L.7 Dependance of high order harmonics intensity on laser focal spot position in pre-formed plasma plumes

High order harmonic generation using ultra-short pulse lasers is an attractive method of generating coherent radiation in the XUV region, as an alternative to soft x-ray lasers, and to achieve attosecond duration soft x-ray radiation. For practical applications, it is desirable to have high conversion efficiency from the driving laser beam to the harmonic radiation. While most studies have been performed using gas jets, pre-formed plasma plumes have been used recently to generate high order harmonics. The use of plasma plumes is attractive for resonance intensity enhancement. However, it may adversely affect the conversion efficiency due to phase-mismatch problem. Since the plasma refractive index depends on the electron density, which in turn is governed by the laser beam intensity, the amount of phase mismatch would depend on the laser intensity, the length of the plasma plume, and the plasma refractive index profile. The laser focussing conditions may therefore play an important role in governing the efficiency of harmonic generation. Hence it is important to optimize the focussing conditions of the laser beam w. r. to the location of the plasma plume to obtain maximum intensity of the harmonic radiation.

At Laser Plasma Division, an experimental study of the dependence of harmonic intensity on the laser focus position w. r. to the plasma plume has been carried out in pre-formed plasma plumes. The laser used in this study was a Ti:sapphire laser system operating at 10 Hz rep-rate. A part of the uncompressed laser radiation (energy : 30 mJ, τ=300 ps) was split from the main beam by a beam splitter. This beam was focussed at normal incidence by a 500 mm focal length spherical lens on a planar silver strip of 2 mm width, kept in a vacuum chamber evacuated to 10^{-5} mbar. This beam (pre-pulse beam) created a plasma plume to serve as the medium for harmonic generation. The laser intensity on the target was ~3×10^{10} W/cm^2. After a time delay of 60 ns, the main laser pulse, compressed to 48 fs (energy: 120 mJ), was focussed in the above pre-formed plasma plume from a direction parallel to the target surface at a distance of ~ 100 μm, using a spherical lens of 500 mm focal length. The peak intensity at the best focus position was ~10^{18} W/cm^2. The high-order harmonics were analyzed by a home-made flat-field grazing-incidence XUV spectrograph based on a variable line spacing grating. The spectrum was recorded on a multi-channel plate detector, the output of which was imaged onto a 12 bit digital CCD camera connected to a PC. The best focus position was varied from -7 mm to +9 mm from the plume centre by moving the focussing lens. The femtosecond laser intensity at the centre of the plasma plume for different locations of the best focus varied from ~10^{15} W/cm^2 to ~10^{18} W/cm^2.

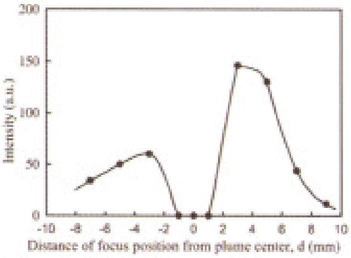

Fig.L.7.1: Variation of the 23rd harmonic intensity with the change in focus position of the femtosecond laser beam w. r. t. the centre of the plasma plume.

The harmonic intensity nearly vanished when the laser beam was focussed at the centre of the plume (see Fig.L.7.1). Further, the harmonic intensity showed peak when the best focus was located on either side of the plume centre. The peak harmonic intensity was higher when the laser beam was focussed after the plasma plume as compared to the opposite case, and this difference decreased for higher harmonic orders. Moreover, the distance of the best focus position corresponding to the peak harmonic intensity increased for higher harmonic orders. The results have been explained in terms of variation in coherence length for harmonic generation, relativistic drift of electrons, and defocussing of the harmonic radiation due to the radial ionization gradient in the plasma for different positions of the laser focal spot. [For more details, please see *H. Singhal et al, J. Appl. Phys. 103,013107 (2008)*]. The study can be useful in optimizing laser focus position for achieving maximum intensity for various harmonic orders.

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L.8 Spatial profile of laser wake-field accelerated electron beam

Conventional accelerators are large size systems because the accelerating electric field has to be kept below ~50 MV/m to avoid electrical breakdown in the accelerating structures. On the other hand, laser wake-field generated inside a plasma can give extremely high accelerating field ~100 GV/m, and this may pave way for developing very compact accelerators in future. Laser Plasma Division of RRCAT has recently initiated experimental investigations in laser wake-field electron acceleration, in collaboration with scientists from KEK, Japan. Initially, a scintillator (NE102) photo-multiplier tube combination was used to detect the high-energy electrons [RRCAT Newsletter 20, 1, p.10, 2007]. Now, the spatial profile of the electron beam has been measured using DRZ phosphor and CCD camera combination.

