Table-Top Soft X-Ray Laser Interferograms of Dense Laser-Created Plasma

E. Jankowska, E. C. Hammarsten, J. Filevich, M. C. Marconi, and J. J. Rocca

***Abstract*—We report soft X-ray interferograms that illustrate the use of a very compact table-top soft X-ray laser in mapping the electron density evolution of a dense plasma. The spatial density distribution of a point-focus laser-created plasma with $\sim$300 μm dimension was measured for densities up to $\sim 6.5 \times 10^{20}$ cm^{-3}.**

***Index Terms*—Capillary discharge lasers, plasma diagnostics, soft X-ray interferometry, soft X-ray lasers.**

THE DEVELOPMENT of soft X-ray lasers allows the extension of plasma interferometry to previously unreachable plasma parameter regions of high electron densities and large plasma lengths [1]. The advent of compact saturated soft X-ray table-top lasers that can be fired at increased repetition rate [2], [3] in combination with new soft X-ray interferometers [4] now permits the application of this powerful plasma density diagnostics technique to the study of a variety of high-density plasmas. We have previously used a capillary discharge pumped table-top soft X-ray laser operating at 46.9 nm in combination with an amplitude division interferometer to study the evolution of a large-scale line-focus laser-created plasma [4]. This soft X-ray interferometer, that uses diffraction gratings as beam splitters, allows for significantly increased fringe visibility when compared to that obtained with the same laser source and a wavefront division interferometer based on Lloyd's mirror [5]. Interferograms of line-focus laser-created plasmas a few millimeters in length, with densities up to 5×10^{19} cm^{-3} were previously reported.

Herein, we report soft X-ray interferograms that depict the evolution of a point-focus laser-created plasma. The electron density profiles constructed from the interferograms map plasma densities up to $\sim 6.5 \times 10^{20}$ cm^{-3} in regions where the plasma is about 300 μm in diameter. The measurements correspond to Cu plasmas generated by focusing 0.62 J pulses from a Nd:YAG laser onto spots $<$30 μm diameter ($\sim$7 TW/cm^2). The soft X-ray laser used in this experiment is a very compact capillary discharge-pumped Ne-like Ar amplifier that emits at a wavelength of 46.9 nm [2], corresponding to a critical density of $n_c = 5 \times 10^{23}$ cm^{-3}. The measurements

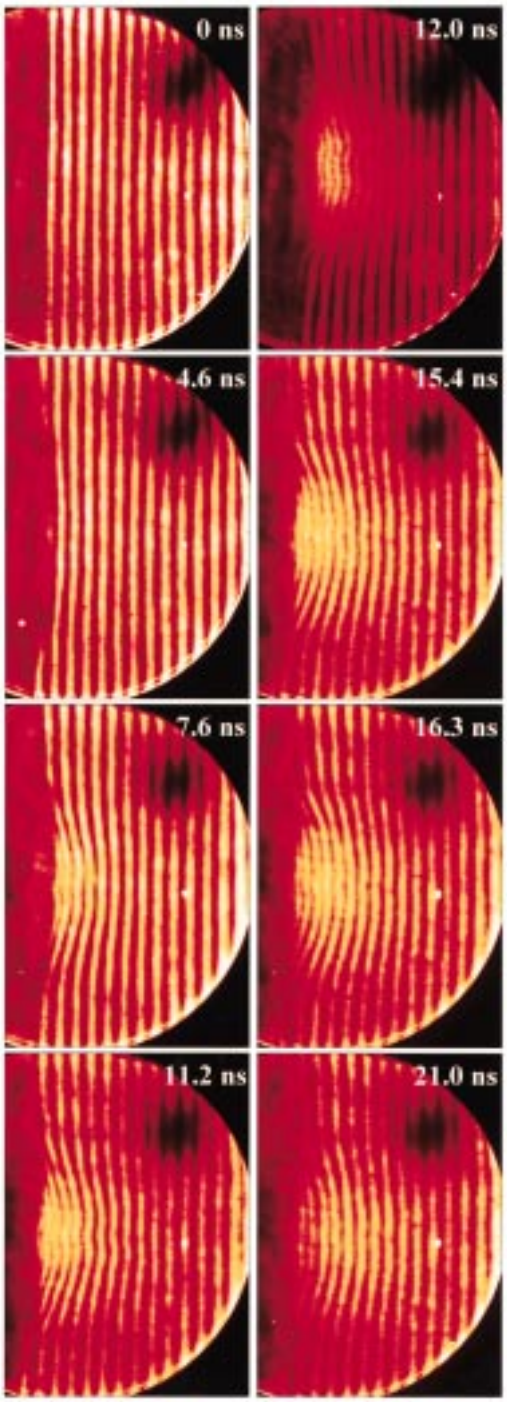

Fig. 1. Series of soft X-ray interferograms depicting the evolution of the laser-created plasma. The times are measured with respect to the initiation of the Nd:YAG laser pulse.

