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BOOK OF PROCEEDINGS

INSTITUTE OF PLASMA PHYSICS AND LASER MICROFUSION

FORWARD SECOND HARMONIC EMISSION FROM LASER PLASMA FILAMENTS

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1.Introduction. The study of filamentary structures of a laser beam interacting with an underdense plasma is of great interest. Filamentation Instability (FI) can actually degrade the coupling efficiency between laser radiation and fusion targets. Second Harmonic (SH) light emitted from plasma filaments has demonstrated some possibilities as a diagnostic tool for FI in underdense plasmas. SH observations related to filamentation in underdense plasmas have been done at 90° to the laser axis (Stamper et al. 1985, Giulietti et al.1989), as well as in the forward direction (Meyer and Zhu 1987, Giulietti et al.1988). However Young et al.1989 using a specially designed experiment has concluded that the SH emission at 90° to the laser axis is spatially correlated to the filaments but these latter do not emit SH for their full length. In an underdense plasma, the radiating current is directly related to both density and electric field intensity gradients (Giulietti et al. 1989).

In the present paper we will discuss experimental measurements in which the second harmonic of the laser radiation is observed in the forward direction during the interaction of a Nd laser with plasmas produced from thin plastic films. Some theoretical plots showing the dependence of the SH energy flux on filament dimensions are also reported. They are obtained by calculations based on a one fluid plasma model.

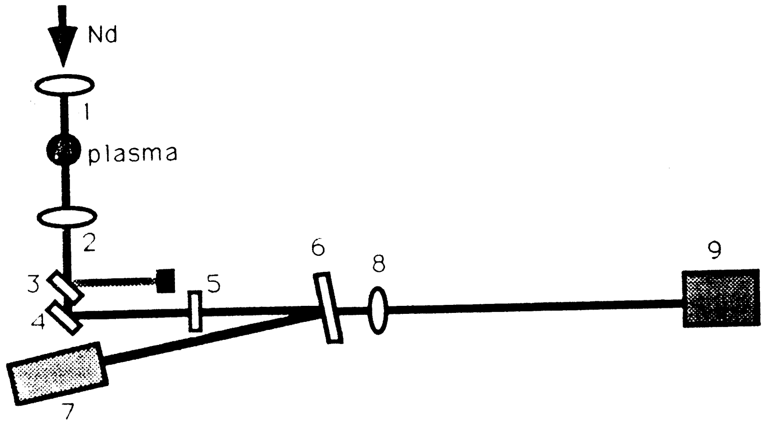

Figure 1. Experimental setup: (1) Focalization lens, (2) Collecting lens, (3) ω–Mirror, (4) 2ω Interferential Mirror, (5) Interferential Filter for 2ω, (6) Beam Splitter, (7) Photomultiplier, (8) Gated Optical Imager .

2.Experimental observations. A neodymium laser delivering up to 2 Joules in 3 ns is focussed up to an intensity of $2x10^{13}$ W/cm^2 on a thin Formvar plastic film (1 μm). The experimental setup is shown in Fig.1.

The Second Harmonic light emitted by the plasma is collected by a lens. A part of it is reflected by a beam splitter and sent to a Photomultiplier (PM), the other part is imaged on a Gated Optical Imager (GOI) which has 120 ps time exposure and is synchronized with the peak of the laser pulse. The reflected SH light can also be passed through a spectrometer ,and imaged on the slit of a Streak Camera (SC). Narrow band interferential filters centred on SH light (5300±20 Å) are used in front of the SH detectors.
We studied the behaviour of the SH power by moving the target axially without introducing large changes in the incident intensity. Fig.2 is a plot of the SH power versus target position. For quite small displacements of the target (lower than the beam waist depth), we observed dramatic variations (by 2 orders of magnitude) in the measured SH power. In Fig.3 the dependence of SH power on the incident energy is reported. Non linearity of SH generation is clearly shown by over-quadratical slope.

