Magneto-optical Effects in Subwavelength Nanoparticles Enhanced by Optically-induced Magnetic Resonances

M. G. Barsukova[1], **A. S. Shorokhov**[1], **A. I. Musorin**[1], **M. R. Shcherbakov**[1], **D. N. Neshev**[2], **A. A. Fedyanin**[1], **and Yu. S. Kivshar**[2]

[1]Faculty of Physics, Lomonosov Moscow State University, Moscow 119991, Russia
[2]Nonlinear Physics Centre, Research School of Physics and Engineering
The Australian National University, Canberra, Australian Capital Territory 0200, Australia

Abstract— Control of light by an external magnetic field is one of the important methods for modulation of its intensity and polarization. The concept of metamaterials allows to design artificial subwavelength meta-atoms that support a strong magnetic response, usually termed as optical magnetism, even when they are made of nonmagnetic materials. Then, the important fundamental question is what would be the effect of interaction between an external magnetic field and artificial magnetic response of metamaterial structures. Here, we make the first step toward answering this fundamental question and study magneto-optical response of nanostructured dielectric metasurfaces.

High-index nanostructures offer novel opportunities for controlling light at the nanoscale based on a strong localization of both electric and magnetic fields in such structures near the corresponding Mie resonance [1]. This fact makes them similar to plasmonic nanostructures with an advantage, however, that all-dielectric metamaterials composed of nanoparticles with high refractive index can overcome this limit and establish a new platform for nanophotonic metadevices [2]. It is well established that by applying a magnetic field one can control the optical response of various magnetic structures [3, 4].

We consider metasurfaces composed of a thin nickel (Ni) film deposited on top of an array of silicon (Si) nanodisks with different diameters and study optical and magneto-optical response of such hybrid planar structures. The shape of the nanodisks is chosen to match the position of the lowest Mie resonances [5]. Magnetic dipole resonance of such structures exists in the visible spectral range and the spectrum of the magneto-optical response shows a resonant enhancement in the spectral vicinity of the magnetic dipole Mie resonance. Magneto-optical response is defined as follows: $[T(H) - T(-H)]/T(0)$, where T is the transmittance and H is the applied external magnetic field. We also compare magneto-optical response of the sample with the reference thin Ni film. The magneto-optical spectrum achieved for a plain Ni film does not have any resonant features. On contrary to the original sample, the magneto-optic effect is approximately 5 times larger for the spectral position of the optical magnetic resonance at 680 nm. Thus, we can connect the magneto-optical enhancement with the magnetic dipole resonances of the Si nanodisks in the metasurface.

REFERENCES

1. Kuznetsov, A. I., et al., "Optically resonant dielectric nanostructures," *Science*, Vol. 354, aag2472, 2016.
2. Zheludev, N. and Y. Kivshar, "From metamaterials to metadevices," *Nature Materials*, Vol. 11, 917, 2012.
3. Inoue, M., et al., "Magnetophotonics," *Springer Series in Materials Science*, Chap. 178, Springer-Verlag, Berlin Heidelberg, 2013.
4. Inoue, M., et al., "Magnetophotonic crystals," *Journal of Physics D: Appl. Phys.*, Vol. 39, R151, 2006.
5. Staude, I., et al., "Tailoring directional scattering through magnetic and electric resonances in subwavelength silicon nanodisks," *ACS Nano* Vol. 7, 7824, 2013.