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FAST PHOTOGRAPHY OF PLASMA FORMED BY LASER ABLATION OF ALUMINUM

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Abstract. In this paper we present results of the temporal and spatial analysis of laser induced plasma performed by use of ICCD fast photography. The plasma is formed by excimer laser ablation of aluminum target in vacuum, air or different pressures of argon and helium. It is shown how the plasma luminous intensity and duration depends on gas pressure. The obtained time dependence of wave propagation distance is also compared with predictions given by the blast wave and drag-force theory also.

1. INTRODUCTION

The study of plasmas obtained by laser ablation of different materials is of extreme importance in different areas of physics, starting from laser fusion to micro sampling for analytical investigations. Our attention is devoted to applications such as creation of nanocomposites by pulsed laser deposition or matrix assisted pulsed laser evaporation - MAPLE. In these processes the final product depends on properties of the laser (wavelength, energy density, pulse shape and duration, repetition rate, number of pulses), the target (material, rotation speed, angle etc.), the substrate (material, temperature, distance from target) and the surrounding atmosphere (air, vacuum or gas at different pressures) (Chrisey and Hubler 1994, Eason 2007). Among these properties, interaction with a background gas is probably the most important one, so here we demonstrate the use of ICCD fast photography for its study.

2. EXPERIMENT

Experimental setup is presented in Figure 1. The target was set in the center of the 30 cm diameter and 15 cm height, nonmagnetic stainless steel interaction chamber (1) that has eight equally spaced standard KF40 vacuum openings. The vacuum inside chamber ($\sim 10^{-6}$ mbar)was established through electromagnetic valve (2) by use of mechanical (4) and turbo molecular pump (3) and measured with Pirani (5) and ionization gauge (6). Argon or helium was introduced through a needle valve (7) and measured with MKS baratron gauge. As a radiation source an excimer, XeCl (308 nm) laser (8) with a maximum energy of 150 mJ, pulse duration 35 ns and repetition rate of 50 Hz was used. The radiation was focused with a quartz lens (10) on the Al target under angle of 45 degree. In this way an energy density greater than 1 J/mm2 was obtained and plasma formed. The position of the target and ICCD camera (Andor DH734) (11) was adjusted using He-Ne laser (9). In order to obtain a more reliable data the target was mounted on a rotational vacuum feedthrough and rotated by use of a DC motor (12).

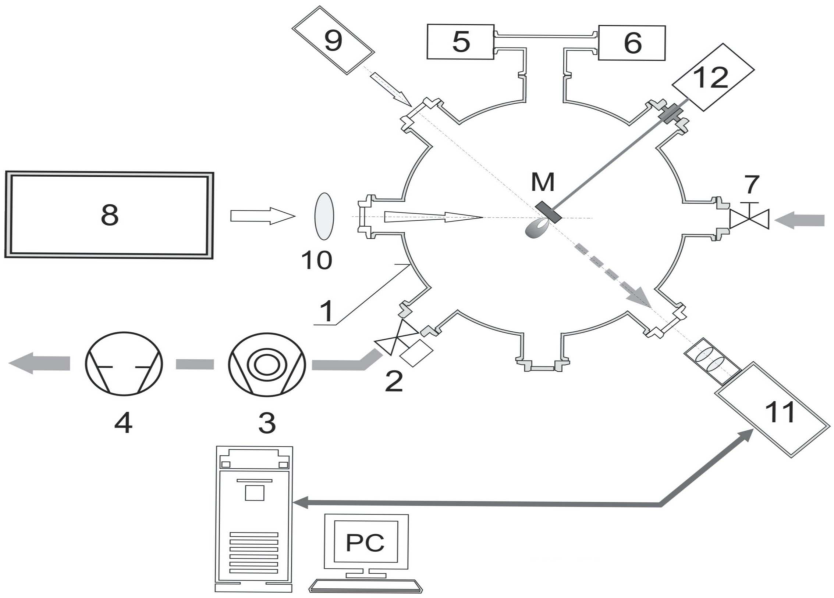

Figure 1: Experimental setup. (1) interaction chamber, (2) electromagnetic valve, (3) turbo molecular pump, (4) mechanical vacuum pump, (5) Piranni gauge, (6) ionization gauge, (7) needle valve, (8) excimer laser, (9) He-Ne laser, (10) quartz lens, (11) ICCD camera, (12) DC motor for target rotation.

