DF 9: Poster Session

Many thanks to NT-MDT for providing sustenance.

1-6:	Optical and nonlinear optical properties, photonic
7-12:	Nano- and microstructured dielectrics / thin films
13-14:	Dielectric surfaces and interfaces
15:	High- and low-k-dielectrics
16:	Developments and applications of Dielectric Materials
17-24:	Ferroic domains and domain walls
25-33:	Multiferroics

Time: Tuesday 14:00–16:00 Location: P1C

DF 9.1 Tue 14:00 P1C

Wave vector dependent dielectric function and ab initio materials physics — •René Wirnata[1], Ronald Starke[1], Giulio Schober[2], and Jens Kortus[1] — [1]Institut für Theoretische Physik, TU Freiberg — [2]Institut für Theoretische Physik, Uni Heidelberg

We study the wave vector dependence of the dielectric function for a set of crystallographically simple materials (such as C, Si, AlP, GaAs, LiF in fcc structure). For this purpose, the FP-LAPW method in Density Functional Theory (DFT) has been combined with the Kubo formula in order to connect quantum mechanical ab initio calculations with quantities from classical electrodynamics. Conceptually, our work is motivated by the rising importance of modern microscopic approaches to electrodynamics in materials, which lead to universal though wave vector dependent response relations between different electromagnetic material properties.

DF 9.2 Tue 14:00 P1C

Second-Harmonic analysis of ion-implanted $LiNbO_3$: Effect of ion-implantation on the nonlinear susceptibility — •Kai J. Spychala[1], Lei Wang[2], Gerhard Berth[1], and Artur Zrenner[1] — [1]Department Physik, Universität Paderborn, 33098 Paderborn, Germany — [2]School of physics, Shandong University, 250100 Shandong, PR China

On the way to integrated $LiNbO_3$ optics a key technology is the fabrication of high quality optical waveguides. The formation of waveguides is accompanied by a severe modification of the crystal structure, which may substantially change the optical properties of the used material. Within this work, the effective nonlinear coefficients in ion-implanted $LiNbO_3$ waveguides have been studied via surface-near Second-Harmonic (SH) analysis for single domains as well as for periodically poled structures. The studies have been performed on a set of samples with different implantation dose and energy. The analysis was carried out in backscattering geometry on wedged samples to acquire depth-resolved information. The experimental data shows that a characteristic SH-signal drop is produced for all samples in the implanted region. A comparison with simulation data calculated with the software package "SRIM" by Ziegler et al. suggests that the characteristic drop can be traced back to the implantation-induced defects. In particular, it is possible to correlate the used ion-dose and energy to specific features of the modified optical properties. In a second step a thermally annealed sample series was examined with the same method, revealing that the induced damage can be healed partially.

DF 9.3 Tue 14:00 P1C

Hopping transport of small strong-coupling polarons in magnesium doped lithium niobate — •Tobias Noerenberg[1,2], Lukas M. Eng[1], Simon Messerschmidt[2], Andreas Krampf[2], and Mirco Imlau[2] — [1]Institut für Angewandte Physik, Technische Universität Dresden, Germany — [2]School of Physics, Osnabrück University, Germany

Lithium niobate is an important, widely used ferroelectric in optics and photonics. Its nonlinear optical properties and electrical conductivity are largely influenced by small strong-coupling polarons [M. Imlau *et al.* Appl. Phys. Rev. **2**, 040606 (2015)]. Their microscopic movement is usually investigated in the high-temperature regime and therefore described by a thermally activated hopping transport.

For the first time we were able to measure the polaron transport for magnesium doped lithium niobate (above and below the optical damage resistance threshold) via light-induced absorption in a temperature regime where the thermal energy does not suffice to provide the hopping's activation energy, i.e. as low as 40 K.

The results will be qualitatively compared to Emin's hopping theory [Emin. *Polarons.* Cambridge (2013)] who predicted three different temperature dependent hopping processes: the well-known Arrhenius behaviour at high temperatures, the multiphonon freezeout and at low temperatures the atomic tunneling regime.

Financial support by the DFG (project numbers: IM 37/5-2, INST 190/137-1 FUGG, INST 190/165-1) is gratefully acknowledged.

