photograph. This holder includes a ground glass focusing screen and permits polaroid film and holographic film to be easily interchanged. The scene mirror is mounted on a rail which runs the length of the camera box. By adjusting the position of this mirror (D_4), the experimental region can be brought into sharp focus for a wide range of magnifications. To the right of the photograph, the dual mirror mounts which determine the delay D_1 , D_2 and D_3 can be seen. In the background below the mirrors which direct the scene and reference beams to the film, some of the mirrors used in obtaining the delay D_0 , which can be ~ 40 nsec long, can be seen.

The four scene beams are similarly split but then recombined using beamsplitters to permit them to traverse the measurement region colinearly. Although this reduces their intensity by about four, the total laser intensity required for an exposure is about the same as if each exposure were on a separate plate. The signal-to-noise ratio is reduced however, by about a factor of four. The four colinear scene beams are then expanded if necessary, passed through the experimental region and focused onto the film at normal incidence with either a 50 cm, f/3 or a 35 cm, f/5.6 lens. The delay, D_4 , is adjusted to image the experimental region on the film. Since refraction of the scene beam due to sharp plasma boundaries can be an

FIGURE 2 Photograph of holographic system showing mirrors which relay reference beams (R) and scene beam (S) to holographic plate.

important effect in REB diode plasmas, the ability to image refracted beams is an important advantage of this system over other systems designed for REB experiments.⁸

RESULTS

This system has been used in a number of REB experiments^{10,11,12,13} to date. Typical results are shown in Fig. 3 for diode plasma measurements performed on the Nereus accelerator.¹⁴ The exposures were taken at 16 nsec intervals and the data from two shots combined to provide a more detailed time history. The uniform fringes are reference fringes generated to indicate fractional fringe shifts as well as to indicate whether the shifts were due to plasma or neutral gas. In the second hologram, bending of the reference fringes due to plasma near the cathode is observed. As time progresses plasma is formed on the anode and the two plasmas converge causing a collapse in the diode impedance.¹³

These holograms indicate the type of data obtainable with this holography system and suggest that the reduction in signal-to-noise ratio due to the use of a single plate does not cause significant degradation of the holographic image. This system has proven to be a valuable diagnostic tool in the study of various transient phenomena. The only known limitations of the system are due to (a) the laser pulse length which defines the minimum time scale for investigations and (b) the laser divergence which limits the total path length for any beam to several 10's of meters. This latter limitation suggests that for significantly longer interpulse spacings, the more expensive systems designed previously,^{3,7} or modifications of these systems, are definitely more appropriate.

FIGURE 3

Holograms of plasma formed with diode of a Nereus accelerator at times of 6, 22, 30, 38, and 46 nsec; the anode is above and cathode, below.

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