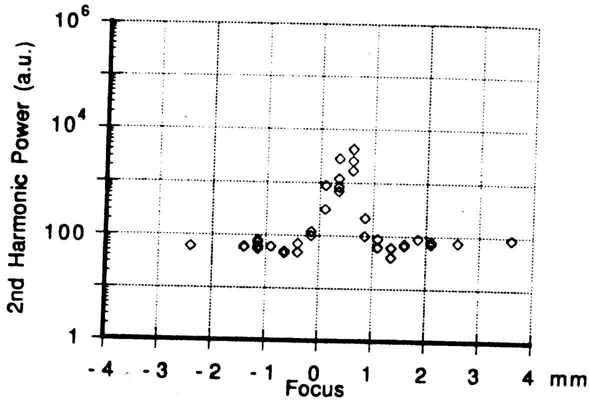

Figure 2. Second harmonic power versus target position.

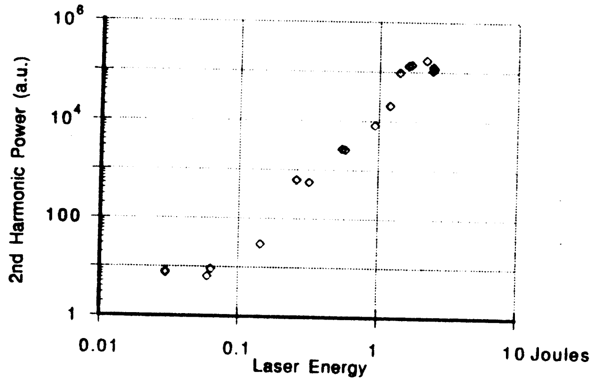

Figure 3. Second harmonic power versus incident laser energy.

Fig.4 is an image of the emitting region taken at the position corresponding to the maximum SH production. The dimension of the overall image is no more than 60 μm which is the laser focal spot diameter. Structures with dimensions lower than 5 μm are evident. This position seems to be favourable for the growth of small scale transverse structures and consequently to the Filamentation Instability. Fig.5 is an image taken out of the position of maximum production In this position (our laser beam presents some large scale inhomogeneities) no small structures are present. Each part of the beam self-focuses as a whole. This position seems to be favourable for whole beam self-focusing.

3.Second Harmonic generation: theoretical considerations. The e.m. fundamental field is written as $\mathbf{E}=\mathbf{E}_0(r)e^{i(k_0 z-\omega t)}$. Using the continuity equation and the equation of motion for the electrons and doing an iterative expansion one gets

$$\mathbf{j}(2\omega)=-en(\omega)\mathbf{v}(\omega)-en_0(r)\mathbf{v}(2\omega) \;;$$

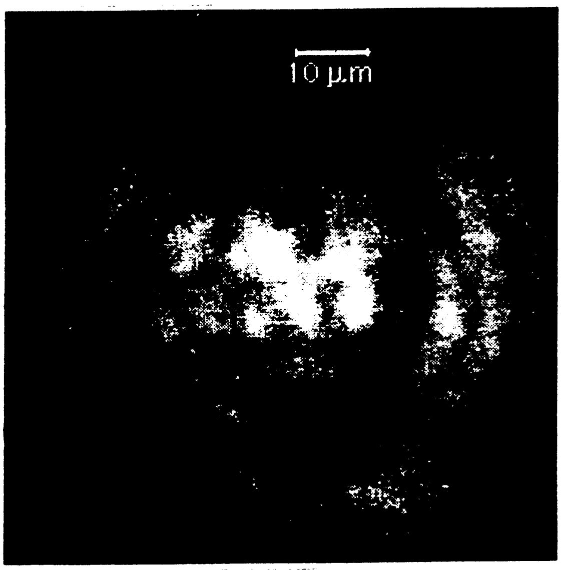

Figure 4. 2 ω image taken at the position of maximum second harmonic production.

