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Ultrafast plasmonics for all-optical switching and pulsed lasers

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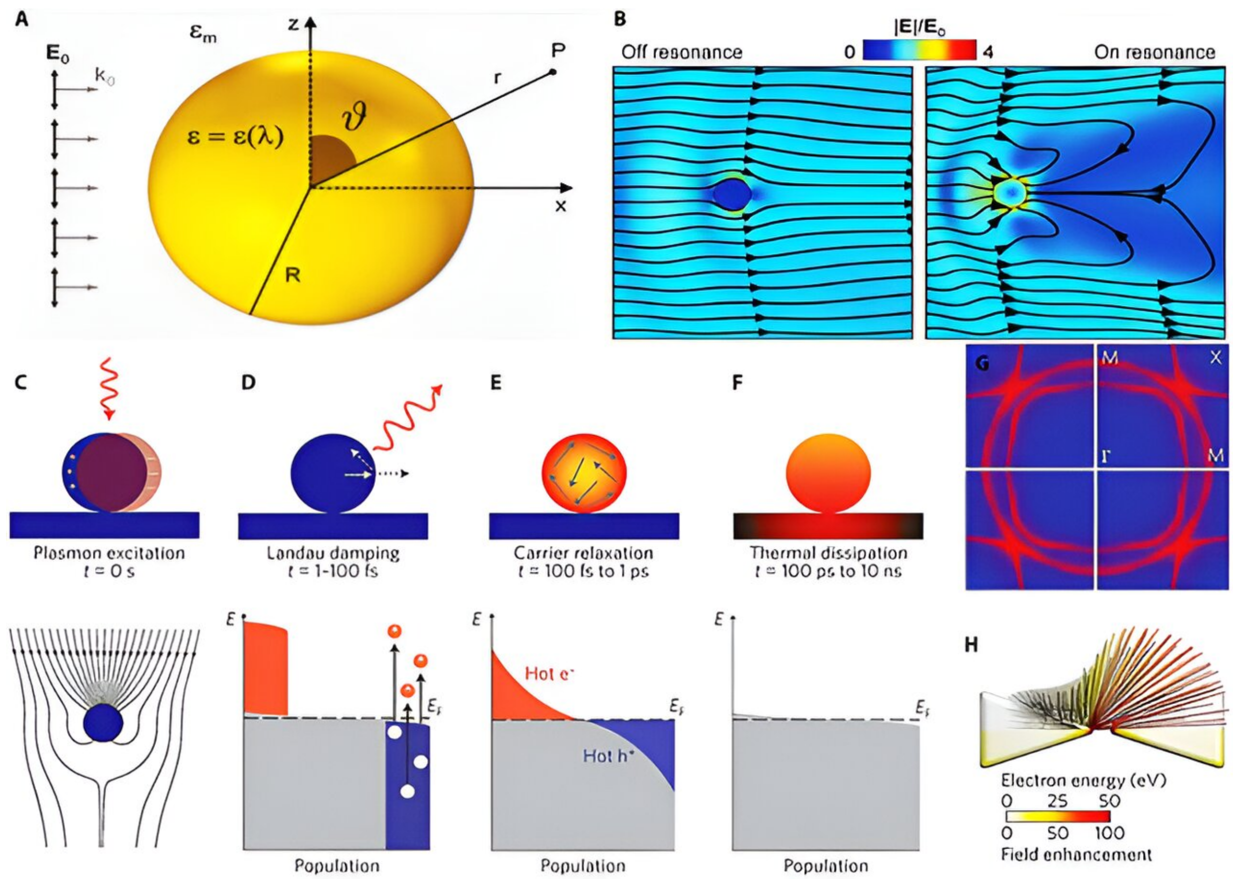

LSPR in small metallic NPs. (A) Schematic illustration for the depiction of applying an electric field along the z axis. (B) A small Ag NP is surrounded by the field enrichment (color map) and field lines of the full Poynting vector, which is either on resonance (right) at 346 nm or off-resonance (left) at 600 nm [44]. Photoexcitation and relaxation of metallic NPs. (C to F) The excitation and subsequent relaxation processes that occur when a laser pulse illuminates a metal NP. Here, gray depicts the electronic states, while red denotes excited electrons, and a deficiency of electrons (a hole) is shown in blue. (C) The activation of an LSP directs light toward and into the NP first [94,97]. (D) By following Landau damping, e–h pairs re-emit photons, or charge multiplication occurs due to e–e interaction, leading to decay within a time of τnth in the 1- to 100-fs range. (E) Scattering of e–e occurs within a time of τel in 100 fs to 1 ps. (F) Heat dissipation in the environment from 100 ps to 10 ns through the process of thermal conduction [97]. (G) Symmetry point depiction in the reciprocal wavevector space of Sr2RuO4 to monitor the momentum and energy of light-emitted electrons [102]. (H) Electronic paths and simulated field enhancement within the energy range of 0 to 100 eV, with a length of 160-nm antenna [103]. Credit: *Ultrafast Science* (2023). DOI: 10.34133/ultrafastscience.0048

Plasmonics is playing a crucial role in advancing nanophotonics, as plasmonic structures exhibit a wide range of physical characteristics that are benefited by localized and intensified light-matter interactions. These properties are exploited in numerous applications, such as surface-enhanced Raman scattering spectroscopy, sensors, and nanolasers.

In addition to these applications, the ultrafast optical response of plasmons is also a crucial property that has been exploited to attain optical signal switching across different spectral bands, which is critical for advanced optical logic circuits and telecommunication systems.

Recently, optical switching has become a significant component in the advancement of all-optical computation and signal processing, wherein these optical switching devices are required to have enhanced response speed and modulation depth along with a wide range of spectral tunability.

The recent developments in the fabrication and characterization of plasmonic nanostructures have stimulated continuous effects in the search for their potential applications in the photonics field.

Concentrating on the role of plasmonics in photonics, Prof. Liu and his team have covered recent advances in ultrafast plasmonic materials with a prime focus on all-optical switching.

Fundamental phenomena of plasmonic light-matter interaction and plasmon dynamics have been discussed by elaborating on the ultrafast processes unraveled by both experimental and theoretical methods, along with a comprehensive illustration of leveraging ultrafast plasmonics for all-optical switching and pulse laser generation with a focus on device design and performance.

Here, they have introduced light-matter interactions associated with the ultrafast plasmonic response observed in different plasmonic materials and structures in the first section and then illustrated the theoretical and experimental methods developed to investigate the ultrafast mechanism in plasmons.

In the following sections of this article, they have discussed and summarized the ultrafast plasmonic optical switching systems categorized based on plasmonic metasurfaces made of noble metals, phase-change hybrid materials, conducting oxides, and waveguides, which are further divided by spectral bands in the visible and near-infrared ranges. The last section discusses the generation of ultrafast pulse lasers by using plasmonic ultrafast optical switches.

Ultrafast plasmonics have been extensively exploited for a growing number of photonics applications. This review article will serve as reference literature for researchers to explore novel processes in photonics by incorporating plasmonics.

The findings are published in the journal *Ultrafast Science*.

More information: Muhammad Aamir Iqbal et al, Ultrafast Plasmonics for All-Optical Switching and Pulsed Lasers, *Ultrafast Science* (2023). DOI: 10.34133/ultrafastscience.0048

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