AGjDPG 2: PhD Symposium: Magnon Plasmonics (jointly with MA)

Organizers: Th. Meyer, P. Melchior, M. Rollinger, Ph. Thielen (TU Kaiserslautern)

This symposium intends to bring researchers from both research fields in contact and trigger new cooperations and future research projects in the field of Magnon-Plasmonics. In order to merge both research fields, the symposium will start off with an introductory talk presenting the basics of both fields and developing a common basis for the following talks. This introduction is given by Prof. Robert Stamps (University of Glasgow). Prof. Dirk Grundler (University of Technology München) is going to give an invited talk about spin waves in artificial ferromagnetic materials, i.e. two-dimensional magnonic crystals. Afterwards, Dr. Antonio García-Martín (Instituto de Microelectronica de Madrid) will present a theoretical overview of the field of Magneto-Plasmonics, followed by Dr. Alexandre Dmitriev (Chalmers University of Technology Göteborg) presenting his experimental work on magneto-plasmonics and nanoplasmonics. Finally, an invited talk on ultrafast dynamics in magneto-plasmonic multilayer structures will be held by Dr. Vasily Temnov (Université du Maine, Le Mans).

Time: Tuesday 9:30–15:45 Location: HSZ 04

Topical Talk AGjDPG 2.1 Tue 9:30 HSZ 04

Plasmons & Magnons: Collective excitations of charge and spin — •Robert Stamps — SUPA School of Physics and Astronomy, University of Glasgow, Glasgow, UK

An overview of basic concepts essential for understanding GHz and THz excitations in magnetic spin and plasmonic systems will be presented. The talk will provide an introduction to spin waves in magnetic insulators and metals. Methods of generating and detecting magnetic spin excitations will be surveyed, and the interaction of optical light with magnetic materials will be discussed. A similar overview of how plasmons propagate in films and at surfaces will be presented, including a summary of how plasmons can be excited and observed. Lastly, some of the issues involved in considering possibilities for plasmon-magnonics will be highlighted and reviewed.

Topical Talk AGjDPG 2.2 Tue 10:15 HSZ 04

Nanomagnonics - reprogrammable wave control beyond plasmonics — •Dirk Grundler — Lehrstuhl fuer Physik funktionaler Schichtsysteme, Physik Department, TU Muenchen, Garching, Germany

Periodically nanopatterned thin-film ferromagnets have been shown to form magnonic crystals (MCs) [1], i.e., artificial crystals exhibiting tailored band structures for spin waves (magnons). In the GHz frequency regime, wave lengths of spin waves (SWs) are shorter by a few orders of magnitude compared to electromagnetic waves at the same frequency. At the same time unit cells of periodic magnetic lattices can exhibit different non-volatile remanent configurations leading to both reconfigurable band structures [2] and metamaterials properties for SWs [3] not known from photonics or plasmonics. MCs thereby offer a further approach for wave control in solid-state devices on the nanoscale. We show reprogrammable magnonic properties that might fuel further ideas when plasmonics meets magnonics.

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[1] S. A. Nikitov, P. Tailhades, and C. S. Tsai, J. Magn. Magn. Mater. 236, 320 (2001). [2] J. Topp, D. Heitmann, M. Kostylev, and D. Grundler, Phys. Rev. Lett. 104, 207205 (2010). [3] R. Huber et al., Appl. Phys. Lett. 102, 012403 (2013).

