

1. Introduction

Laser-induced plasma are complex, dynamical systems that are characterized by large N_e (10^{19} cm⁻³), high temperatures (>10 eV), and the rapid propagation of a shockwave. The shockwave is formed through deposition of energy to a point source following tight focusing of a pulsed laser beam, as described by the Taylor-Sedov blast wave model [1,2]. The propagation of the shockwave in the direction of laser incidence is known to be altered due to interactions of the laser with the plasma material [3,4]. Free electrons absorb the laser energy but, due to the presence of the shockwave, sections of higher N_e and temperature exist. This results in a non-isotropic spreading of the energy and asymmetries in the shockwave propagation are noted. The shockwave is imaged using the shadowgraph imaging technique, which directly images regions of higher density as shadows onto collection optics. Correlations between the shockwave and the plasma state are considered by determination of the N_e from Stark broadened 500.14 nm N⁺ and 358.7 nm Al⁺ lines. The N_e is found by analyzing the spectroscopic line widths which are determined by fitting to Voigt profiles.

2. Experiment

Simultaneous measurements of the plasma shockwave and emission spectra were collected following laser-induced optical breakdown on the surface of an Al alloy 6061 target. Breakdown was initiated using a 1064 nm Nd:YAG laser with an 8.6 ns pulse width. A 700 ps pulsed laser was used to back light the plasma for the collection of the shadowgraph images. The spectra were imaged onto the slit of a Princeton Instruments IsoPlane SCT320 spectrometer installed with an 1800 grooves/mm grating to collect spectra in the 200-800 nm wavelength range at systematically varied time delays in the first microsecond following ablation of the Al target sample. Figure 1 shows block diagrams illustrating the shadowgraph and spectroscopic image collection. The shadowgraphs were viewed orthogonally to the spatially and temporally resolved spectra.

