Preface

Laser-induced plasma is a subject of investigations in light matter interaction which will solve many of the unanswered problems related to interaction of radiation with matter. There have been many developments in laser plasma physics since the last few decades. Laser-produced plasma (LPP) is a rich, expanding topic of growing interest in different fields because of its substantial application to inertial confinement fusion (ICF), material processing, plasma diagnostics, space applications and pulsed laser deposition, basic spectroscopy of excited neutrals and ionic species etc.

With the advent of very short duration laser pulses, intensities broaden from the threshold of plasma formation ranging from $10^9$ W/cm$^2$ on the nanosecond time scale up to the highest energy flux densities of several $10^{22}$ W/cm$^2$ currently available in the femtosecond lasers. These lasers are capable of supplying large amount of energy in extremely short time duration. Interaction of high power laser radiation with matter causes the vaporization of surface layers which leads to the formation of an expanding atomic plasma. The first salient aspect of the laser-induced plasma is its fast dynamics, and in concomitance, inhomogeneity in density, temperature and flow velocity.

The formation and dynamics of laser-produced plasma (LPP) from solid target has been studied extensively for long time. In LPP, high power laser focused onto a solid material (known as 'target'), leads to rapid ionisation and generated plasma propagates in the opposite direction to the laser beam, i.e., normal to the target surface. In contrast to this, laser-induced forward transfer technique also knows as laser blow off (LBO), consists of the propagation of the ablated material along the direction of the laser beam. In this case the laser pulse is irradiated through a transparent substrate onto a thin film target and the energy of the pulse will be absorbed in the layer and an expanding plasma cloud is formed along the laser beam direction.
The present thesis report the results obtained from the studies carried out on the laser blow off plasma (LBO) from LiF-C (Lithium Fluoride with Carbon) thin film target, which is of particular importance in Tokamak plasma diagnostics. Keeping in view of its significance, plasma generated by the irradiation of thin film target by nanosecond laser pulses from an Nd:YAG laser over the thin film target has been characterized by fast photography using intensified CCD. In comparison to other diagnostic techniques, imaging studies provide better understanding of plasma geometry (size, shape, divergence etc) and structural formations inside the plume during different stages of expansion. The thesis has been divided into seven chapters:

**Chapter 1** aim to give a brief introduction to laser induced plasmas with particular focus to laser-induced forward transfer or laser blow off (LBO) technique. A short description on the plasma formation and dynamics is discussed. Some of the theoretical considerations in connection with laser matter interaction are also discussed in this section. The motivation of choosing lithium (Li) target for this study has been explained on the basis of diagnostic applications in Tokamak plasma. This chapter also gives an overview of the various diagnostic techniques used for characterisation of the laser-induced plasma.

**Chapter 2** discusses the design and development of the experimental setup to study the expansion dynamics of laser-induced plasma plume from both thin film as well as solid target under various experimental conditions. The details of different diagnostic techniques, which are used in this research, have been explained in this chapter. This includes ICCD imaging, emission spectroscopy and probe diagnostics. One of the main topics presented in this chapter is the study of the influence of magnetic field over the expanding plasma. In order to carry out these studies, magnetic field setup is designed, fabricated and calibrated. A timing sequencing control module has also been developed for time synchronization of diagnostics with laser pulse, ICCD and magnetic field.
The main emphasis of Chapter 3 is to present the study carried out to understand the effect of different ambient gases on the plume expansion dynamics of laser blow off plume from LiF-C target. First part of the chapter discusses the plume propagation in vacuum and various argon pressure levels. In the later part, the investigation has been extended to study the influence of helium ambient on the LBO plasma. Helium is chosen for this due to the large difference in atomic mass and ionisation potential. Images of the plume recorded with intensified CCD at different time intervals after the plasma formation reveal several interesting observations. This includes enhancement of the plume intensity, change in size and shape of plume focusing, plume stopping etc. Details of which are included in this chapter. The geometrical data extracted from the images have been examined by means of appropriate theoretical models and are found to be in good agreement with the observations.

Chapter 4 has divided into two sections: First part sketches the results of the influence of intensity profile of the ablating laser on the dynamics of LBO plume. This work mainly emphasizes the geometrical aspect of the plume generated with lasers having gaussian and flat-top laser intensity profiles. Results from the studies demonstrate that laser beam with gaussian profile produces a well-collimated, low divergence plasma plume as compared to the plume formed by laser beam with top-hat profile. The sequence of film removal processes is invoked to explain the role of energy density profile of the ablating laser in LBO mechanism. This study has also been carried out with three different ambient gases and results of which are described in the second section of this chapter. Further investigations reveal the possibility of the phenomenological development of shock waves when high velocity plasma plume propagates in an ambient gas and sweeps the background medium. Shock strength and other shock parameters have been extracted from the plume images recorded. These data clearly show the dependency of shock wave formation over the ambient medium and is highly influenced by the mass of ambient gas.
Chapter 5 is to describe the effect of magnetic field on the dynamics of plasma generated from solid Li and thin film LiF-C targets. This study has been of particular relevance in the context of Tokamak application of Li neutral beams and plasma confinement. In addition to this, there are several interesting phenomena induced by magnetic field, like plume splitting and intensity enhancement over the plasma upon applying magnetic field. Image analysis shows the enhancement in the overall emission intensity as well as appearance of distinct structures (lobes) in the plasma plume in the presence of magnetic field. By introducing a variable magnetic field, the influence of Lorentz force \((\mathbf{J} \times \mathbf{B})\) in expanding plasma plume across the transverse magnetic field has been explored. In the second part, influence of magnetic field on the plasma plume formed from LiF-C thin film target in LBO scheme has been discussed. In the presence of magnetic field, the temporal profiles of Li neutral lines show distinct features with an enhancement in their intensities.

Chapter 6 discusses the comparative study between the plasma formed by two different schemes viz., the laser-blow off (LBO) of multicomponent LiF-C thin film and conventional laser-produced plasma (LPP) from solid lithium have been studied. On comparing their evolution geometry, apart from similarities, some interesting differences are also noticed in propagation dynamics of the plumes generated by LPP and LBO both in vacuum as well as in the presence of the ambient gases. The differences of LBO and LPP plumes with regard to plume splitting, plume confinement and plume expansion are discussed using fast imaging technique.

General conclusions drawn from the present studies and some of the directions for future work form the subject matter of Chapter 7