Enhanced and tunable magneto-optical activity in magnetoplasmonic crystals

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Abstract

We present a novel concept of a magnetically tunable plasmonic crystal based on the excitation of Fano lattice surface modes in periodic arrays of magnetic and optically anisotropic nanoantennas [1]. Due to the intrinsic magneto-optical activity of the system, two perpendicular lattice surface resonances can be induced in the crystal plane in the spectral range explored (visible/near-infrared): one directly excited by the incident light and perpendicular to its oscillation direction, and the other one, which is parallel to the oscillation direction of the incoming radiation, induced by the application of an external magnetic field perpendicular to the crystal plane (polar Kerr effect configuration). We show how the coherent diffractive far-field coupling between elliptical nickel nanoantennas is governed by the two in-plane, orthogonal and spectrally detuned localized plasmonic resonances of the individual building blocks, one directly induced by the incident radiation and oscillating parallel to it, and the other induced by the applied magnetic field and oscillating orthogonally to the directly excited localized resonance. The consequent excitation of these two Fano-like lattice surface modes leads to highly tunable and amplified magneto-optical effects as compared to a continuous magnetic film or metasurfaces made of disordered non-interacting magnetoplasmonic anisotropic nanoantennas. We demonstrate how, by tuning the pitch of the array and the shape of the individual building blocks, it is possible to design magnetoplasmonic crystals with huge and engineered optical and magneto-optical anisotropies.

We also study magnetoplasmonic crystals made of periodic nanostructured magnetic surfaces combining the features of surface plasma-polaritons excitation and magneto-optical tunability [3]. While in continuous metallic film surfaces plasma-polaritons can be excited only by a p-polarized incident radiation, a periodic modulation of the surface enables the coupling of free space radiation either p- or s-polarized to certain surface plasma-polariton modes, so called “non-collinear plasmonic modes”. Here we demonstrate that in this kind of magnetoplasmonic crystals this property, in conjunction with the intrinsic polarization conversion due to the inherent magneto-optical activity, enable coupling of non-collinear propagating surface plasmon polariton modes. We observe that the magneto-optical spectral response arises from all the excitable plasmonic modes, conventional and non-collinear, in the magnetoplasmonic crystal irrespective of the incoming light polarization. Moreover, we demonstrate that a large resonant enhancement of the longitudinal Kerr effect is induced when those special non-collinear plasmonic modes are excited.

Our findings besides unveiling the fascinating underlying physics that governs the peculiar magneto-optical properties of magnetoplasmonic crystals, open a clear path to the design of novel active metamaterials with tailored and enhanced magneto-optical activity. The concepts presented here can be exploited to design novel and ultrasensitive magnetoplasmonic sensors [3] and nanoscale metamaterials for precise control and magnetically-driven tunability of light polarization states.

References

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