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.

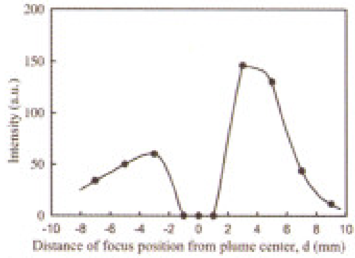

Fig.L.7.1: Variation of the 23rd harmonic intensity with the change in focus position of the femtosecond laser beam w. r. t. the centre of the plasma plume.

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