Ultrafast Physics of High-Intensity Bessel Beam Interaction with Sapphire and Applications

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When tightly focused inside transparent dielectrics, femtosecond Bessel beams generate nanoplasmaswith very high aspect ratio. We explore the microphysics of the laser-matter interaction and the nano-plasma formation using a particle-in-cell code. Our results are compared to several experimental diagnostics across various imaging diagnostics. Hitherto, these diagnostics could not be reproduced using more conventional physical models. We adapted the massively parallel Particle-In-Cell (PIC) code EPOCH, incorporating background permittivity and Keldysh field- and impact-ionization modules. We show that the formation of plasma waves by mode conversion and Landau damping are crucial in the interaction. The formation of dense plasma where the permittivity decreases down to zero allows the emergence of a rich nonlinear dynamical effects spanning from second harmonic and THz wave generation to warm dense matter formation and high-precision materials nano-structuring.

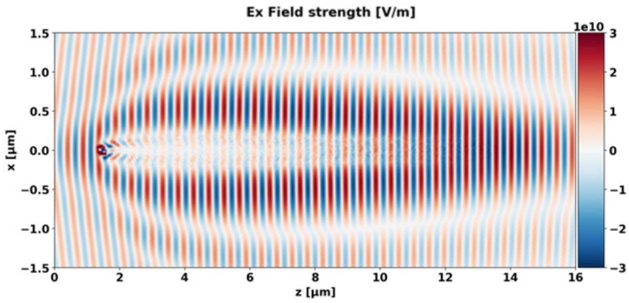

Figure 1: Numerical simulation of electric field distribution in the plane of polarization when a zeroth-order, high-intensity Bessel pulse ionizes sapphire