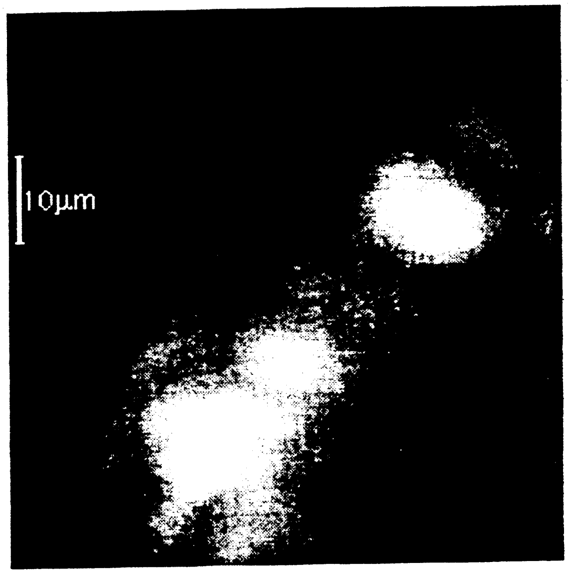

Figure 5. 2 ω image taken with the target 1 mm displaced toward the laser with respect to the position of maximum SH production.

$J(2\omega)$ being the second order current density given by

$$J(2\omega) = -i\,\frac{e^3}{m^2\omega^3}\left(\frac{1}{2}\, i n_0 k_0 (E_0 \bullet E_0) + \frac{1}{4} n_0 \nabla (E_0 \bullet E_0) + E_0\, \frac{\nabla n_0 \bullet E_0}{\varepsilon}\right) e^{2i(k_0 z - \omega t)}\,.$$

The first term of the right hand side being parallel to the wave vector k_0 cannot radiate, the second and third terms will radiate. They are non vanishing if there is a radial

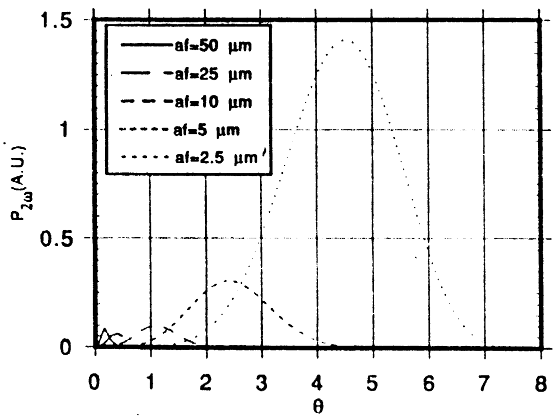

Figure 6. Theoretical plots of SH power versus θ, angle between k_0 and $k_{2\omega}$, for different filament radii a_f.

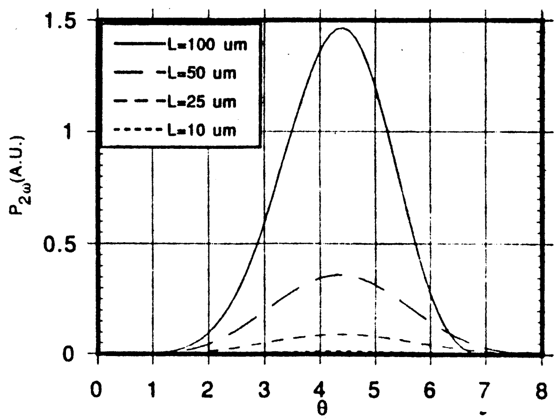

Figure 7. Theoretical plots of SH power versus θ, angle between k_0 and $k_{2\omega}$, for different filament lengths L.

dependence of the field intensity $E_0(r)^2$ and plasma density $n_0(r)$. Plots of the SH energy flux are shown in Fig.6 and Fig.7. They are obtained with gaussian profiles for electron density and laser field intensity.

We see that the emitted energy flux increases when the filament radius is decreased or when its length is increased. As can be expected for cylindrical symmetry there is no emission in the axis. However when the field intensity is not radially symmetric, as in our case, the emission in the axis is possible.

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