AGjDPG 2.3 Tue 10:45 HSZ 04

Plasmonic excitations in permalloy wires imaged by XPEEM — •Ahmet Akin Ünal[1], Judith Kimling[2], Sergio Valencia[1], and Florian Kronast[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Strasse 15, D-12489 Berlin, Germany — [2]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung Hamburg, Universität Hamburg, Jungiusstrasse 11, D-20355 Hamburg, Germany

We investigate the influence of surface plasmon resonances in laser-excited gold nanoantennas on the demagnetization of neighboring magnetic microstructures. At metal surfaces, electromagnetic waves and light waves can couple with each other, forming surface plasmons (SP). A gold nanoantenna can be regarded as a resonator for SPs. In the case of resonant excitation, the oscillation amplitudes of the plasmon waves can overcome the excitation amplitude by orders of magnitude giving rise to a strong enhancement of the local electromagnetic field. Here, we investigate this local field effect of the plasmonic antennas on the neighboring permalloy microstructures, specifically on their magnetization dynamics. Permalloy (Ni0.81Fe0.19) microstructures and gold antennas were prepared by e-beam lithography on a Si(110) substrate. We studied the switching as function of laser polarization and power and we find that the laser power threshold, above which switching occurs, is much lower for structures with antennas than for reference structures without antennas next to them. This allows us to quantify the effect of the plasmonic antennas in each structure and compare it to plasmonic wave fields imaged by PEEM.

AGjDPG 2.4 Tue 11:00 HSZ 04

Tuning of the transverse magneto-optical Kerr effect in magneto-plasmonic crystals — •L.E. Kreilkamp[1], M. Pohl[1], V.I. Belotelov[2,3,4], I.A. Akimov[1], A.N. Kalish[2,3,4], N.E. Khokhlov[2,3], V.J. Yallapragada[5], A.V. Gopal[5], M. Nur-E-Alam[6], M. Vasiliev[6], D.R. Yakovlev[1], K. Alameh[6], A.K. Zvezdin[3,4,7], and M. Bayer[1] — [1]Experimentelle Physik 2, TU Dortmund, D-44221 Dortmund, Germany — [2]Lomonosov Moscow State University, 119991 Moscow, Russia — [3]Russian Quantum Center, 143025 Moscow, Russia — [4]Prokhorov General Physics Institute, Russian Academy of Sciences, 119991 Moscow, Russia — [5]Tata Institute of Fundamental Research, 400005 Mumbai, India — [6]Electron Science Research Institute, Edith Cowan University, 6027 Joondalup, WA, Australia — [7]Moscow Institute of Physics and Technology (State University), 141700, Dolgoprudny, Russia

Spectral properties of the transverse magneto-optical Kerr effect (TMOKE) in periodic metal-dielectric hybrid structures are studied, in particular with respect to the achievable magnitude. It is shown that the TMOKE is sensitive to the magneto-optical activity of the bismuth-substituted rare-earth iron garnet, which is used as dielectric material. For samples with larger Bi substitution level and, consequently, larger gyration constant, the magnitude of the TMOKE increases and reaches 13% in the case of a $Bi_{1.8}$ $Lu_{1.2}Fe_{3.6}Al_{1.4}O_{12}$ magnetic film. Further, it is demonstrated that the TMOKE vanishes at the high-symmetry points of the Brillouin zone (at the γ and X points). The role of different surface plasmon polaritons is discussed.

15 min. break

Topical Talk AGjDPG 2.5 Tue 11:30 HSZ 04

Basic concepts of magneto-plasmonics illustrated with an exactly solvable system — •Antonio García-Martín, Gaspar Armelles, Alfonso Cebollada, and Maria U. Gonzalez — IMM-Instituto de Microelectrónica de Madrid (CNM-CSIC), Issac Newton 8, PTM, E-28760 Tres Cantos, Madrid, Spain

In this talk I will give a brief introduction about the concept of magneto-plasmonics (our perspective). That will be followed by a discussion on the relevant materials or combinations. To finish we will focus on a simple example of an exactly solvable (analytic) system for coupled localized magneto-optically active plasmons, that will be compared with a, very illustrative, analog based on classical oscillators.

