Generation of second-harmonic in focusing structured laser beams inside dielectrics

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Second-harmonic emission at a frequency that is twice the laser frequency is an important diagnostic for nonlinear laser-plasma interaction. It is forbidden for centrosymmetric materials such as the bulk of sapphire. The symmetry, however, can be broken by dielectric discontinuities as a result of laser-induced plasma inside a solid dielectric. Here, for the first time to our knowledge, we have experimentally measured second-harmonic from plasmas inside the bulk of sapphire. This is performed focusing single-shot 100 fs Bessel pulses inside sapphire. This configuration creates dense sub-wavelength plasmas (diam. ≈ 200 to 500 nm) which relaxation in the material is capable of creating Warm Dense Matter [1] and lately opening voids [2].

In our experiments, a single Bessel pulse at central wavelength 800 nm was focused in the bulk of sapphire at an intensity of 10^{14} W/cm^2, in conditions where voids can be opened [1, 2]. Second-harmonic emission was recorded in a single-shot mode in the far-field. To reproduce the experiments, we performed simulations using the massively parallel EPOCH particle-in-cell (PIC) code [3].

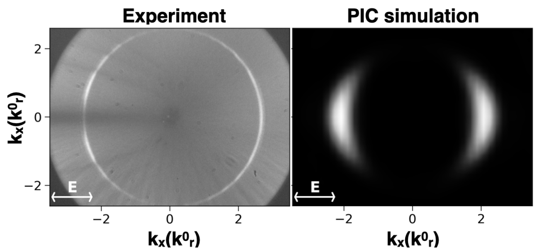

Figure 1: *Second-harmonic spatial spectrum from experiment versus simulation.* $k_\mathrm{r}^0 = k_0 \sin\theta$ *where* θ *is the cone angle.*

We analyze how the efficiency of second-harmonic generation and its polarization depend on the plasma parameters. We find that the second-harmonic is generated either due to the coalescence of two surface electromagnetic waves or nonlinear interaction between the transverse electromagnetic wave and the electron plasma wave driven by linear mode conversion. Experimental results agree very well with the theoretical predictions [see Fig. (1)] and confirm the existence of over-critical plasma inside the sapphire that is essential for the resonance of plasma waves or excitation of surface plasmons.

This research has received funding from the H2020 European Research Council (682032-PULSAR). This work was granted access to the PRACE HPC resources (PRA19_4980, RA5614), HPC resource at TGCC, CEA (A0070511001, A0090511001), and Mésocentre de Calcul de Franche-Comté.

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