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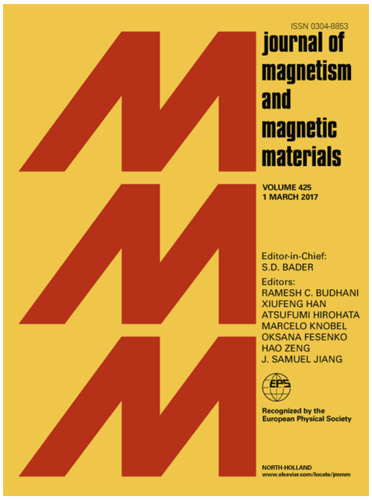

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Manipulating the light intensity by magnetophotonic metasurfaces

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Abstract

We study numerically the possibility of controlling light properties by means of an external magnetic field. Considerable changes in the shape, value, and spectral position of the magneto-optical response are demonstrated in Voigt geometry for the transmitted light depending on the parameters of the magnetophotonic metasurface made up of nickel/silicon nanoparticles. The spectral overlapping of the fundamental magnetic and electric dipole Mie resonances leads to interference with a strong modification of phase relations, which manifests itself through an enhanced magneto-optical signal.

Keywords: Mie resonances, high-index nanoparticles, metasurfaces, optical magnetism, magneto-optical effects

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1. Introduction

A pursuit to use optical circuits as a faster alternative to electronic ones demands building blocks with the size smaller than the wavelength of light. These blocks are meant to work as active devices, which are capable of manipulating the light properties under the action of an external stimulus. The nature of such influence can be various: thermal [1], electrical [2, 3], optical [4, 5, 6] or magnetic as well [7]. Modern photonics is going hand in hand with the magnetic science, thus opening new horizons for controlling the optical response via magnetic field [8] as well as magnetic domains of the sample via light impact [9]. The miniaturization of devices can be realized through nanostructuring of the materials. This gives rise to various types of resonances and optical effects that can be significantly enhanced under these coditions. Thus, being a multilayered system with alternative quarter-wavelength-thick magnetic and dielectric layers, magnetophotonic crystals can enhance Faraday effect by more than one order of magnitude [10, 11, 12]. This result accounts for the effect of slow light leading to an enlarged interaction time of light with a magnetic medium. A new apparatus for measuring Faraday rotation as low as 0.001° is suggested recently [13]. These nanostructures allow one to modulate polarization state of the light even at a femtosecond time scale [14]. An alternative way is to use plasmonic structures [8, 15, 16, 17, 18]. Excitation of the surface plasmon-polariton leads to the transverse magneto-optical Kerr effect being significantly increased [15]. The use of magnetoplasmonic crystals provides for the shape manipulating of a femtosecond pulse driven by an external magnetic field [17]. The excitation of local plasmons is another way to amplify the magneto-optical response [18, 19]. A significant progress in studying magneto-optics is reached in systems with extraordinary transmission [20, 21]. These resonances are highly dependent on the choice of geometry and environment, which makes it possible to shift the magneto-optical enhancement to the desired spectral region [22]. However, plasmonic materials have a certain disadvantage: a high imaginary part of the material refractive index results in undesirable losses at optical frequencies.

Optical resonances of high-index dielectric nanostructures are known for a high concentration of light energy at the nanoscale with low losses [23]. A strong magnetic dipole resonance, now called as *optical magnetism*, can be realized according to the exact Mie solution of light scattering by a small sphere, even if it is made of nonmagnetic materials [24]. Recently, this has been experimentally demonstrated for silicon nanoparticles in the visible spectral range [25]. The magnitude of the magnetic dipole resonance exceeds the electric dipole one. The increase of the particle size shifts these resonances to the infrared region, while multipoles of higher orders are moved to the visible part of the spectrum. Significant progress has been achieved in the development of not only silicon spheres' optical response, but also from other shapes of nanoparticles as well [26, 27, 28, 29]. These nanoparticles are known for their high impact of the magnetic component of light leading to strong magnetic dipole resonances of the Mie-type. Furthermore, nanodisks made of materials with high refractive indices can enhance nonlinear optical response and oligomers of such nanoparticles also pave the way for new bright nonlinear phenomena [30, 31].

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