L.1: Soft X-ray Lasing achieved in Capillary Discharge Plasmas

Efforts to operate the lasers at shorter and shorter wavelengths had begun since the invention of lasers themselves. The last two decades have witnessed a steep increase in these efforts, especially for lasers in the soft x-ray region. Rocca's group at University of Colorado, USA had first demonstrated a table top soft x-ray laser at 46.9 nm (25.6 eV) in argon plasmas. At RRCAT, a program had been taken up jointly by LPD and LESD to develop a soft x-ray laser in argon plasmas at 46.9 nm. Recently, a low divergence (< 3.5 mrad), short duration (FWHM ~ 1 ns) x-ray laser has been successfully demonstrated at RRCAT, and the results are briefly described below.

Fig.L.1.1: Photograph of the capillary discharge system

The capillary discharge system (Fig.L.1.1) consists of a high voltage Marx bank (V_{max} = 500 kV), a compact water line capacitor (6 nF), a pressurized spark gap switch, and a capillary filled with argon gas at different pressures. A fast rising (~50 ns) high current pulse (40 kA) pinches the pre-formed plasma radially inwards, forming a long, 100-300 m wide hot dense column. This transient, short duration column acts as a lasing medium generating coherent radiation in the soft x-ray region (46.9 nm) in the Ne- like Ar^{8+} species, which are excited via collisional excitation mechanism.

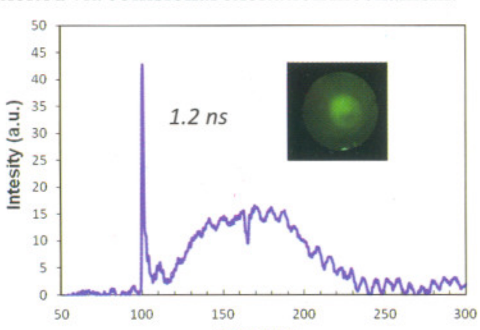

Fig.L.1.2 Temporal and spatial profiles of the laser

The temporal profile of the x-ray emission was measured using a Cu/Au coated bi-planar vacuum diode (biased at -500 to -750 V) fabricated in-house. After optimizing the various parameters which include : a) main current, b) pre-pulse current, c) delay between the pre-pulse current and the main current, and d) gas pressure, the duration (FWHM) of laser pulse can be reduced to ~1 ns as shown in Fig.L.1.2. The signal consists of the laser emission (sharp spike) over-riding a long, highly divergent plasma radiation. The spatial profile (inset of Fig.L.1.2) of the laser was recorded using a micro-channel plate (MCP) detector placed 165 m away from the capillary source. It shows a low divergence (< 3.5 mrad) of the beam.

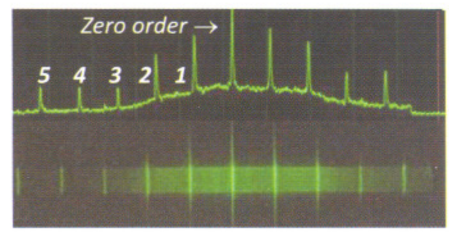

Fig.L.1.3 The recorded spectrum of the x-ray laser and its line-out. Diffraction upto 5th order can be seen

To ascertain the wavelength of the lasing, a transmission grating (700 lines/mm) spectrograph coupled to a MCP detector was set up. The recorded spectrum (Fig.L.1.3) shows the an intense monochromatic line radiation at 46.9 nm and its higher orders (upto 5th), much above the background plasma radiation. When the pre-pulse is switched off, all these features disappear confirming the lasing action.

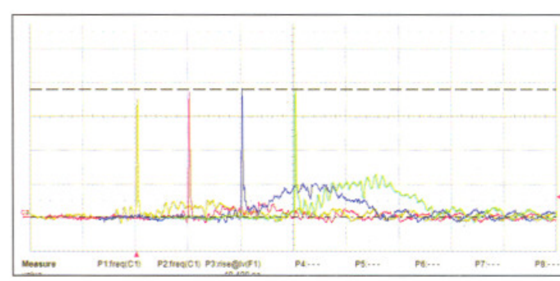

Fig.L.1.4 Signals from the quadrant vacuum diode when the laser is symmetrically incident on all quadrants.

In order to place these fine dispersion elements like the transmission gratings or entrance slits (of the spectro graph) whose width is typically few tens of micron (μm), one needs to know the exact location of the laser beam in space. A quadrant vacuum diode had been developed and used for this purpose. The typical signals from the four quadrant are shown in Fig.L.1.4 when the laser is symmetrically incident on all the four quadrants. Any asymmetry in the signals indicates misalignment of the laser beam w.r.t. the quadrants.

Presently, efforts are on to measure the laser pulse energy by characterizing the diodes, and to study the effect of different parameters like current and gas pressure on the laser output energy, divergence etc.

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