Fig.L.8.1 shows a schematic of the experimental setup used to measure the electron beam profile. At a gas jet pressure of 37 bar and laser intensity of ~2 x 10^{18} W/cm^2, a collimated beam of electrons with a low-divergence (~10 mrad), with few tens of MeV energy was observed. A typical electron beam profile recorded on DRZ phosphor screen is shown in Fig.L.8.2.

The experiments were carried out using the 10 TW Ti:sapphire laser facility at RRCAT. This provides laser pulses of maximum energy of about 450 mJ in 45 fs pulses. The laser beam was focussed on a helium gas jet using a 40 cm focal length gold coated off-axis parabolic mirror. The gas jet was produced by a shock wave-free slit type (10 mm x 1.2 mm) supersonic Laval nozzle. Helium gas was puffed using a fast solenoid valve and its density was varied by changing the backing pressure of the gas. The Ti:Sapphire laser beam was focussed at the entrance edge of the gas jet, about 1.5 mm above the nozzle entrance. The focal spot diameter of the beam was 18µm (FWHM).

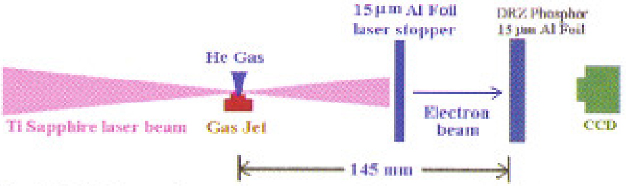

Fig.L.8.1: Set-up for measurement of beam profile of the laser accelerated electrons.

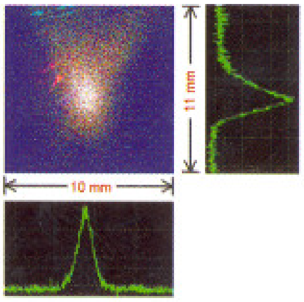

Fig.L.8.2: Electron beam profile recorded using DRZ phosphor, on a CCD camera.

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L.9 Improving performance of porous silica sol-gel anti-reflection coated optics for high power Nd: glass laser

Porous silica sol-gel coated optics is used in high power laser systems because it has high laser induced damage threshold (LIDT) and has high spatial uniformity over large diameters. High power laser systems have MOPA (master oscillator power amplifier) architecture and use sequential optical relaying using vacuum spatial filters to overcome laser wavefront distortions caused by self-focusing of the laser at high intensities. In order to use the sol-gel AR coated optics in spatial filters, the degradation of optical performance and LIDT of the coatings at the laser wavelength upon exposure to the vacuum oil vapours is an important consideration. Laser Plasma Division of RRCAT has developed a technique using hexamethyl-disilazane (HMDS) vapour treatment of the coatings to overcome the degradation of optical performance [R. Pareek et al Optical Engineering (in press)] of sol-gel AR coatings. The degradation in the optical quality of the coatings occurs mainly due to the adhesion of contaminant vapours to the polar silica nano-particles in the coatings. The polar nature of the silica coatings can be reduced if the coatings are exposed to HMDS vapours. This may prevent the degradation of the coatings upon exposure to contaminant vacuum oil vapours.

Two sets of single layer AR coatings, namely silica and ammonia and HMDS treated porous silica were prepared and exposed to rotary pump oil vapours in a vacuum chamber. Fig.L.9.1 shows the reflection spectra of a) porous silica coating, and b) the same coating exposed to oil vapours. It is seen that for the silica coating not exposed to oil vapours, the spectrum has a minimum of its reflectivity spectrum at λ_{min} = 1054 nm (lasing wavelength) with a reflectivity of R = 0.26%. It is also observed from Fig.L.9.1b that the minimum of reflectivity shifts to a higher wavelength by 122 nm as compared to the minima of the coating not exposed to oil vapours. A substantial degradation of the reflectivity occurs for vapour exposed silica coating giving a reflectivity of 2.1% at 1054 nm in comparison to the 0.26% reflectivity of the coating not exposed to oil vapours.

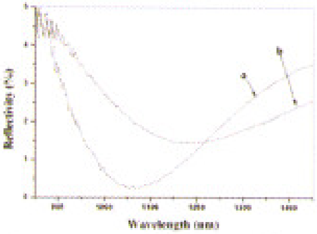

Fig.L.9.1: Reflection spectra of a) porous silica coating and b) the same coating after exposure to oil vapour.

Figure L.9.2 shows reflection spectra of a) a porous silica coatings treated with ammonia and HMDS, and b) the same coating exposed to oil vapours. It can be seen that there is only a marginal shift of ~20 nm of the λ_{min} value between the oil vapour exposed and un-exposed coatings that were treated with ammonia and HMDS. The shift in the minima of the spectra of treated coatings is much smaller than that of