

Photo-induced plasma confinement in ultrashort laser-excited nanostructures

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Intense ultrashort lasers modify transient optical properties of transparent materials, converting them into cold plasma non-equilibrium state of matter. This electron-hole plasma can be confined to subwavelength nanoscale dimensions by tightly focused laser beams but remains challenging to control due to complexity of ultrashort pulse propagation in nonlinear medium and is mainly associated with laser material damage in laser processing [1]. Subwavelength nanostructures and their periodic planar arrangements (metasurfaces) enable not only plasma confinement on record nanoscales by ultrashort laser excitation [2] but also better control over the nonlinear optical response while resisting to material damage [3], which is promising for new-generation optical devices for light manipulation and modulation.

Modeling of the involved physical processes remains challenging, as it requires coupling non-paraxial full-vector light propagation in nonlinear medium with a comprehensive model for electronic excitation and material ionization at high intensities. Laser interaction with subwavelength nanostructures is discussed in the frame of 3D plasma fluid model coupled with nonlinear Maxwell propagation solver. Simulation results elucidate the spatio-temporal aspects of the electron-hole plasmas and their influence on ultrashort pulse propagation and harmonic generation.

Apart from numerous applications relying on transient optical properties, plasma nanoconfinement in nanostructured transparent materials opens new opportunities for controlling thermal gradients, melt flow, and ablation at the nanoscale, with the ultimate objective to develop new strategies for nanofabrication and adjustment of metasurfaces.

Références

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