CLM-P 389

HOLOGRAPHIC INTERFEROMETRY OF COLLIDING LASER PRODUCED PLASMAS

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(Submitted for publication in Physics Letters)

A B S T R A C T

High density plasmas produced by colliding two laser produced carbon plasmas have been investigated interferometrically using holographic techniques. Electron densities remain in the region of 10^{18} cm^{-3} for about 100 ns.

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March 1974

The experimental determination of the electron density distribution in high density plasmas by interferometry has been greatly simplified with the advent of holographic techniques [1] in which the stringent requirements on alignment and quality of optical components are relaxed. In the particular system used here, fourier transform holography [2, 3, 4], the spatial and temporal coherence requirements of the illuminating source are also considerably reduced allowing standard pulsed laser systems to be used. In this letter we describe the use of such a system to examine the high density phase of novel plasmas created by colliding two separate plasmas formed by laser irradiation of a solid surface.

The experimental arrangement used, consisting of scatter plate, lens system and holographic film, is similar to those used in references [3] and [4] except that we use one ruby laser to form the plasma and another ruby laser to expose the holograms after any desired time interval. This second pulse (10 ns wide, 0.5 J) is obtained by pulse clipping the 25 ns pulse from a Korad K1 laser system. The pulse clipping pockel cell is driven electronically [5] avoiding the use of a laser triggered spark gap. Two exposures of the holographic film (Agfa 10E75) are taken, one with and one without plasma. If the film is moved laterally about 100 μm between exposures a series of background fringes is formed. A He-Ne laser is used to reconstruct the developed holograms which are then photographed using Polaroid 410 film. We have found that the best results are obtained using a scatter plate made by smoking a glass plate with ammonium chloride to a density, such that the ratio of directly transmitted to scattered light intensity, measured at the holographic film, is about 5:1.

Fig. 1(a) shows an interferogram obtained 70 ns after the formation of two adjacent laser produced plasmas on a carbon plate target. The two focal spots, separation 5 mm, are formed by splitting the beam from a ruby laser (6 J, 18 ns) with a biprism placed immediately in front of the 200 mm focusing lens. The displacement of the background fringes shows that a region of enhanced electron density occurs in a thin interaction region normal to the target and to the interferogram and midway between the two focal spots. Such a situation has been treated in detail elsewhere [6] for a focal spot separation of 10 mm and the conclusions drawn there explain the present situation. As the two adjacent plasmas expand and collide their densities are sufficiently high for ion-ion binary collisions to prevent interpenetration. The ion energy lost in the direction parallel to a line joining the two focal spots is rapidly converted into thermal energy and this hot plasma rapidly expands in the form of a disc with plane perpendicular to the target plane and the interferogram plane. We have measured the fringe shifts occurring on interferograms taken at various times after the peak of the laser pulse and assume a plasma depth (increasing in time) which is consistent with the ion energy gained along the line of sight. We estimate that at 2.5 mm from the target surface the peak electron density in the centre of the interaction region reaches a value of 3×10^{18} cm^{-3} at t = 30 ns and decays slowly to about 10^{18} cm^{-3} at t = 100 ns.

Fig. 1(b) shows an interferogram of the collision between two opposing laser produced carbon plasmas at t = 50 ns. The carbon rod targets are separated by 6.4 mm and the focal spot intensities are as in the adjacent plasma case. The strong collisional interaction gives rise to a rapid enhancement of density in the centre of the system. As no background fringes have been imposed on this interferogram fractional fringes shifts are less obvious. The continuous dark band is a contour of $\pi/2$ phase shift while within this the reappearance of a bright region indicates a phase shift of π has occurred. In this opposing plasma case ion energy lost in the direction joining the two focal spots is converted into radially directed energy and so the interaction region has the form of a disc viewed edge on. From various interferograms taken we deduce that the peak electron density in the centre of the interaction region reaches 2×10^{18} cm^{-3} at t = 30 ns and decays to about 5×10^{17} at t = 100 ns.

