Ultrafast control of surface plasmon propagation

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Excitation of an aluminium/dielectric plasmonic waveguide with 200 fs optical pulses leads to the transient modulation of surface plasmon-polariton (SPP) signals propagating in the waveguide. We show that by tuning the excitation wavelength to aluminium's interband absorption peak at ~810 nm, a modulation depth of more than 35% can be achieved at an excitation fluence of 13 mJ/cm^2. We also consider issues relevant to the propagation of short SPP pulses in a range of metal/dielectric waveguides.

SPPs have considerable potential as information carriers for next-generation nanophotonic devices. Indeed, plasmonic technologies offer to combine the small size of today's electronic systems with the speed and bandwidth of photonic systems. Recent years have seen a range of material systems investigated for 'active' transient plasmonic switching and modulation applications, with the latest studies pushing performance limits into the femtojoule switching energy and terahertz operating frequency domains.

Here, we report on the spectral dispersion of the ultrafast optical modulation effect for an aluminium/silica SPP waveguide (inset to Fig. 1) in the vicinity of aluminium's near-infrared interband absorption peak. 'Fast' (femtosecond light-SPP coherent nonlinear interaction) and 'slow' (picosecond `Fermi smearing'/thermal) response components both increase in magnitude with wavelength towards the absorption peak at ~810 nm, providing up to 35% modulation of plasmon wave intensity (Fig. 1).

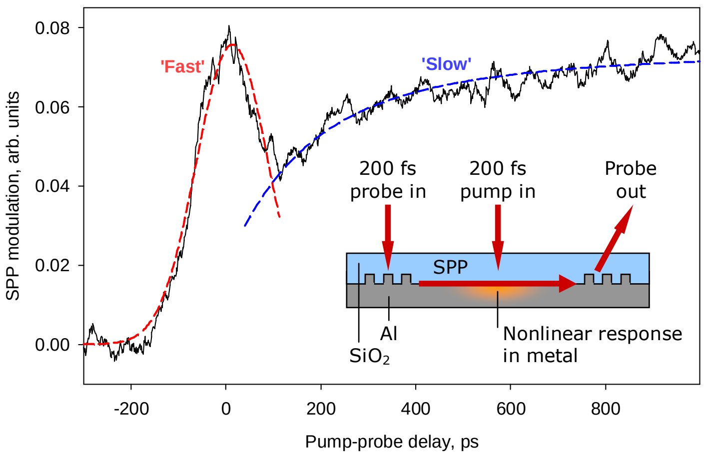

Fig. 1: Transient pump-induced modulation of decoupled SPP probe signal at 810 nm as a function of pump-probe delay, showing 'fast' (fs) and 'slow' (ps) response components. The inset shows a schematic of the experimental configuration: probe SPP generated by grating coupling on an Al/SiO$_2$ interface, modulated during propagation by direct optical excitation of the metal.

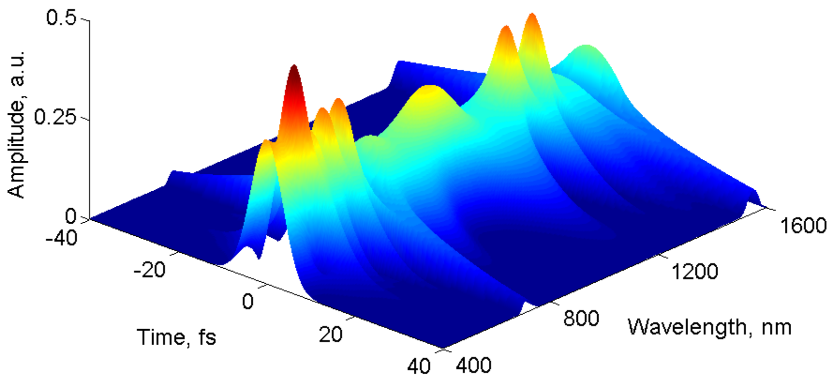

Fig. 2: Reshaping, as a function of wavelength, of a 10 fs SPP input pulse during propagation over a distance of one decay length on a gold/silica waveguide.

With regard to considering what may ultimately be achieved in nonlinear and active plasmonics, we have also numerically analyzed the propagation of short SPP pulses. These calculations reveal that significant pulse reshaping can occur (with obvious implications for repetition rate and signal contrast in device applications) as a result of the group velocity and loss dispersions in plasmonic waveguides (Fig. 2), and that these effects depend strongly on the material composition of the waveguide.

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