L.11: A time resolved optical diagnostics for laser plasmas with chirped laser probe

Obtaining accurate plasma information is very important in order to understand the laser plasma interaction processes. This becomes even more relevant in the case of ultra-short high intensity lasers. Since the laser plasmas are very small in size (100s of μm), with the plasma conditions varying quite rapidly in time (over sub ns), the required plasma diagnostics should provide good spatial and temporal resolutions. The spatial resolution can be obtained by using suitable optics providing high magnifications. In order to obtain the time resolved information, plasmas are probed repeatedly with different time delays and the information is reconstructed from these snap shots. However, this is not very reliable as the experimental conditions are not exactly similar in all these shots. Streak cameras have been used, but their use is limited by the time resolutions and high cost. A novel method to obtain time resolved information on a 'continuous' basis in a single shot is reported here. Lasers of tens of fs duration are used to study the laser plasma interaction at ultra high intensities. In these laser systems, a 'stretcher' is used to temporally stretch the pulse to hundreds of ps by using a pair of gratings. The stretched pulse has a definite wavelength-time relationship (the longer wavelengths arrive earlier than the shorter wavelengths). Using this unique feature of the 'chirped' pulses, a novel diagnostics has been designed at Laser Plasma Division. Based on this technique, time resolved shadowgraphy and interferometry have been carried out to obtain information about time variation of the plasma expansion velocity and densities, respectively. The principle behind this technique is that once these chirped laser pulses are well characterized, either using a streak camera or any other suitable method, they can be used for probing the plasma.

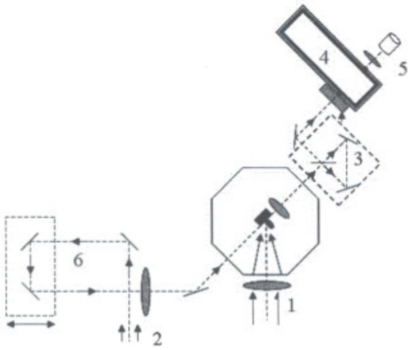

Fig.L.11.1: Experimental setup for chirped pulse interferometery : 1) Main beam, 2) Probe beam, 3) Interferometer, 4) Spectrograph, 5) CCD, 6) Delay line

By simply recording the spectrum of the probe beam that passes through the plasma, one can retrieve the temporal information of plasma from the changes in the spatial profile of the spectrum. The spatial information is retained in a direction perpendicular to the spectral dispersion.

The experimental setup to measure the expansion velocities of a plasma produced by a fs laser (Ti:saphire ~798 nm, 45. fs) at intensities 1 x 10^{15} w/cm^2 is shown in Fig.L.11.1. For shadowgraphy experiments, interferometer in Fig.L.11.1 was removed. The output of the pulse stretcher (before the pulse compressor) was used to probe the plasma The FWHM of this pulse was ~200 ps at ~ 798 ± 10 nm. This pulse was synchronized with the main heating pulse by a delay line with an accuracy of 100 ps. The plasma plane was imaged onto the entrance slit of a Czerny-Turner spectrograph (~3.2 nm/mm dispersion) with a magnification ~50X. the plasma was produced by irradiating aluminum slab targets. The width of these targets was chosen as low as possible (< 1mm) to minimize the shadow region due to possible angle between the probe beam direction and the target front plane. The plasma plane was rotated using an image rotator so that the target surface was perpendicular to the slit direction.

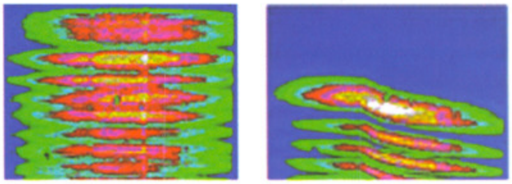

Fig.L.11.2 Results from the chirped pulse shadowgraphy

Similarly, in order to obtain the time resolved electron density profiles of the laser produced plasma, a lateral shearing interferometer was used as shown in Fig. L.11.1. In this case, a beam splitter divides the probe beam in to two equal components after it passes through the plasma. These two were reflected and folded back by a pair of 100% mirrors. The output of the interferometer was coupled to the spectrograph. A magnification of ~80X was used. The interferograms are shown in Fig.L.11.3.

