DYNAMICS AND SPECTRAL ANALYSIS OF LASER PRODUCED PLASMAS IN THE PRESENCE OF EXTERNAL MAGNETIC FIELD

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by

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ABSTRACT

Plasma is produced by focussing a laser beam on to a material and study of it has grown importance since last few decades due to its rich physics and substantial applications to space physics, inertial confinement fusion, laser plasma thruster, pulsed laser deposition, material characterization, etc. Magnetic field can be used to control the dynamics of plasma and plays important role in these applications.

In the present work, the effects of transverse magnetic field and argon ambient on the Nd:YAG laser produced barium and tungsten plasmas have been studied using optical emission spectroscopy and fast imaging. Barium and tungsten were used as the target materials due to their importance in space and tokamak applications, respectively. Experiments were performed at various magnetic fields of 0.3, 0.45, 0.52 Tesla and Ar pressures of 10^{-5}, 10^{-2}, 10^{-1}, 1, 3 Torr. Laser fluence is varied from 12 to 31 $\mathrm{J/cm^2}$ in these experiments. The time-of-flight spectroscopy gives the detailed information about the velocity distribution of a particular species while the fast imaging gives the structural information of the plasma plume.

In the time of flight studies, the temporal profiles of two neutral lines and two ionic lines of barium are recorded at various distances 2 mm, 4 mm, up to 12 mm in vacuum (10^{-5} Torr). The temporal profiles of neutral lines are broadened in presence of magnetic field due to increased collisions where as the temporal profiles of ionic lines are narrowed down which showed that all emitting ionic species are confined in a small volume. Since the particle distribution in laser produced plasma can be described by a one-dimensional Shifted Maxwell-Boltzmann distribution function and therefore, a multiple component Shifted Maxwell-Boltzmann distribution was adopted to resolve the individual components. The neutral profiles showed two components in the absence of magnetic field where as an additional component appears in presence of magnetic field. The ionic profiles could be fitted with two Shifted Maxwell-Boltzmann components. Possible mechanisms of various SMB components are explained on the basis of collisions among plume species and correlated to electron temperature, electron density, etc. The ionic profiles showed efficient confinement in the presence of the magnetic field at higher fluences (This part of the work is published in Journal of Applied Physics, 2014).

Time of flight studies of barium plasma were performed at different ambient argon pressures of 10^{-5},10^{-2}, 10^{-1}, 1 and 3 Torr. The time-of-flight profiles of ions showed ambient pressure independent behaviour at 6 mm distance from the target which is attributed to diamagnetic behavior of laser plasma. A theoretical model is proposed to explain the compression of temporal profiles of the ionic lines. The neutral lines showed a fast peak which is attributed to recombination of singly ionized atoms (This part of the work is published in Optics Letters, 2015).

Effect of uniform magnetic fields of different strengths on tungsten and barium plasmas has been investigated using fast-imaging. Field aligned striations are observed in barium and tungsten plasmas in the presence of magnetic field at very low pressure of 10^{-5} Torr. These striations are investigated at different magnetic fields of 0.3, 0.45 and

0.52 Tesla. Different instabilities were discussed and electron-ion hybrid instability induced by the shear in the electron speed is identified as the potential mechanism for the observed striations. The plume front of the tungsten plasma showed a sharpening feature at 10^{-1} Torr pressure which is attributed to Laser Supported Detonation wave. At higher pressures of 1 Torr and 3 Torr, plasma showed turbulence attributed to R-T instability (This part of the work is communicated to Physics of Plasmas).

In conclusion, this thesis presents the dynamics and formation of structures in the expanding barium and tungsten plasmas in presence of magnetic field and argon ambient gas.