3. RESULTS AND DISCUSSION

The ambient gas present during laser ablation scatters, attenuates and termalizes the plasma, which is clearly illustrated in Figure 2. as it can be seen that the luminous intensity decreases as the pressure increases. Also, it can be seen that the duration of the plasma formed in front of the target decreases as the gas pressure is increased.

The ambient gas also causes: a) sharpening of a plasma boundary, indicative for the shock front, b) slowing of the plasma relative to the propagation in vacuum, resulting in c) spatial confinement of the plasma, which can be seen in Figure 3. Also, from the Figure 3a (at 0 - 50 ns) it is visible that two (slow and fast) components of plasma appear. This effect was also detected earlier in laser ablated Al plasma by Tillack et al. 2003. The distance versus time, R = f (t), plots shows that from the linear dependence i.e. constant velocity in the first 50 ns, the plasma slow down. This behavior can be theoretically described by the:

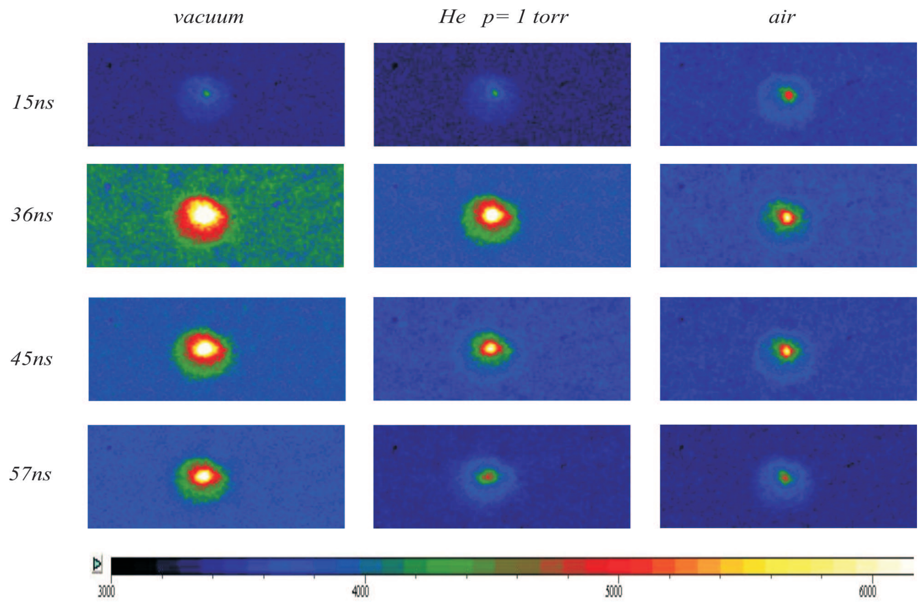

Figure 2: The fast photographs of Al plasma in different background gases.

