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Editorial

Focus on magnetoplasmonics

Gaspar Armelles[1] **and Alexandre Dmitriev**[2]
[1] IMM-Instituto de Microelectrónica de Madrid (CNM-CSIC), Isaac Newton 8, PTM, E-28760, Tres Cantos, Madrid, Spain
[2] Department of Applied Physics, Chalmers University of Technology, Göteborg 42196, Sweden

E-mail: gaspar@imm.cnm.csic.es and alexd@chalmers.se

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Abstract
In this ‘focus on’ collection, a snapshot of the new, fast emerging field of magnetoplasmonics is presented. The research in the field deals with the combination of plasmonics and magnetism to elucidate the fundamentals of spin–plasmon interactions and reach new functionalities such as the enhancement of magneto-optical activity in various materials, active control of plasmons with weak magnetic fields, magnetoplasmonics-based bio- and chemical sensing, magnetophotonic and magnetoplasmonic crystals as modulators of light transmission and reflection, and many others.

Keywords: magnetoplasmonics, magneto-optics, nanoplasmonics

In the last few years, much effort has been devoted to the study of the properties of collective electromagnetic excitations with a formidable ability to couple free-space electromagnetic radiation to the nanoscale, and to strongly localize and enhance the corresponding electromagnetic fields. These excitations, known as surface plasmons, play a very prominent role in the optical response of the large range of nanoscale material systems, from metals to graphene. Their relevance to light–matter interactions was recognized more than a century ago, but it was not until the strong recent development of nanotechnology and our ability to control materials at the nanoscale that plasmonics has become a burgeoning research field, with applications spanning energy harvesting, telecoms and sensing [1].

To achieve new functionalities, the combination of plasmons with other material properties has become increasingly appealing. In particular, the field dubbed 'magnetoplasmonics' combines magnetism and plasmonics to develop several novel concepts in materials science [2]. To name a few, these are: the fundamental studies of plasmon–spin interactions in various spectral ranges; the enhancement of magneto-optical activity in materials, including diamagnetics, graphene and others; active control of plasmons with weak magnetic fields; magnetoplasmonics-based bio- and chemical sensing; and magnetophotonic and magnetoplasmonic crystals as modulators of light transmission and reflection.

One of the mentioned lines of research in magnetoplasmonics concerns the studies of new ways to control the properties of surface plasmons using magnetic fields (figure 1(a)). Its effect was first analyzed in the early 1970s on structures made from highly doped semiconductors, where surface plasmons occur in the far-infrared region. It was shown that depending on the relative orientation of the surface plasmon wave vector and the applied magnetic field, the magnetic field could control properties of surface plasmons such as, for example, propagation or localization. This versatility makes the magnetic field very attractive for the development of new active devices, but, unfortunately, for pure noble-metal-based structures, the magnetic field required to achieve proper control of surface plasmon properties is too high for application purposes. To decrease this magnetic field, the use of complex structures made from ferromagnetic materials and noble metals has been proposed. These systems exhibit simultaneously magnetic and plasmonic properties. By an adequate choice of the internal structure of the system, the plasmon properties can be controlled by a (low) magnetic field. The plasmon enhancement of magneto-optical (MO) activity towards optical isolation, acousto-magnetoplasmonics or plasmon-mediated MO transparency are explored [3]. There is a move towards ultrafast magnetoplasmonics with such hybrid plasmon–ferromagnet thin films systems for the eventual on-chip control of light [4].

Another facet of magnetoplasmonics is the focus on localized plasmons in magnetic nanostructures or in the combined magnetic–nanoplasmonic architectures (figure 1(b)). Here, in contrast to heavily damped propagating surface plasmons in magnetic metals, strong effects on magneto-optics are present due to plasmon-induced phase modification of the reflected or transmitted light. As a consequence, the enhancement of MO effects [5] and the large tunability of the magneto-optical response [6] are achieved. In practice, magnetoplasmonics start to play a prominent role in the design of next-generation memory storage technology. The hard disk drive industry is facing a major challenge in continuing to provide increased areal density, driven by the ever-increasing data storage requirements. The heat-assisted magnetic recording approach provides a combination of high coercive field magnetic materials with local heating by a plasmon nanoantenna [7]. This approach currently allows up to record-breaking 1 Tb $inch^{-2}$ storage densities.

