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Preface

The interaction of laser light with materials and the properties of the plasma produced by focusing high peak power laser radiation onto a solid target is still a developing area in basic science, engineering and material processing technology. Studies in this direction have gained further importance due to recent discoveries related to tabletop particle accelerators. In-depth theoretical and experimental investigations are essential to obtain detailed knowledge related to physical processes involved in the light-matter interactions leading to plasma generation. Moreover, since the thermo-physical properties of solid matter are fairly well known, numerical models have been proposed by several groups and compared the results with experimental data. Experimental studies related to laser induced plasma (LIP) have been carried out by employing investigation techniques of atomic and molecular physics such as optical emission and absorption spectroscopy, mass spectrometry, time-of-flight, laser induced fluorescence and charge collection measurements. Fast photographic techniques, holographic interferometry and different methods of tomographic reconstructions have also been used to study LIP. The proposed thesis in seven chapters reports the studies on spectral characterization and diagnostics of LIP from a few metal oxide targets. Time and space resolved spectroscopic methods and electrical characterization techniques are applied to LIP from solid targets in magnetic field as well. Tomographic projection methods and digital holographic interferometry (DHI) are employed for diagnostic imaging of plasma cross sections.

Chapter 1 contains a brief review of the laser-plasma interactions and numerical modeling. The laser pulse duration is an important parameter describing its interaction with the material as well as with the plasma. Femtosecond laser beams can induce promising properties which might allow analytical improvements of nanosecond-laser induced breakdown spectroscopy (ns-LIBS). A literature survey on the plasma emissions induced by nanosecond and ultra-short laser pulses is also included in this chapter.

The main objective of **Chapter 2** is to describe the experimental investigations on fundamental physical phenomena during laser pulse interaction with dielectric or metallic surface using time and space resolved optical emission spectroscopy (OES) and optical time of flight emission spectroscopy (OTOF-ES). Diagnostic applications of plasma spectroscopy in determining electron temperature and plasma density are discussed in this chapter. LPP generation from some metal oxide targets are studied with reference to corresponding metal targets of pure quality as reference. Line emissions from atomic and ionic species are employed for the characterization. The experiments were conducted at diffusion vacuum level. For each of the selected targets, plasma density and temperature are evaluated using spectroscopic characteristics and dynamics of neutral and ionic species. Under the same laser fluence and experimental conditions, LPP from oxide target of Titanium (TiO_2 Pellet) shows a higher ionization degree compared to the corresponding Ti target. In contrast to metallic target, a fast degradation of ion drift velocities near the target and relatively higher values of electron densities are observed in the LPP of Aluminium oxide (Al_2O_3 Pellet) target. During free expansion into vacuum, the differential expansion of the plume elements becomes noticeable at larger distances. For both metallic and oxide targets of Tin (SnO_2 Pellets), time integrated temperature is found to increase with distances farther than 4mm.

The principal factors influencing the nature of interaction between laser radiation and a solid target in vacuum are duration, wavelength and power density of the laser pulse, laser absorption processes, physical and chemical properties of the target and geometry of the target. **Chapter 3** discusses the applications of electrical signal between the target and collector (plasma chamber body or metallic wire mesh) on laser plasma diagnostics. Target materials get electrically charged when they are photo-ablated with high energy laser pulse. This leads to fast-rising voltage transients between the target and the collector, which serves as an alternate probe signal providing information about the nature of ablated species, their expansion velocities, extent of ionization in the plume and electron and ion currents in real time. Plasma generation and plume evolution processes get reflected on the temporal variations of the recorded TOF spectrum. Expansion dynamics in field free vacuum and the effects of external magnetic field on the dynamics of LPP are probed using source target signal derived from metallic copper targets, results of which are also included in this chapter.

Chapter 4 deals with the emission characteristics and dynamics of laser induced Lithium plasma in magnetic field. Behavior of neutrals and ions with magnetic field strength are studied results of which are also included in this chapter. It is observed that the intensity of recombination radiation is strongly reduced by the field. The magnetic field does not significantly affect the arrival time distribution of the ejected species. With sufficient ambient pressure, presence of the field increases the lifetime of neutral species. During the interaction between expanding plasma and ambient gas, buffer gas is ionized and more free electrons are produced. The enhanced values of electron density increase the excitation probability of species.

Imaging techniques are used on a routine basis in fusion research to provide much information about the plasma emissivity, plume shape, emission positions relative to the laser spot, fluctuations in the spatial distribution of different plasma parameters and so on. **Chapter 5** presents the irradiance dependence of plasma emissivity studied using tomographic projection measurements on expanding LIP from the target. The emissivity contours are reconstructed through an image processing technique called pixel method. Pixel method is suitable if the plasma cross-section is smooth in polar coordinates with a zero level near the origin. A photo detector of nanosecond rise time observes the plasma through a cone of small solid angle. The axis of this cone is designated as chord. The emitting region is divided into pixels of constant emissivity and a definite number of pixels are always seen by the detector. Local emissivity values are calculated from the system of simultaneous linear equations formed when all the detector positions are taken into account. Irradiance dependence of plasma emissivity and chord brightness are generated and analyzed by a tomographic inversion of the system of integral equations.

Chapter 6 describes the technique of digital holographic interferometry (DHI) as applied to the in situ diagnostics of LPP which serves as the phase object for the digital hologram. DHI enables full digital recording and a completely different way of processing. For each case of the LIP from a Titanium target, a digital hologram is recorded using a continuous laser beam and reconstructed numerically. The hologram acts as an amplitude grating and the analysis is made using well known diffraction theory. Reconstruction of the numerical hologram is realized by a convolution approach available from the Fresnel-Kirchoff diffraction integral. The numerically generated reference beam will get diffracted from the holograms and the wave fields are reconstructed in a plane behind the hologram, thereby forming the objects. From the resulting complex amplitudes, interference phase can be calculated. Interference phase is proportional to the integral of refractive index distribution within the plasma which is directly related to the free electron density.

Chapter 7 deals with the general conclusions drawn from the present studies and outlines some of the directions in future works.