Driving resonance absorption with Bessel beams in the bulk of dielectrics

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At high power, ultrafast laser pulses inside transparent propagate in the "filamentation" regime. This regime is highly complex because the pulse undergoes a strong reshaping due to the combined dynamics of Kerr effect and plasma generation. However it was shown a decade ago that ultrafast pulses, when shaped into Bessel beams with sufficient focusing, can generate voids inside transparent materials in the single shot regime.

A number of materials can be processed at high aspect ratio using Bessel beams, and this has particularly led to the development of high-speed cutting of glass using the non-ablative stealth dicing technique. However, the mechanism of energy deposition was hitherto unclear. Simulations using the nonlinear Schrödinger equation combined to a plasma equation or simulations based on Maxwell's equations with a permittivity description of the plasma, were enable to reproduce to the experimental results.

Here, we demonstrate that Bessel beams can create over critical plasma densities inside the bulk of solid dielectrics, and that an essential mechanism for energy absorption is resonance absorption on the overcritical plasma.

Our approach is based on the combination of experimental campaigns and first-principles particle-in-cell simulations. By comparing experimental and simulation results, we show that the phenomenon of resonance absorption can be efficiently triggered to transfer significant amount of the laser pulse energy (typically 50%) into the laser generated plasma.