L.5 Development of a Raman shifted optical probe for plasma diagnostics

Self-generated magnetic fields (SMF) ~ 100 kilo Gauss to few mega Gauss are generated in laser produced plasmas. They are estimated by measuring the Faraday rotation angle of a linearly polarized probe laser beam passing through the plasma. The rotation of the polarization plane is proportional to the integral of product of plasma density and the magnetic field along the line of propagation of the probe beam. A three-channel polaro-interferometer was set-up in Laser Plasma Division, RRCAT, for simultaneous measurements of : a) Faraday rotation, b) interferograms for plasma density measurement, and c) shadowgram. (RRCAT Newsletter, p. 4, Vol 21, Issue 2, 2008).

The probe laser beam used with the polaro-interferometer must be linearly polarized, should be of higher frequency, should have smaller pulse duration than the pump laser, and should be temporally synchronized with the latter. It should have a uniform spatial intensity distribution to avoid any artifacts in the measurements. The energy should be sufficiently high so that it is well above the background radiation emitted by the plasma, at the same time, it should be low enough so that it does not contribute significantly to plasma heating. A second harmonic probe beam, derived from the main laser beam, by frequency doubling a part of it, usually satisfies most of the above criteria, and is most commonly used in optical probing of plasmas. However, due to the process of harmonic generation in the plasma, the back-ground plasma emission at the harmonic frequency of the pump beam is of higher magnitude than at other frequencies. Hence, a diagnostic probe beam at a frequency other than the harmonic frequencies, is more suitable for plasma experiments at high intensity.

A Raman shifted probe beam at a wavelength of 673.5 nm, generated from a high pressure hydrogen cell pumped by second harmonic (527 nm) of an Nd:glass laser, has been set up at Laser Plasma Division. Fig.L.5.1 shows a schematic of the probe laser set-up. The pump laser for the plasma is a two beam Nd:glass laser chain that works on master oscillator-power amplifier (MOPA) configuration. It is sequentially optically relayed and spatially filtered. It can deliver peak power between ~100-150 GW (in a variable pulse duration ~ 0.5 - 1.5 ns) in a 94 mm dia. laser beam. The second harmonic beam to pump the Raman cell was generated by tapping a small energy (~150 mJ) from the main high power Nd: glass pump laser beam, using a BK-7 glass blank wedge. For synchronization, the beam was tapped after the spatial filter R5-6 of the laser chain (see Fig.L.5.1). The polaro-interferometer (on the plasma chamber) was at a distance of ~ 21 m from the glass wedge. The effects of diffraction on propagation over such large distance was overcome by using two optical relays R-1 and R-2, which sequentially relayed and de-magnified the laser beam to a diameter of ~13 mm, from initial diameter of 63mm, along with spatial filtering of the beam to remove spatial frequencies above 1.5 lines/cm. A variable delay line of ± 2 ns allows one to study the temporal evolution of the plasma. An Nd:glass laser amplifier was used to amplify the 1054 nm beam to an energy of ~ 1 J, with a pulse duration of 1.5 ns, and intensity of ~190 MW/cm^2. This beam was converted to it's second harmonic using a type II cut KDP crystal. A lens of 1 m focal length, focused the second harmonic beam into a hydrogen gas filled Raman cell (pressure ~20 bars) of length 56 cm . The Raman shifted red beam was re-collimated using another lens of focal length 1.6 m that magnified the red beam to a diameter of ~20 mm. The magnification was done mainly to have the probe beam of larger size than the aperture size (10 mm x 5 mm) of the polaro-interferometer, to select the most uniform part of the probe beam. Fig.L.5.2 shows the Raman conversion efficiency obtained as a function of the input second harmonic pump energy. Raman conversion of ~25 % was obtained at an input energy of ~ 65 mJ in the pump second harmonic beam. This Raman shifted probe beam of energy ~20 -30 mJ, and a pulse duration of ~ 1 ns, with appropriate linear polarization, will be used to record optical images with the polaro-interferometer.

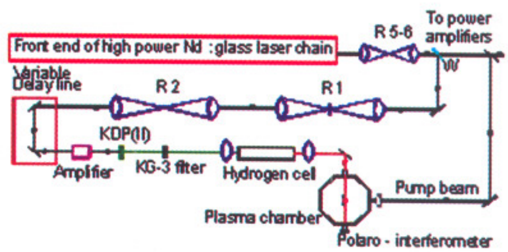

Fig.L.5.1 : A schematic of the layout of the Raman shifted probe beam

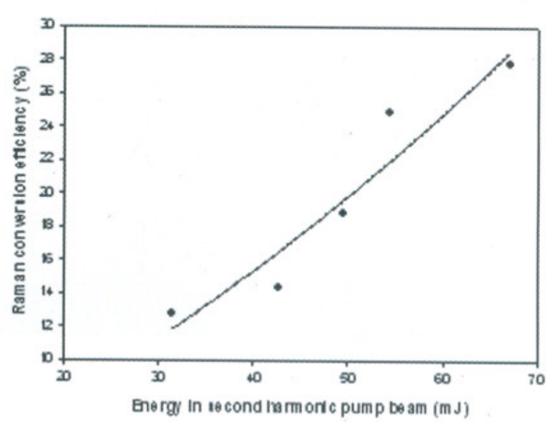

Fig.L.5.2 : Variation of the Raman conversion efficiency as a function of the pump beam energy.

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