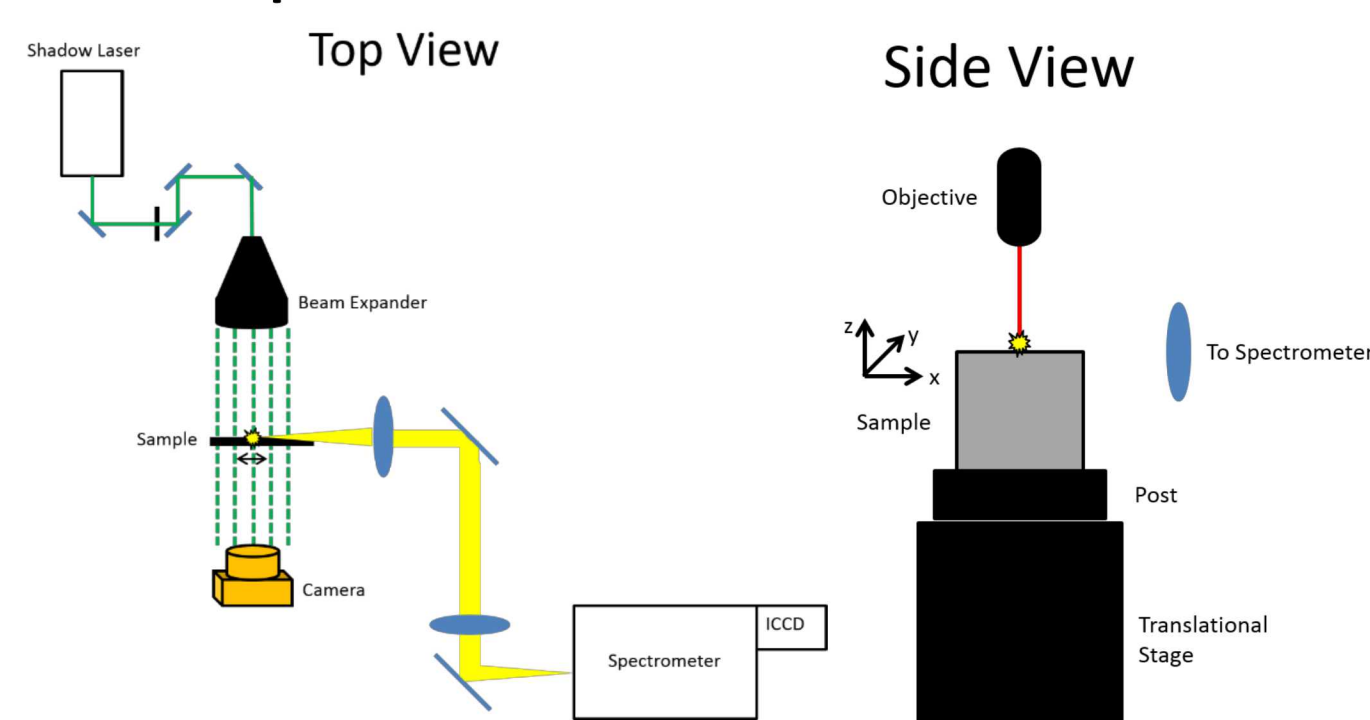


Figure 1: Block Diagram of the experimental apparatus

3. Shadowgraphs

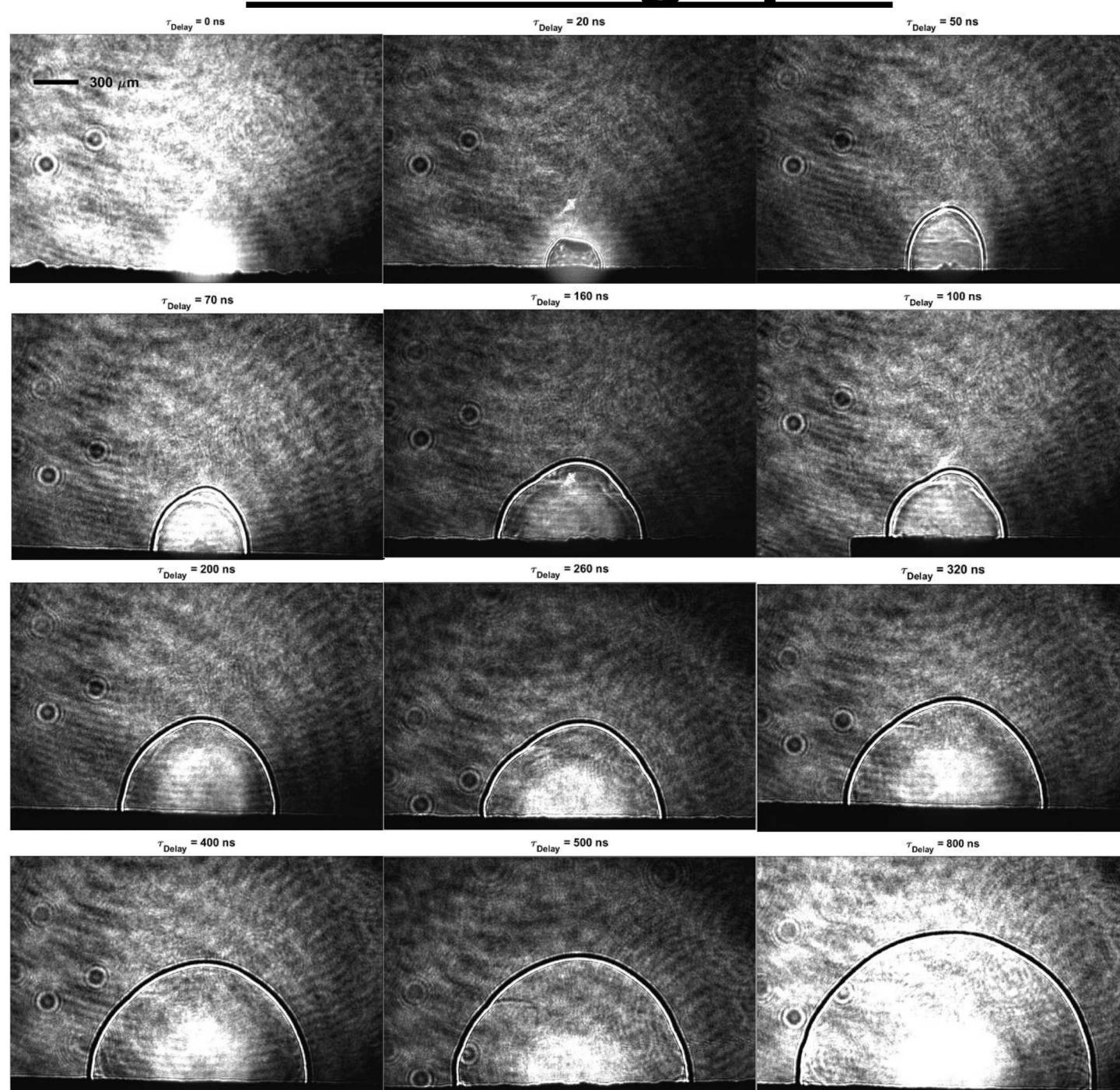


Figure 2: Shadowgraph images collected at selected time delays following laser ablation

4. Results

The shadowgraphs are analyzed to determine the height and width of the shockwave as function of the plasma temporal evolution. This was completed by applying Canny edge detection methods [5]. A sample of the image analysis and the determined widths and heights are depicted in Figure 3.