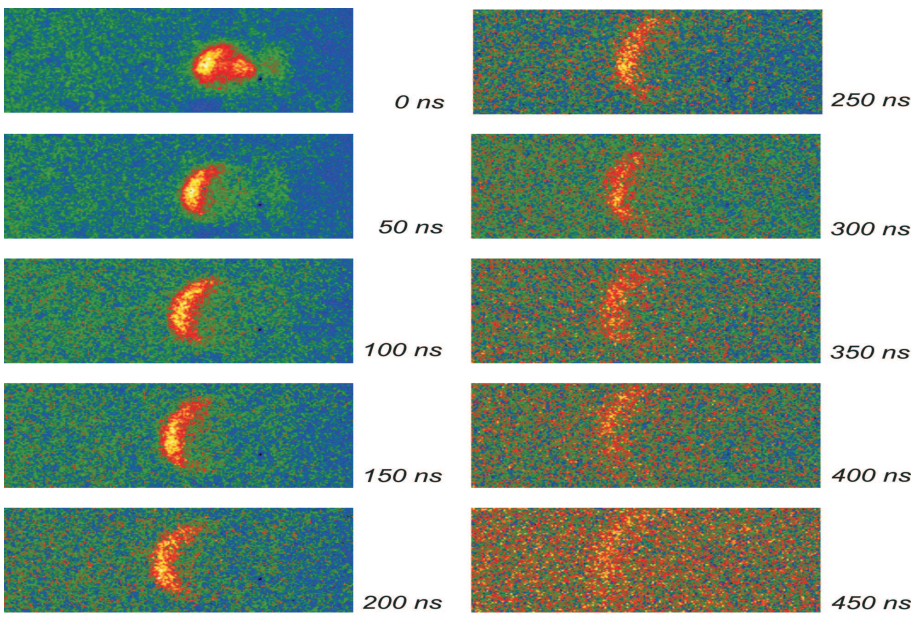

Figure 3: Aluminum ablation plasma evaluation in 0.3 mbar of Ar.

blast wave theory $R = \zeta_0 \, (E_0 / \rho_0)^{0.2} \, t^{0.4}$ (Zeldovich, Raizer 1966) or
drag force theory $R = R_0(1 - \exp(\beta t))$ (Geohegan 1992).

Comparison of the experimental results of the R = f(t) for Ar gas pressure of 0.3 and 3 Torr with both theories was presented in Figure 4.

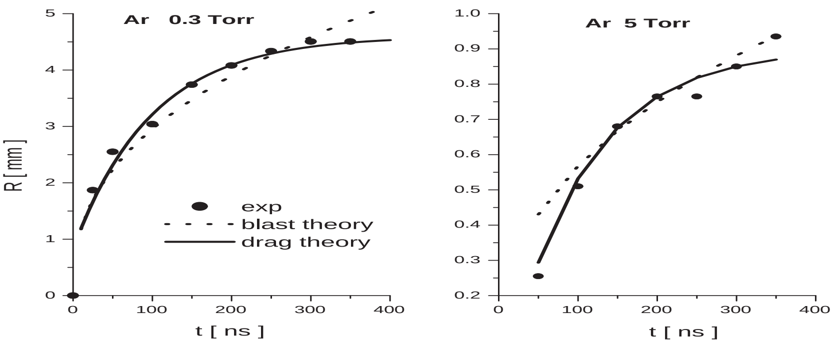

Figure 4: Comparison of ablation plasma propagation distance versus time in Ar at different pressures with a blast and drag theory.

As can be seen from Figure 4 due to the inclusion of viscosity the drag-force model better describes propagation of shock wave in the analyzed case.

Acknowledgement

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References

Chrisey, D. B and Hubler, G. K.: 1994, Pulsed Laser Depositon of Thin Films, Wiley-Interscience publications, John Wiley & sons Inc.

Eason, R.: 2007, Pulsed Laser Deposition of Thin Films: Application-Led Growth of Functional Materials, Wiley-Intersience publications, John Wiley & sons Inc.

Geohegan, D. B.: 1992, in "Laser Ablation: Mechanisms and applications", (Miller J. C and Haglund R. F., eds) Springer-Verlag, Heidelberg, p. 28.

Tillack, M. S., Blair, D., Harilal, S. S.: 2002, UCSD-ENG-103.

Zeldovich, Y. B., Raizer, Y. P.: 1966, Physics of Shock Waves and High-Temperature Hydrodynamic Phenomena (Academic Press) p. 93.