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Resonance absorption in the bulk of dielectrics

K. Ardaneh[1], M. Hassan[1], J. Hoyo[1], R. Meyer[1], B. Morel[1], L. Froehly[1], R. Giust[1], C. Xie[1,2] and F. Courvoisier[1]

[1]FEMTO-ST Institute,
Univ. Bourgogne Franche-Comté, UMR CNRS 6174,
15B avenue des Montboucons, 25030 Besançon, France
[2]Ultrafast Laser Laboratory,
Key Laboratory of Opto-electronic Information Technology of Ministry of Education, School of Precision Instruments and Opto-electronics Engineering,
Tianjin University, 300072 Tianjin, China
e-mail: francois.courvoisier@femto-st.fr

At high intensity, femtosecond laser pulses shaped as Bessel beams can generate void channels with extremely high aspect ratio inside dielectrics such as sapphire, glass or fused silica [1]. This can be usefully applied to glass cutting via the ”stealth dicing” technique. This enables glass cutting a very high-speed. Many advances have been made in this regard by improving the shape of the Bessel beam to make it for instance elliptical, or to increase the aspect ratio of the beam so that stealth dicing now can be used to cut glass with thickness up to 1 cm [2]. However, the exact mechanism of energy deposition is hitherto largely unknown.

We report on several experimental campaigns where we measured single shot transmission and beam fluence sectioning, to evaluate how the energy is deposited inside dielectrics. We showed that extremely high absorption is reached during the laser pulse propagation (typically 50 percent) [3]. This raises the question why is so high energy density deposited while multiphoton absorption and avalanche ionization are generally relatively inefficient at femtosecond pulse durations.

We have conducted a series of laser plasma interaction modeling using a Particle-In-Cell (PIC) approach with EPOCH code [4]. We show that resonance absorption occurs in the bulk of dielectrics and that the transverse dimension of the laser-generated plasma is below the wavelength. This is assessed via comparisons between experimental and numerical simulation results over a number of different diagnostics. The resonance absorption phenomenon is an efficient collisionless mechanism to transfer energy from the laser wave to the plasma even for femtosecond pulse durations.

In conclusion, spatial shaping of laser pulses into Bessel pulses allows for accessing plasma profiles that are much steeper than those conventionally produced using Gaussian beams. With additional transmission measurements in a dual shot configuration, we could demonstrate that the high energy density deposited allows for transforming the material into warm dense matter in a temporal scale of 10 to 100 ps [3].

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