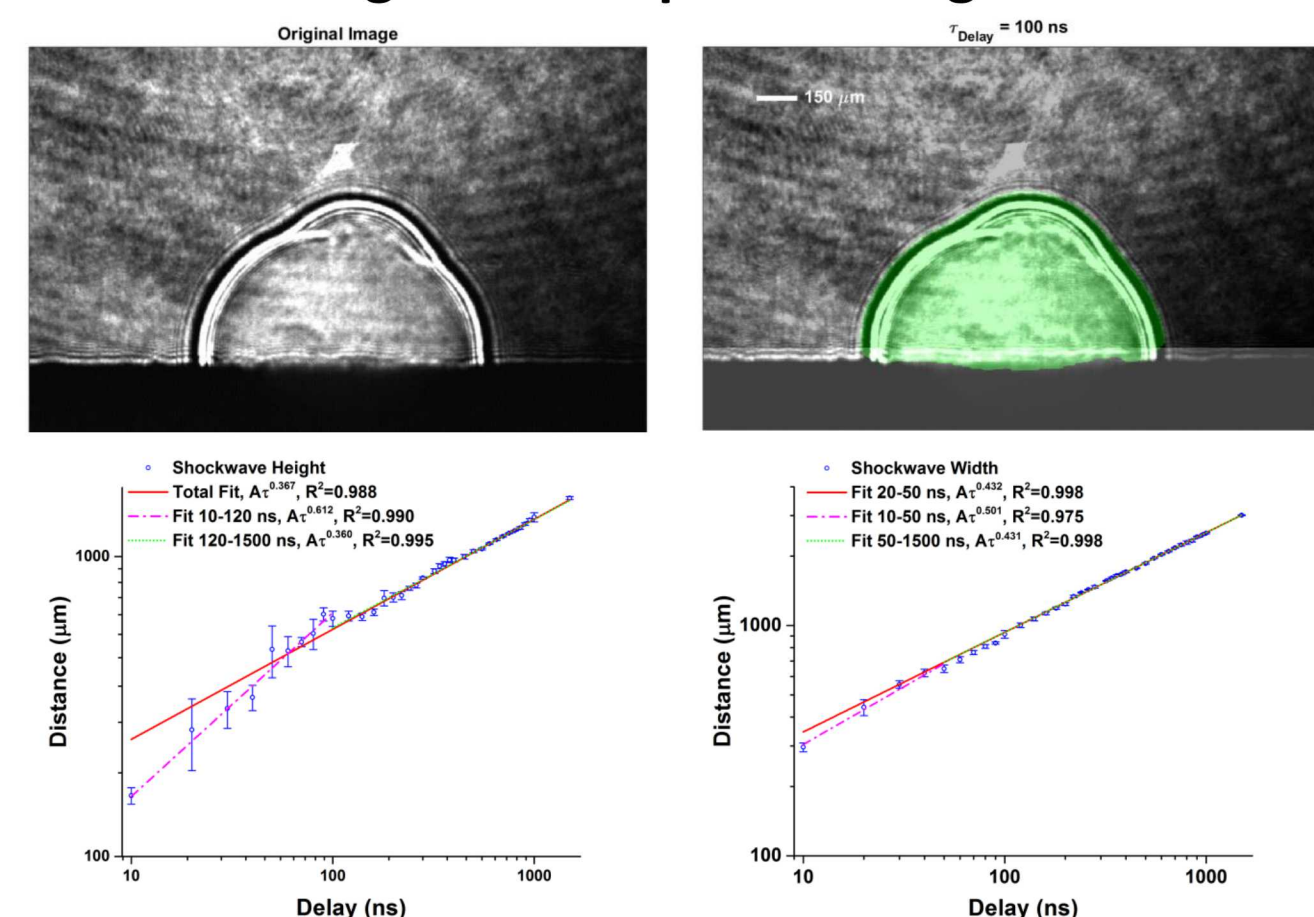


Figure 3: Shockwave analysis results

Under a modified Taylor-Sedov blast model, the shock front expansion geometry is given by

$$R(t) = \xi \left(\frac{E}{\rho} \right)^{1/(n+2)} t^{2/(n+2)} \quad (1)$$

where the temporal exponent determines the geometry of the expansion. The results from Fig. 3 indicate that the width expands spherically. In the first 50 ns, the height expansion is planar in nature and then changes to a spherical expansion. The transition occurs due to the shockwave interaction with the laser pulse. The plasma N_e was determined by fitting Voigt profiles to the measured spectra. Figure 4 shows spatially and temporally resolved N_e results. The N_e found for the 20 ns time delay from the N⁺ line indicates a drop in the N_e due to the shockwave interaction. Compression on the leading edge of the shockwave causes an increase in the electron collisions, creating a higher density plasma.

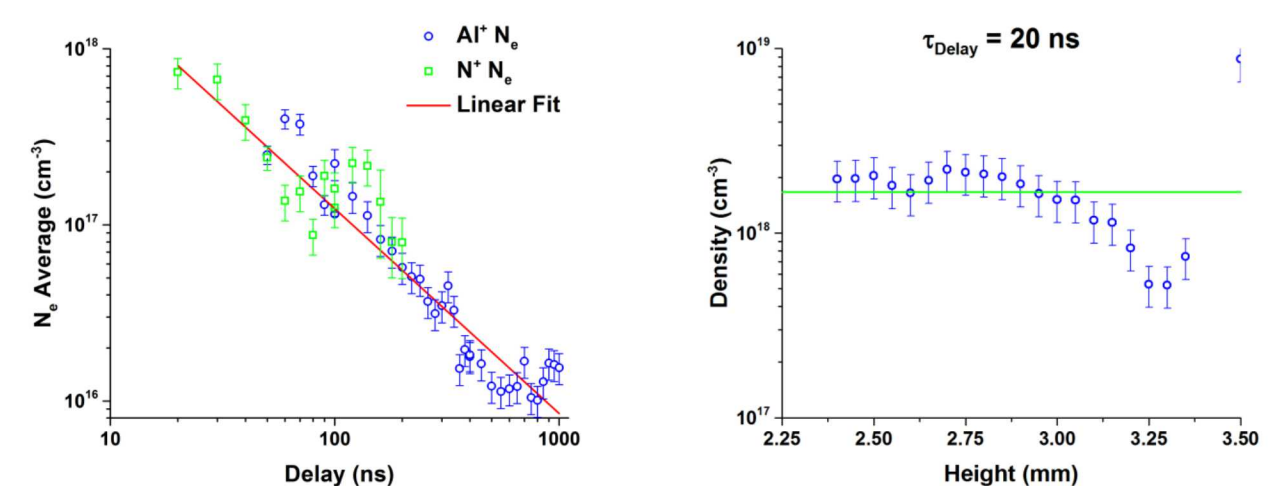


Figure 4: Spatially and temporally resolved N_e results

References

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