Finally it should be noted that at a given position in the interaction region the peak densities measured in both colliding plasma situations are 4 - 5 times the peak density occurring with only one plasma present. These high density conditions persist for considerably longer than in a single freely expanding plasma (10 - 20 ns).

These results are in agreement with those presented in Ref. 6.

We wish to acknowledge the technical assistance given by Mr P. Moore.

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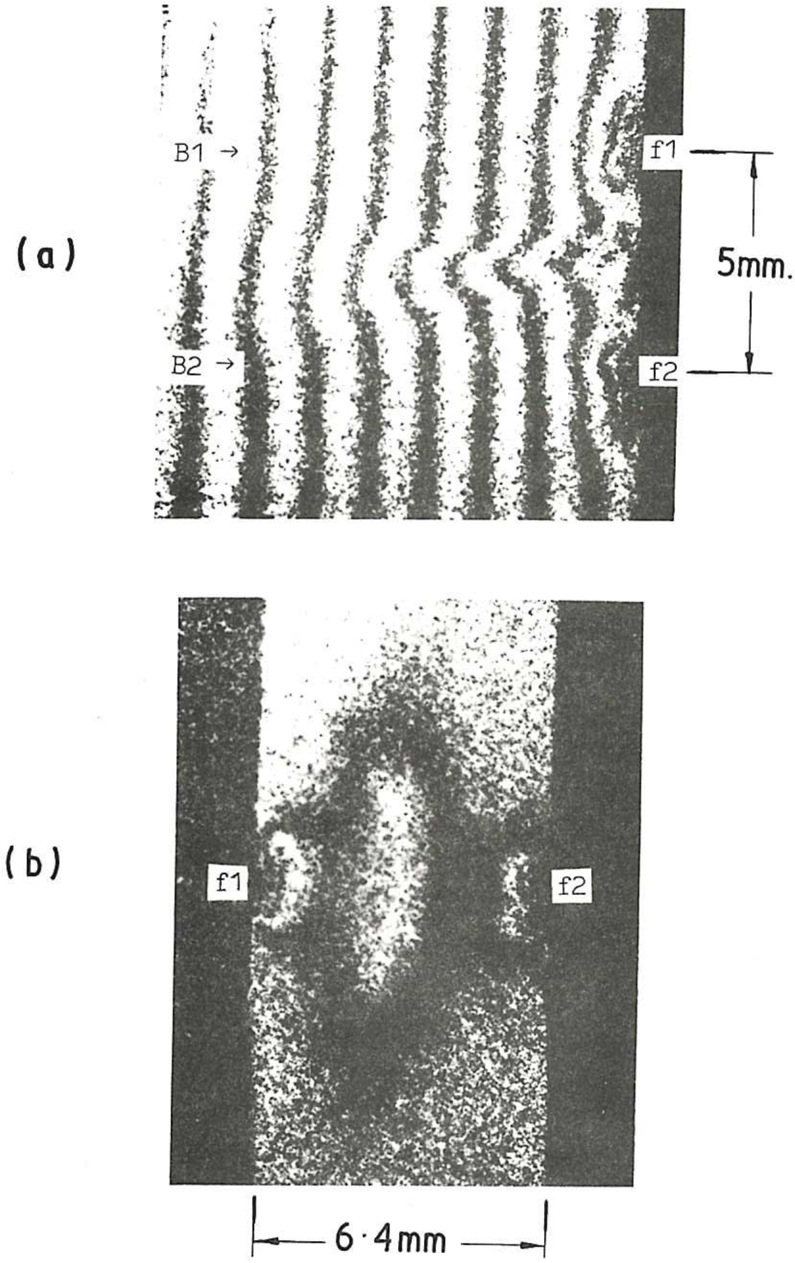

Fig. 1. Interferograms of colliding plasmas.
a) Two adjacent plasmas, separation 5mm.
Exposure time 70 ns after laser pulse.
b) Two opposing plasmas, separation 6.4mm
Exposure time 30 ns after laser pulse.
Beam directions denoted by B1, B2 and corresponding focal spots by f1, f2.