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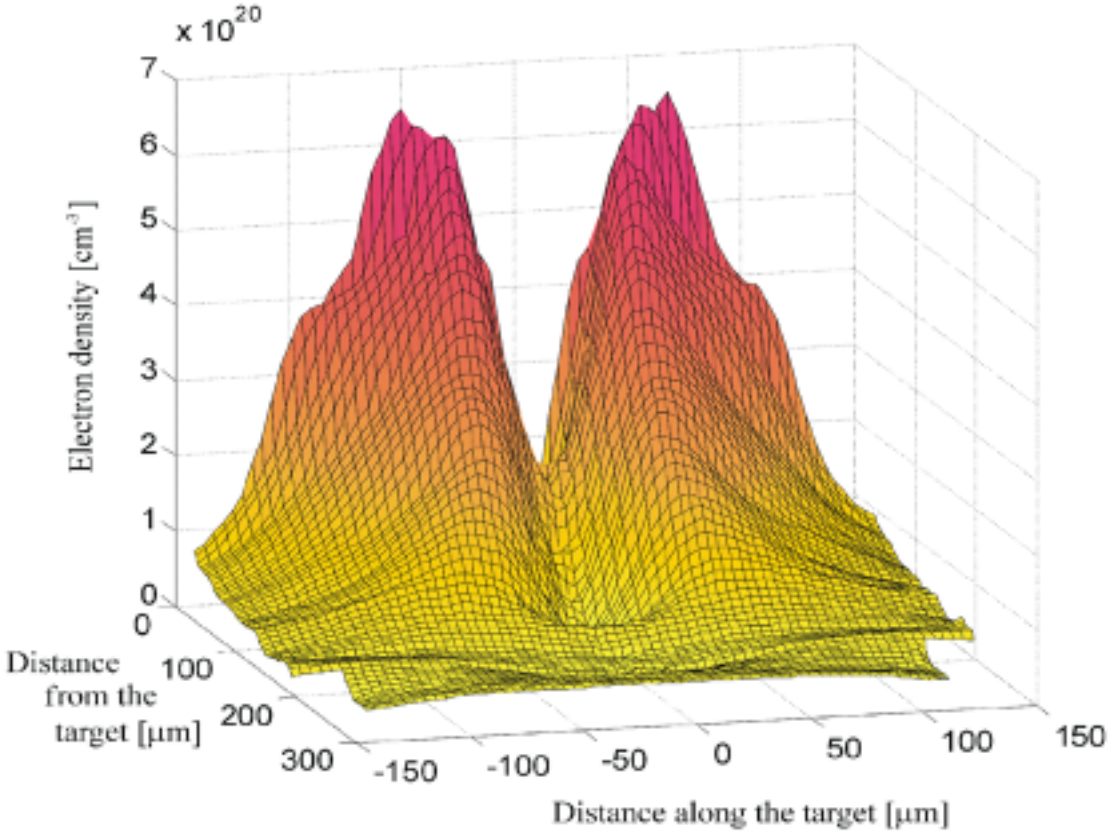

Fig.2. Electron density profile computed by an Abel inversion of the 12.0-ns interferogram.

were conducted using X-ray laser pulses of approximately 0.1 mJ and 1.2 ns. A description of the diffraction grating amplitude division interferometer used in the experiment was presented in a recent publication [4]. The plasma was imaged with 51.2X magnification into a gated soft X-ray sensitive detector composed of a microchannel-plate, a phosphor screen, and a charged coupled device (CCD) array.

Fig. 1 shows a series of interferograms corresponding to fifth shots of the Nd:YAG laser on the same target location, a situation in which the observed plasma emanates from a 300–400-μm-deep hole drilled by the previous four shots. The electron density evolution of the plasma was mapped firing the capillary discharge soft X-ray laser at different time delays with respect to the beginning of the Nd:YAG laser pulse. Abel-inversion [6] of the measured fringe shift reveals electron density distributions such as that in Fig. 2, in which the electron density is plotted as a function of distance from the target. This electron density profile corresponds to an interferogram obtained 12.0 ns after the initiation of the laser pulse, the time at which the electron density is observed to reach a maximum value of $\sim 6.5 \times 10^{20}$ cm^{-3} at a distance of ~ 24 μm from the target plane. A pronounced density depression, caused by the interaction of the high-density Nd:YAG laser beam with the expanding plasma is observed along the propagation axis of the laser beam. Comparison of such measurements with hydrodynamic code simulations can contribute to an improved understanding of the dynamics of high-density plasmas.

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