AGjDPG 2.6 Tue 12:00 HSZ 04

Control of light emission with magneto-optical particles — •Nuno de Sousa[1], Luis S. Froufe-Perez[2], and Antonio Garcia-Martin[3] — [1]Dept. Fisica de la Materia Condensada, Universidad Autonoma de Madrid, E-28049 Madrid, Spain — [2]Instituto de Estructura de la Materia, CSIC, Serrano 121, E-28006 Madrid, Spain — [3]IMM-Instituto de Microelectrónica de Madrid (CNM-CSIC), Issac Newton 8, PTM, E-28760 Tres Cantos, Madrid, Spain

The possibility of creating and manipulate nanostructured materials encouraged the exploration of new strategies to control the electromagnetic properties with an external agent. A possible approach is combining magnetic and plasmonic materials, where it is feasible control the optical properties with magnetic fields.

In this presentation we will show a fundamental study of the properties of an emitter in two different situations: in the presence of a single magneto-optical nanoparticle and inside of a cavity formed by two magneto-optical nanoparticles. We analyze the dependence of the decay rate and the field patterns in the presence and absence of the magnetic field.

In the first case we show that the decay rate of an emitter is invariant in respect to the out-of-diagonal elements of the polarizability tensor, although the field patterns of the system can be modified.

In the second case we study the modification of the emission pattern considering the coupling between particles. Like in the previous situation, we also explore the modifications of the decay rate dependence as well as the field patterns.

AGjDPG 2.7 Tue 12:15 HSZ 04

Magneto-Photonic Intensity Effects in Hybrid Metal-Dielectric Structures — V.I. Belotelov[1,2,3], •M. Jäckl[4], L.E. Kreilkamp[4], A.N. Kalish[1,2,3], I.A. Akimov[4,5], D.A. Bykov[6], S. Kasture[7], V.J. Yallapragada[7], Achanta Venu Gopal[7], A.M. Grishin[8], S.I. Khartsev[8], M. Nur-E-Alam[9], M. Vasiliev[9], L.L. Doskolovich[6], D.R. Yakovlev[4,5], K. Alameh[9], A.K. Zvezdin[2,3], and M. Bayer[4] — [1]Lomonosov Moscow State University, Leninskie gori, 119991 Moscow, Russia — [2]Russian Quantum Center, 143025 Skolkovo, Moscow Region, Russia — [3]Prokhorov General Physics Institute, Russian Academy of Sciences, 119991 Moscow, Russia — [4]Experimental Physics 2, TU Dortmund University, 44221 Dortmund, Germany — [5]Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [6]Image Processing Systems Institute, Russian Academy of Sciences, 443001 Samara, Russia — [7]Tata Institute of Fundamental Research, 400005 Mumbai, India — [8]Royal Institute of Technology, Kungl Tekniska Hogskolan, 164 40 Stockhol-Kista, Sweden — [9]Electron Science Research Institute, Edith Cowan University, 6027 Joondalup, W.A., Australia

We present our study on a novel magneto-optical phenomenon observed in a hybrid metal-dielectric structure consisting of a one-dimensional gold grating on top of a magnetic waveguide layer. A magnetic field applied perpendicularly to the grating slits modifies the field distribution of the optical modes and thus changes the mode excitation conditions. In the optical far-field, this manifests in the alteration of the optical transmittance or reflectance.

Lunch Break (60 min.)

Topical Talk AGjDPG 2.8 Tue 13:30 HSZ 04

Magnetoplasmonics with plasmon nanoantennas — •Alexandre Dmitriev — Applied Physics, Chalmers University of Technology, 41296 Göteborg, Sweden

The combination of magnetism and plasmonics developed into a new burgeoning field, where the control of non-reciprocity in light's interaction with a magnetized media is targeted for various applications. I discuss the use of various ferromagnetic or hybrid noble metal-ferromagnetic plasmon nanoantennas to achieve broadband control of the magneto-optic response over the entire visible and near-infrared wavelength range. One example is the deployment of the magneto-plasmonic anisotropy to earn the broadband tunability of both the sign and amplitude of the Kerr rotation, crafting the manifold enhanced magneto-optical response of a chosen sign in spectral regions where the same ferromagnetic thin-film material shows the complete absence of naturally occurring magneto-optical Kerr effect. Another example is magnetoplasmonics-controlled circular dichroism.

