L.6 : Enhanced x-ray emission in water-window region from Ti:-sapphire laser irradiation of carbon nano-fibres

Ultrafast imaging of live biological samples with high contrast requires high brightness, short duration point x-ray source in the "water-window" region (23-44 Å). Plasma produced by intense femto-second laser pulses from solid targets may serve as a compact and low cost source for such applications. However, the absorption of high intensity, ultrashort laser pulses by solid targets being low, various nano-structured targets have been used to enhance the laser energy absorption and thereby the x-ray conversion efficiency. Carbon nano-fibres (CNF) are one such potential target. Experimental studies on x-ray emission in the water-window region from ultrashort pulse irradiation of CNFs performed at Laser Plasma Division of RRCAT have shown an order of magnitude enhancement over that for a graphite plate target.

The CNFs were produced through chemical vapour deposition in a resistively heated quartz tube furnace at ~ 800 ^{0}C using iron catalyst at Indus Synchrotrons Utilization Division. Fig.L.6.1. shows scanning electron microscopy (SEM) images of CNFs of average diameter of 60 nm and 160 nm. The nano-fiber length was typically of ~ 10 μm. The deposited thickness of the nano-fibres on the graphite plate was in the range of 20 – 50μm. These targets were irradiated by focussing 150 mJ, 45 fs laser pulses from a Ti-sapphire laser at an intensity of ~ 4x10^{17} W/cm^2. X-ray emission spectrum was recorded with a spectral resolution of ~ 1 Å using an in-house developed micro-channel plate - CCD camera detector based on-line transmission grating spectrograph.

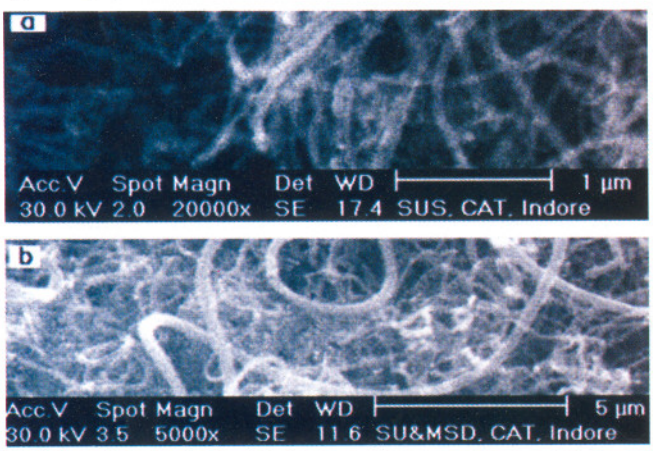

Fig.L.6.1. SEM pictures of CNFs of different average diameters (a) 60 nm (b) 160 nm.

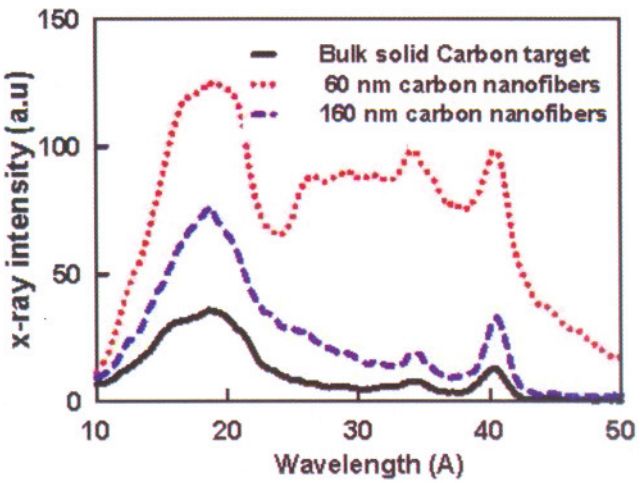

Fig.L.6.2. X-ray emission spectra from plasma produced from carbon nano-fibres and graphite plate targets.

Fig.L.6.2 shows the x-ray emission spectra from plasmas produced from a graphite plate, and from 60 nm and 160 nm diameter carbon nano-fibre-deposited targets. Intense lines from carbon plasma *viz.* C V 1s^2-1s2p (λ=40.3 Å) and C VI 1s-2p (λ=33.7 Å) are seen to be riding over a strong continuum for the case of 60 nm nano-fibre targets. The x-ray intensity is much higher for 60 nm and 160 nm diameter carbon fibres in comparison to that for the graphite plate. Integrated x-ray intensity over the water window range (23-44 Å) for the 60 nm fibre target for different laser shots was 12 to 20 times higher than for the graphite plate. The corresponding x-ray intensity enhancement for the 160 nm diameter fibre target was ~ 1.8 to 3.4. The detailed results are reported in a paper "*Enhanced x-ray emission in water window region from ultrashort laser pulse irradiation of carbon nano-fibers*" by U. Chakravarty, P.A. Naik, B.S. Rao, V. Arora, H. Singhal, R.A. Khan, P.D. Gupta, G.M. Bhalerao, and A.K. Sinha, at the "5th International Symposium on Modern Problems of Laser Physics", at Novosibirsk, Russia (August 24-28, 2008).

The observed x-ray intensity enhancement may be occurring due to higher laser coupling in nano-fibre targets which would produce a hotter plasma. This could possibly be due to the fact that a nano-fibre structure has a high ratio of the effective surface area to the volume, leading to a greatly increased interacting mass of the target with the laser pulse, in comparison to the planar target.

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