L.3 : A 3-channel polaro-interferometer to detect magnetic fields in laser produced plasmas

A 3-channel polaro-interferometer has been set up and tested in the Laser Plasma Division of RRCAT, in collaboration with scientists from P.N. Lebedev Physical Institute, Moscow, to measure the magnetic fields generated in the plasmas during laser plasma interaction.

High spontaneous magnetic fields of mega-gauss order are generated in laser produced plasmas at intensities > 10^{13} W/cm^2. Since these fields can influence laser interaction with the plasma (e.g. inhibit thermal conduction, hot electron generation etc.), it is important to study these fields in detail. In order to detect these fields, different diagnostic techniques have been used in the past e.g. techniques using magnetic probes, current probes, magnetic tapes or technique based on Zeeman effect. However, these techniques were not able to probe areas which are close to the critical density surface where high magnetic fields are produced. Optical probing of the plasma based on Faraday rotation principle can do this job. The technique makes use of the fact that plane of polarization of linearly polarized light gets rotated by an angle which depends on the magnetic field present in the plasma and the electron density of the plasma.

Initially, optical probing based techniques were used for measuring only the angle of rotation and an average density was assumed to obtain maximum value of the magnetic field B_{max}. Also, non-uniformities in the probing beam, which can lead to wrong estimation of magnetic fields, were often neglected. These issues could be resolved by recording a) the rotation in the plane of polarization (polarometry), b) the electron density (interferometry) and c) the spatial profiles of the probe beam intensity (shadowgraphy), simultaneously. The 3-channel polaro-interferometer, developed in-house, combines the above three techniques in one, and measures all these three parameters simultaneously.

A schematic of the optical set-up of the polaro-interferometer is shown in Fig.L.3.1. A glan prism polarizer GP1 decides the input polarization of the laser probe beam. The optic axis of first birefringent calcite wedge (W1) makes a very small angle (β) with the transmission direction of GP1. It splits the beam into two parts, ordinary ('o' beam) and extraordinary ('e' beam). The optic axis of second birefringent calcite wedge (W2) is normal to the transmission direction of GP1. So, it again splits each of the two input beams (i.e. 'o' and 'e' beam) and forms four output beams viz. 'ee', 'oe', 'eo' and 'oo' beams. Out of these, 'oe' beam is sensitive to detect Faraday rotation of probe beam and is termed as '*polarometric channel*' [A in Fig.L.3.1]. The 'oe' and 'ee' beams, having equal intensity and same polarization, interfere partially with each other and form '*interferometric channel*' [B]. Shift in interference fringes in this channel is used to estimate the density profile of the plasma. The 'eo' beam, termed as '*shadowgraphy channel*' [C], provides just the spatial profile of the probe beam which can be used to account for any non-uniformity present in its intensity profile. The intensity of fourth 'oo' beam is very small and is comparatively negligible. The transmission direction of second glan prism GP2 is oriented such that the intensity of shadowgraphy channel becomes equal to that of polarimetric and interferometric channels. The small decrossing angle (β) helps in determining the direction of the magnetic field.

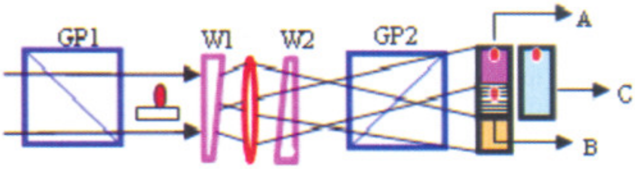

Fig.L.3.1: Optical set-up of the three channel polaro-interferometer.

The experiments were conducted using the polaro-interferometer on the 600 ps high power laser system at LPD, at laser energy up to 5 J. The laser beam was focussed (focal spot ~100μm dia.) on to a planar aluminum target kept in a vacuum chamber. The second harmonic of the main laser beam was used as the probe beam. Both the beams (heating beam and probe beam) were synchronized in time within 1 ns. All the three images were recorded using a digital camera for further processing. Typical pictures of the three channels are shown in Fig.L.3.2, a) shadow, b) polaro, c) interferometry, and d) interferometry (zoom in) channels respectively. Enhancement in the 'polaro' channel could be seen in the experiment indicating the presence of self generated magnetic field. Analysis of the recorded data is underway.

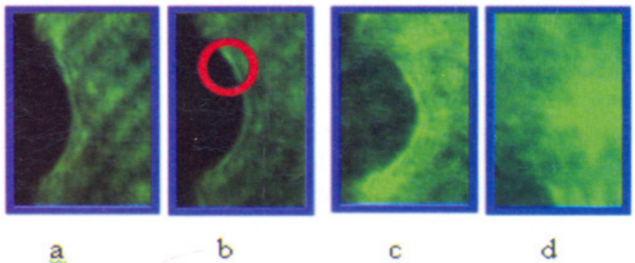

Fig.L.3.2: a) Shadowgraphy channel, b) polarization channel, c) interferometry channel and d) expanded picture of the interference channel. Circle shows the presence of magnetic field.

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