AGjDPG 2.9 Tue 14:00 HSZ 04

Optical and magnetic properties of ferromagnetical nanostructures evolving from islands to holes — •Hui Fang — Institut fuer Experimentalphysik, Freie Universitaet Berlin Arnimallee 14 D-14195 Berlin (Germany)

The optical and magneto-optic properties of nanostructured ferromagnetic films will be presented. A series of Nickel and Cobalt thin-film periodic nanostructures evolving from islands to holes were produced by the method named self-assembly sphere lithography (SSL), varying the holes diameters while keeping the lattice constant fixed. We have observed the enhancement of Kerr rotation, which is related to the surface plasmon resonances and the size and the shape of the periodic nanostructures. Further we provide the experimental demonstration of plasmonic resonances in a percolation series of periodic nanostructures even in ferromagnets.

AGjDPG 2.10 Tue 14:15 HSZ 04

Spatially resolved magneto-optic surface plasmon resonance measurements in IrMn/Co/Au layers with parallel-stripe domains — •Nicolas Müglich, Sebastian Kübler, Kerstin Kämpf, Friedrich Herberg, and Arno Ehresmann — Department of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel

In the past it has been demonstrated that the sensitivity of surface plasmon resonance (SPR) based biosensors can be improved by a combined measurement of the SPR effect and the transverse magneto-optic Kerr effect. The magneto-optic surface plasmon resonance (MOSPR) of Au/IrMn/Co/Au exchange biased thin film systems, magnetically stripe patterned by He ion bombardment, has been measured spatially and angular resolved in transverse geometry. We show promising results which indicate that MOSPR based sensors may be designed without the usage of external magnetic fields in the future.

Topical Talk AGjDPG 2.11 Tue 14:30 HSZ 04

Ultrafast phenomena in magneto-plasmonic multilayer structures — •Vasily Temnov — Institut des Molécules et Matériaux du Mans, UMR CNRS 6283, Université du Maine, 72085 Le Mans cedex, France

The ultimate speed limits of magneto-plasmonic devices can be explored by monitoring the ultrafast dynamics in metal-ferromagnet multilayer structures excited by intense femtosecond laser pulses.

In this talk I will discuss the interaction mechanisms between transient plasmonic, electronic, acoustic and magnetic excitations observed in these structures at ultrafast time scales [1].

[1] V.V. Temnov, "Ultrafast acousto-magneto-plasmonics", Nature Photonics 6, 728 (2012)

POSTER

AGjDPG 2.12 Tue 15:01 HSZ 04

Brillouin light scattering investigations of perpendicular standing spin waves at Au and Ag nanoparticles on top of a $Ni_{81}Fe_{19}$ film — •Thomas Meyer, Björn Obry, and Burkard Hillebrands — FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

In the last decades various optical characterization methods like Raman spectroscopy made use of the excitation of plasmons in metallic nanoparticles. Due to a local field enhancement provided by localized plasmons the signal strength as well as the spatial resolution can be significantly increased. This effect is often referred to as surface enhancement like in the case of surface enhanced Raman spectroscopy. We present Brillouin light scattering (BLS) studies of perpendicular standing spin waves in a thin $Ni_{81}Fe_{19}$ film with single gold and silver nanoparticles on top. At the position of the nanoparticles an increase of the BLS signal as well as a frequency shift of the spin waves is observed. Besides their plasmonic properties other influences of the nanoparticles on the magnetization dynamics have to be taken into account. In order to identify the different contributions to the observed signal changes, investigations using different materials, sizes and shapes of the structures have been performed.