In this 'focus on' collection, a snapshot of the field of magnetoplasmonics is presented. The contributions cover both theoretical and experimental investigations in this fast developing field. In particular, the research areas discussed include: the optical response of subwavelength magnetoplasmonic nanowire gratings [8], theoretical and experimental evaluation of plasmonic and magnetoplasmonic interferometers as refractometric-based sensors [9], the magnetic-field-induced wave-vector modulation and field distribution of surface plasmon polaritons in dielectric/metal and dielectric/metal/dielectric systems [10], and the manipulation of the

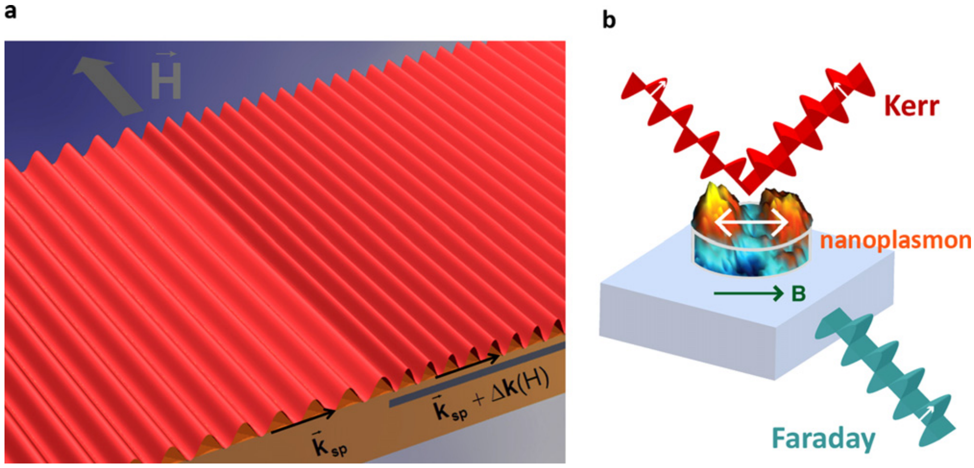

Figure 1. (a) Modulation of a propagating surface plasmon by the applied magnetic field when the ferromagnetic layer (gray) is adjacent to plasmon-supporting noble metal (light brown); (b) tunable Kerr and Faraday effects in nanoferromagnets with localized plasmons—the scattering scanning near-field optical microscopy (s-SNOM) experimentally mapped enhanced electromagnetic fields of the excited localized plasmon resonance in the Ni nanodisk are depicted by the colored landscape.

transverse magneto-optical Kerr effect in periodic metal–dielectric hybrid structures—magnetoplasmonic crystals [11].

References

[1] For recent reviews—see Stockman M I 2011 *Opt. Express* **19** 22029
Atwater H *et al* 2010 *Nat. Mater.* **9** 205
Konstantatos G *et al* 2010 *Nat. Nanotechnol.* **5** 391
[2] Armelles G *et al* 2013 *Adv. Opt. Mater.* **1** 10
[3] Temnov V V *et al* 2010 *Nat. Photon.* **4** 107
Belotelov V I *et al* 2011 *Nat. Nanotechol.* **6** 370
Temnov V V *et al* 2013 *Nat. Commun.* **4** 1468
Chin J Y *et al* 2013 *Nat. Commun.* **4** 1599
Belotelov V I *et al* 2013 *Nat. Commun.* **4** 2128
[4] Temnov V V 2012 *Nat. Photon.* **6** 728
[5] Gonzalez-Diaz J B *et al* 2008 *Small* **4** 202
Banthi J C *et al* 2012 *Adv. Mater.* **24** OP36
[6] Bonanni V *et al* 2011 *Nano Lett.* **11** 5333
Maccaferri N *et al* 2013 *Opt. Express* **21** 9875
Maccaferri N *et al* 2013 *Phys. Rev. Lett.* **111** 167401
[7] Stipe B C *et al* 2010 *Nat. Photon.* **4** 484
Challener W A *et al* 2009 *Nat. Photon.* **3** 220
[8] Marinchio H *et al* 2014 *New J. Phys.* **16** 015007
[9] Martín-Becerra D *et al* 2013 *New J. Phys.* **15** 085021
[10] Torrado J F *et al* 2013 *New J. Phys.* **15** 075025
[11] Pohl M *et al* 2013 *New J. Phys.* **15** 075024