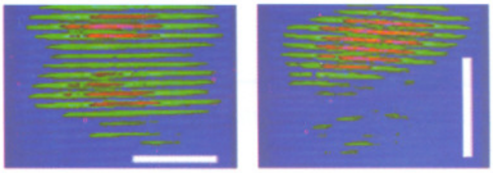

Fig.L.11.3 Interference fringes without and with plasma. The horizontal and vertical lines represent 100ps and 35μm respectively.

The plasma expansion velocity and its variation in time has been calculated from the shadowgrams and the measured peak expansion velocity was ~1.8×10^7cm/s. Similarly, the time resolved interference fringes have been used to get the density profile at different axial distances from target surface.

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L.12: Development of Nitride MOVPE system

Nitride semiconductors are becoming increasingly important in various areas of optoelectronic, high speed and power devices. Metal Organic Vapor Phase Epitaxy (MOVPE) is one of the most widely used techniques for the deposition of these materials. Keeping in view the importance of Nitride semiconductors and MOVPE growth process, we at SCLS have developed an MOVPE system for the growth of Nitride semiconductors. In this article, the salient features of this system are presented.

The process of MOVPE involves a vapor phase reaction between a Metalorganic compound and a hydride gas (referred to as precursors), which are transported to a heated substrate by a carrier gas (N_2 or H_2), resulting in the growth of the desired material on the substrate. In case of GaN, this reaction is as follows: $(CH_3)_3Ga + NH_3 \rightarrow GaN + 4CH_4$. For the deposition of other nitrides like InN, AlN and their ternaries, the precursors used are $(CH_3)_3In$ and $(CH_3)_3Al$ or their combinations. A strict control of the thickness and composition of these epilayers and high material purity are the prerequisites for an MOVPE system. Fig L.12.1 Schematic of the Nitride MOVPE system

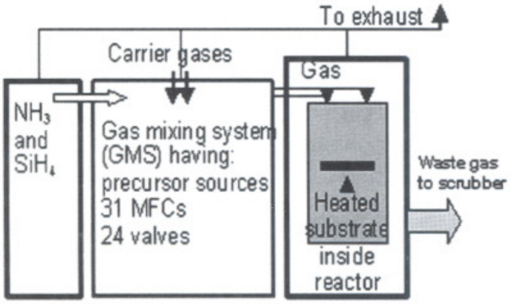

Fig L.12.1 Schematic of the Nitride MOVPE system

Fig. L. 12.1 shows the schematic of the system. The flows of the gases are controlled by mass flow controllers (MFCs) (31 nos) and switching of the various precursors is controlled through a large number of fast switching air actuated valves (24 nos). These devices are controlled through several field controllers and a Labview based GUI, which have been developed and implemented by LESD, RRCAT [RRCAT Newsletter, Vol. 22(1), p14, 2009].

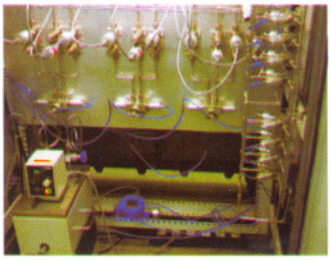

Fig L.12.2. A view of the gas lines and components in a part of the GMS

The high purity of the deposited material is ensured by the use of purifiers for the various gases (NH3, N2 and H2) and the leak tightness of the system (better than 10^{-9} Torr Lit/sec of He). All the MFCs and the switching valves are located in the Gas Mixing system (GMS), that has been assembled by welding ¼ inch OD electro polished from inside SS316L tubes to the various gas components. The view of a part of the (GMS) is shown in Fig L.12.2

The required gases flow into a reactor, where a substrate (Sapphire in our case) is kept at elevated temperatures, to facilitate the growth reaction between the precursors. A high purity Molybdenum based Heater is used to heat the substrate to 1100°C. The external view of the reactor is shown in Fig. L.12.3. To ensure uniform injection of the gases into the reactor without any premixing, a specially designed gas injection showerhead was developed. The showerhead has been designed in our section and was fabricated in Workshop B. Finally the un-reacted precursors pass through a scrubber to avoid any health hazards and environmental contamination. High crystalline quality GaN layers with strong band edge photoluminescence have been deposited in the above system.

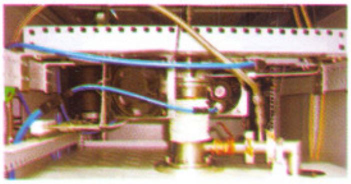

Fig L.12.3. The reactor developed at RRCAT for the Nitride MOVPE system.

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