L.1: Observation of a second plateau in high order harmonic generation from preformed plasma plumes

High order harmonic generation (HHG) from the interaction of ultrashort laser pulses with gaseous media is an attractive method for generation of coherent extreme ultraviolet (XUV) radiation. One of the aims of the HHG research is to produce HHG at the shortest possible wavelengths. Interaction of intense ultrashort laser pulse with gas media is the most common method used to generate HHG. Typically, the harmonic spectrum shows a rapid fall of efficiency with harmonic order, followed by an intensity plateau, ending with a sharp cut-off. The cut-off harmonic order depends on the laser and material properties of the plasma medium. Use of gas jets does not allow one to explore the effect of material properties of the plasma plume on the HHG process, due to limited number of gases available. Use of low excited plasma plumes has opened a new window to explore the effect of material properties on HHG process, while preserving all the benefits of a gaseous medium. Using plasma plume as the medium, Laser Plasma Division of RRCAT has carried out several experimental studies on the generation of HHG [e.g. RRCAT Newsletter P.19, Vol 22,1, 2009]. Recently, we have extended the harmonics well beyond the cut-off (termed as second plateau) to get a jump in the maximum number of harmonic orders achievable.

The laser used in the study was a 10 Hz Ti:sapphire laser (λ= 798 nm). A part of the uncompressed laser pre-pulse of duration ~300 ps was used to produce the plasma from various solid targets. The high intensity ultrashort laser beam (main pulse) traversed the plasma plume, parallel to the target surface and produced high order harmonics. The HHG was optimized by changing the intensity of the pre-pulse and main pulse, in the plasma plume. To increase the harmonic intensity, they were focussed vertically using a grazing incidence gold mirror. The harmonics were dispersed using a home-made flat field grating spectrograph, and detected by an MCP-CCD assembly connected to a PC, for on-line single-shot recording of the harmonic spectrum.

A typical spectrum of HHG from manganese plasma plume is shown in Fig.L.1.1. It shows the odd harmonics in the plateau region from 19th H to 27th harmonic. The cut-off at 27th harmonic can also be observed. As expected, there is no HHG after the cut-off. By tuning the parameters of pre-pulse and main pulse, one can see the appearance of harmonics in second plateau as shown in Fig.L.1.2. To generate the HHG with second plateau, one has to increase the intensity of the picosecond pulse (i.e. the pre-pulse). It can be seen that the HHG spectrum in the lower orders (first plateau) disappears. The HHG spectrum upto 41st order could be obtained easily only by optimizing the intensity of the picosecond pulse. One can extend the harmonic cut-off further by optimizing the intensity and chirp of the femtosecond laser pulse. It is observed that if one increases the intensity of the main pulse inside the plasma plume and introduces slight negative chirp, the second plateau of HHG can be extended to a very high harmonic order. As shown in Fig.L.1.3, the HHG second plateau cut-off has been extended to 73rd harmonic order, corresponding to a wavelength of 10.9 nm. This is so far the highest harmonic order observed in our laboratory.

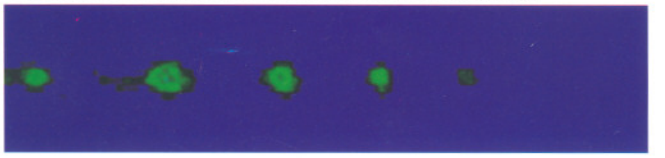

Fig.L.1.1: Typical harmonic spectrum from Mn plasma

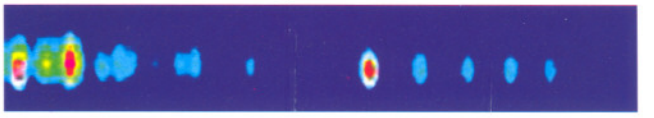

Fig.L.1.2: HHG in second plateau for manganese

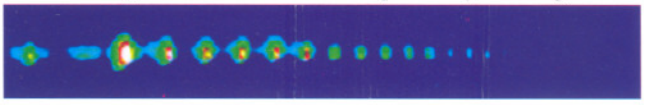

Fig.L.1.3: Extension of HHG cut-off

These studies have shown the capability of plasma plumes in generating high order harmonics in deep XUV range from the extension of harmonic cut-off by generating harmonics in second plateau in certain materials. It may be noted that such second plateaus are observed only in few materials. However, wherever such second plateau is possible to be obtained, one gets a big jump in the cut-off harmonic order. For example, in the case cited above, for manganese plasma, the cut-off was extended from 27th order (first plateau) to 73rd order (second plateau) by adjusting the plasma and laser parameters.

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