Ultrafast magnetophotonics and magnetoplasmonics

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Magnetoplasmonic effects such as resonant enhancement of magneto-optical response in systems supporting either local/localized or propagating surface plasmons are intensively studied last years in various nanostructured metallic materials. Besides, magnetoplasmonic crystals are prospective media for time-domain femtosecond-scale magneto-optics similar to that in magnetophotonic crystals because the mean lifetime of resonantly excited surface plasmon-polaritons (SPPs) varies from tens to hundreds of femtoseconds. One of the most prominent opportunities of using SPP nanostructures is to shape femtosecond laser pulses. The mean lifetime of SPPs in nanostructures varies from several femtoseconds to several hundreds of femtoseconds. A femtosecond laser pulse interacting with such a short-living excitation gets coherently modified as indicated in many preceding works. Temporal shaping of femtosecond laser pulses by plasmonic nanostructures was observed both for the intensity and polarization state. However, the active control of the laser pulse shaping effect with plasmonic nanostructures has not been demonstrated yet. We experimentally demonstrate the magnetic field-controlled shaping of femtosecond laser pulses reflected from a one-dimensional magnetoplasmonic crystal, which is a nickel diffraction grating supporting the SPP excitation via the +/- 1-st diffraction orders. External magnetization of the magnetoplasmonic crystal induces temporal modulation of 200 fs laser pulses when the SPP resonance is tuned across the spectral range of the femtosecond pulse being used. The switching of the pulse shape is attributed to modification of the surface magnetoplasmon dispersion law under magnetization applied in the Voigt configuration with respect to the SPP wavevector. On the other hand, time-resolved magneto-optical experiments are being developed intensively last decade due to a row of fundamental problems of ultrafast magnetization dynamics in a medium and ultrafast magnetization switching. One of the key experiments in the field is ultrafast magnetization reversal by an intense femtosecond pulse leading to, inter alia, picosecond-scale magneto-optical response dynamics. Time modulation of magneto-optical effect at subpicosecond scale is also possible without changes in the state of the media. In this work, femtosecond dynamics of Faraday effect is studied experimentally and numerically in a layered magnetic medium. Despite the conventional view of monotonic increase of Faraday angle yielded by the non-reciprocity of Faraday effect, the time dependence of the rotation angle can be not only increasing, but also decreasing, nonmonotonic, and even can change the sign. Such effects are a consequence of the structural features of the medium leading to multiple interference in magnetophotonic crystals and to large phase shifts between different parts of a single femtosecond pulse.