CHAPTER 7

Concluding remarks and some outlooks

7.1. Conclusions

Laser induced plasma (LIP) emissions from some metal oxide targets were studied with corresponding metal targets of pure quality as a reference. Atomic emissions in the visible region were used in the spectroscopic procedures of LIP characterization. The studies were meant to throw light into LIP dynamics and they provided many experimental results which improved the general awareness of plasma state.

When target materials were photo-ablated with an energetically suitable laser pulse, they developed electric charges in them. An electrical signal which was delivered from the target served as an alternative probe signal for the diagnostics of LIP and to track different charged states in the plasma. The signal showed a double peak distribution with positive polarity and a modified time of flight with various voltage levels of a given polarity. When the ambient pressure was decreased, the multiple structure of the peak became clearer. The expansion dynamics of LIP in magnetic field were also investigated by monitoring the voltage transients generated at the target. The signal was analyzed in the presence and absence of magnetic field to investigate on the plasma responses to the field. The field confined the plasma and the charged particles entered into newly defined territories, with modified trajectories and kinetics. Signs of a transverse expansion were evident. An increased plume lifetime was observed in the presence of the field.

Another set of experiments were presented to investigate the behaviour of LIP under the influence of a perpendicular magnetic field. A pulsed magnetic field was applied to plasma using a Helmholtz coil. The plasma was spectroscopically examined and found that the magnetic field does not much affect the arrival time distribution of the ejected species but modulated the intensity of visible radiation. Neutrals in LIP were greatly affected by the recombination behavior induced by the field and the modified collisions in the plasma.

The technical aspects of tomographic imaging of LIP were investigated using pixel method. This is a powerful tool which can provide detailed information that are useful in optimizing experimental setups for different plasma applications and to improve their analytical performance.

The phase distribution in LIP was obtained from digitally recorded interferograms, using the methods of digital holographic interferometry (DHI) and the angular spectrum propagation approach. The phase maps were reduced to chord integrated density maps and the chord integrated electron density values at different spatial points were plotted. The local electron density values were evaluated and the mapping of radial electron density profiles was done, by inverting the chord integrated data using a discrete Abel inversion method.

7.2. Future prospects

The data derived from spectroscopic methods are reliable and the validity of the assumptions made during the measurements on LIP has been verified. Besides this, spectroscopic imaging and modelled data can give extended support to test and verify the inferences made about plasma dynamics. Both laser induced fluorescence (LIF) and optical emission spectroscopic techniques can be coupled to study LIP formation and propagation. Different ion densities in plasmas can be measured by LIF imaging spectroscopy. In this, tunable laser pulses from an optical parametric oscillator (OPO) are injected into plasmas and the wavelength is tuned to excite plasma ions at different charge states. A charge coupled camera with a gated image intensifier can be used to take the images of fluorescence. Interference filters will separate the fluorescence from stray lights and self emissions of plasmas. LIF can be used as a nondestructive technique to measure the ion velocity distribution. Such diagnostic steps can overcome the existing sensitivity limitations**,** improve the time and space resolution, and simplify the modelling assumptions.

Combining femtosecond pump–probe techniques with optical microscopy, laser induced breakdown in optically transparent solids can be studied with high temporal and spatial resolution. A weaker probe pulse at normal incidence illuminates the surface region overlapping the area of the pump pulse. A microscope objective will pick up the reflected probe light and produce an image of the surface on a digital CCD camera.

With all the measurements and the experimental results presented, the self derived signal from plasma source target is still unexplored, compared to the complexity of the information underlying it. It seems that the diagnostic method of probe signals derived from plasma source target, when implemented together with suitably designed Langmuir probes can throw more light on the hidden aspects of this technique. The electron and ion currents from LIP target can be correctly calibrated with a series of properly arranged Langmuir probes.

A full understanding of the magnetic field effects on plasma dynamics can be effected if the applied variable field is increased to higher values, in which plasma is confined to points near the target. ICCD imaging of field confinements are progressing in the lab as a second phase of our study.

Pixel method for LIP tomography can be improved if light can be collected from more viewing chords at different positions with respect to the normal expansion of the plume. An interfaced photodiode array is the best candidate for the light collection. Monochromatic light collection from suitable wavelength regions, using optical filters, can give wavelength dependent emissivity maps. Time resolved density maps can be obtained from DHI, if the probe beam is from a pulsed laser having good coherence length, instead of a continuous laser beam. If the pulse has picosecond or femtosecond pulse duration, a dynamic picture of the time evolution of plasma density can be derived. A femtosecond pulse has the capability to capture a sequence of frames (from the evolution of LIP) in a single experiment.

When two expanding plasmas collide, several interactions can arise. These interactions may be either of collisionless type, in which case collective plasma effects should occur or, in contrast they may be collision dominated. For example, considering two extreme cases where the ion-ion mean free path is either bigger or smaller than the typical dimension of the system, we can expect two different behaviours to occur during the interaction of the two plasma plumes. In the first case, the expanding plasma plumes should interpenetrate and therefore the heating processes should be mostly driven by binary collisions between the species. In the second case a quite different scenario is expected to occur, once the two plasmas collide. In this case, the region of interpenetration should be relatively small and the two plumes will decelerate rapidly and stagnate. A stationary plasma should then be formed at the interface, if the translational (kinetic) energy of the plasma streams is converted into thermal energy. This localized heated region is frequently referred as the stagnation layer. This stagnation layer emits strongly in the visible region of the spectrum, for some hundreds of nanoseconds. The time and space evolution of the stagnation layer using optical imaging and spectroscopy is another direction to the future studies. Laser induced colliding plasmas find potentially attractive applications in the field of x-ray lasers, in stimulated Raman scattering experiments, and they are of relevance for the design of inertial confinement fusion (ICF) reactors.