AGjDPG 2.13 Tue 15:01 HSZ 04

Magnonic grating coupler effect in a ferromagnetic thin film with a periodic array of embedded nanodisks — •Stefan Maendl, Florian Heimbach, Haiming Yu, and Dirk Grundler — Physik Department E10, TU München, Garching, Germany

Magnonics is a growing research field where one aims at controlling spin waves on the nanoscale. Microwave-to-magnon transducers are in particular important for coupling magnonic devices to conventional microwave circuits. It was found recently that the reciprocal-lattice vector provided by a periodic lattice of non-resonant magnetic nanodisks adds to the wave vector of a Damon-Eshbach mode that a coplanar wave guide induces in an underlying ferromagnetic thin film [1]. In the present work, we aim at optimizing this so-called grating-coupler effect for different material combinations, lattice constants, symmetries of the lattice and/or sizes of the nanodisks. We report our recent results. The work is supported by the DFG via GR1640/5 in SPP 1538 and NIM.

[1] H. Yu et al., Nat. Commun. 4, 2702 (2013)

AGjDPG 2.14 Tue 15:01 HSZ 04

Plasmonic and magnonic waveguide excitations in $Ni_{81}Fe_{19}$-Au bilayer microstructures investigated by means of photoemission spectroscopy and Brillouin light scattering spectroscopy — •Philip Thielen[1,2], Markus Rollinger[1], Pascal Melchior[1], Thomas Meyer[1], Björn Obry[1], Burkard Hillebrands[1], and Martin Aeschlimann[1] — [1]Physics Department and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School of Excellence Materials Science in Mainz, Kaiserslautern, Germany

The interaction between magnons and plasmons has been scarcely investigated up to now. In our contribution, we present a preliminary study on the excitation of magnons and plasmons in microstructured $Ni_{81}Fe_{19}$-Au bilayers. Here, 8-15 μm wide $Ni_{81}Fe_{19}$ stripes act as spin-wave waveguides. The magnonic excitation is induced through the Oersted field of a microwave current in a Cu antenna situated on top of the waveguides. By means of Brillouin light scattering, the excitation of magnons in these waveguides is observed. Additionally, Au nanostructures on top of the $Ni_{81}Fe_{19}$ stripes serve as plasmonic waveguides and resonators. The optical excitation of propagating as well as localized surface plasmons in those structures is observed by employing photoemission electron microscopy. These first investigations show a way to examine magnonic as well as plasmonic excitations in the same structure, providing a starting point to study their interaction.

AGjDPG 2.15 Tue 15:01 HSZ 04

Magnetoplasmonics in Co and Ni nanoferromagnets — •Irina Zubritskaya[1], Kristof Lodewijks[2], Randy Dumas[3], Addis Mekkonen[4], Johan Åkerman[5], and Alexandre Dmitriev[6] — [1]Department of Applied Physics, Chalmers University of Technology, Gothenburg, Sweden — [2]Department of Applied Physics, Chalmers University of Technology, Gothenburg, Sweden — [3]Department of Physics, University of Gothenburg, Gothenburg, Sweden — [4]Department of Applied Physics, Chalmers University of Technology, Gothenburg, Sweden — [5]Department of Physics, University of Gothenburg, Gothenburg, Sweden — [6]Department of Applied Physics, Chalmers University of Technology, Gothenburg, Sweden

In our study, we compare magnetoplasmonic response in pure ferromagnetic nanostructures made of Co and Ni with magneto-optical response in respective continuous films of the same thickness. We show that localized surface plasmon resonances determine the magneto-optical response. Spectroscopic Kerr rotation values for all types of nanostructures and continuous films are obtained using longitudinal magneto-optical Kerr effect (L-moke) in P- and S- configurations of light polarization with respect to the magnetic field covering the region of wavelengths from 450 to 1100 nm. Both magnitude and sign of Kerr rotation angle depend on which plasmonic mode is excited and how the electric and the magnetic fields are oriented with respect to each other. We also demonstrate how the magnetic coupling between the particles in a dimer is affected by the gap size.