Abstract

The two-dimensional diagnosis of laser-induced Zr plasma has been investigated experimentally using Time-Of-Flight (TOF) method by utilizing Faraday Cup (FC), electric and magnetic probes under ultra-high vacuum condition. The axial and radial electrons/ions number densities, electron temperature and ion Kinetic Energy (K.E) of laser-induced Zr plasma have been evaluated as a function of different laser irradiances ranging from 4.5 GWcm-2 to 11.7 GWcm-2 and at different axial positions i.e at 1cm to 4cm and at corresponding fixed radial distance of 2cm. It is observed that overall axial and radial number densities of electron/ions increase with increasing laser irradiance whereas an increasing and decreasing trend is obtained with increasing axial distances. Moreover, the radial component of electron number densities remains higher than the axial number density component whereas ion number density dominates in the axial direction for all laser irradiances and axial distances. During overall expansion of plume, the radial electron number densities range from 3.35 x 1013 to 7.86 x 1013 cm-3 and axial number densities range from 3.13 x 1013 to 6.81 x 1013cm-3. Whereas the radial ion number densities range from 0.34 x 1013 to 2.3 x 1013 cm-3 and axial ion number densities range from 1.84 x 1013 to 4.41 x 1013 cm-3. At low laser irradiances both axial and radial electron temperatures show insignificant variations with axial distances. For moderate irradiances the radial electron temperature exceeds the axial electron temperature and exhibits the Two-Electron Temperature (TET) distribution. However, for the higher irradiances the axial and radial electron temperatures overlap with the persistence of TET distribution. On the other hand, ion kinetic energies increase with increase of laser irradiance but get decreased at higher irradiances. whereas it depicts an alternating increasing and decreasing trend w.r.t. axial distances. The correlation of plasma parameters has been developed with Self-Generated Electric and Magnetic Fields (SGEMFs) measured by E and B probe at same axial positions from 1cm to 4cm. The magnitude of SGEMFs increase with increasing laser irradiances and decrease with increase of axial distances. The axial expansion of plasma has high SGEF values due to effective charge-separation mechanism that decreases radially. Whereas the SGMF remains dominant in radial expansion of plume due to deflection of fast-moving electrons on radial axis. The two-dimensional mapping of spatial evolution of plasma suggests a quadrupolar distribution of charges in it that is also supported by structure and variation of SGEMFs. The variation in both axial and radial electric and magnetic field of plasma coincides with the variation of charge separation. Such comprehensive investigation of laser-induced Zr plasma can be useful for wake-field accelerators and inertial confinement fusion.