DF 9.4 Tue 14:00 P1C

A field-theoretical approach to light propagation and lasing in disordered photonic media — •Zhong Yuan Lai, Oleg Zaitsev, and Johann Kroha — Physikalisches Institut, Universität Bonn, Germany

Random lasing is a phenomena which has continuously received attention since its experimental discovery in 2000. We study the propagation of light in an optically active, nonlinear and dielectrically disordered medium using a functional integral formalism, which enables the derivation of an effective low-energy action, known as the Keldysh nonlinear sigma model [1]. In addition, we were able to calculate explicit transport quantities in the form of counting statistics [2] which we could show, in the case of nonactive media, to be quantitatively the same as previous diagrammatical calculations. Finally we study random lasing by including the full matter-light interacting picture and integrating out the matter fields, thus exposing the nonlinear nature of effective photonic interactions in our theory. By obtaining the full interacting saddlepoint of the nonlinear sigma model and systematically taking into account fluctuations around the saddlepoint we obtain the diffusive modes. In this manner we are able to obtain the photonic density correlation function with a correlation length which we intepret as the average lasing spot size, and the single-particle Green's function which yields information about the average laser linewidth.

[1] Lai, Z. Y. and Zaitsev, O., Phys. Rev. A **85**, 043838 (2012).

[2] Lai, Z. Y. and Zaitsev, O., Phys. Rev. A **88**, 023861 (2013)

DF 9.5 Tue 14:00 P1C

Rogue wave generation due to inelastic quasi-soliton collisions in optical fibers — •rudolf a. roemer[1], antonino savojardo[1], marc eberhard[2], and akihiro maruta[3] — [1]Department of Physics, The University of Warwick, United Kingdom — [2]School of Engineering and Applied Science, Aston University, United Kingdom — [3]Graduate School of Engineering, Osaka University, Japan

Optical rogue waves (RW) are rare and extremely high power pulses. Experimental results in optical fibers and numerical data suggest that these giant waves are due to at least two mechanisms of amplification, modulation instability, which leads to the creation of quasi-solitons, and multiple inelastic quasi-soliton collisions. Based on statistics from more than 17×10^6 quasi-soliton collisions, we establish unambiguously the fat-tail character of the probability distribution function (PDF). We also investigate single pair-wise inelastic quasi-soliton collisions and describe the energy transfer as a resonant-like scattering processes. This allows us to implement a novel cascade model that simulates the RW generation process directly giving quantitative agreement with a full numerical integration of the non-linear Schroedinger equation (gNLSE). This highlights the importance of quasi-soliton energy exchange in giving rise to RWs. Time series analysis for the gNLSE and the cascade model show calm before the storm behavior a few picoseconds before they pass. Surprisingly the cascade model predicts such signature with the only assumption of energy transfer between

quasi-solitons, not further ingredients are needed.

DF 9.6 Tue 14:00 P1C

Global modelling of strong-coupling carriers in lithium niobate — Simon Messerschmidt[1], Andreas Krampf[1], •Tobias Nörenberg[1], Felix Freytag[1], Mirco Imlau[1], Laura Vittadello[2], and Marco Bazzan[2] — [1]School of Physics, Osnabrueck University, Barbarastraße 7, 49076 Osnabrueck, Germany — [2]Dipartimento di Fisica e Astronomia, Università di Padova, Via Marzolo 8, 35131 Padova, Italy

Strong-coupling carriers, such as small polarons and/or self-trapped excitons (STE), are of increasing importance for a variety of dielectric applications. Although, the properties of these quasiparticles have been studied individually over decades in a variety of oxide dielectrics, a comprehensive model for the excitation, transport and transformation between different types of strong-coupling carriers and the mutual interplay is missing. We have addressed this question by considering small, strong-coupling polarons together with self-trapped excitons in the model system lithium niobate, $LiNbO_3$ (LN) [Imlau, M. *et al.* Appl. Phys. Rev. 2 (2015)]. Our studies comprise different measurement techniques and experimental conditions, i.e., transient absorption and luminescence analysis in a temperature range from (15-300) K, involving nominally undoped, Fe-, and Mg-doped LN samples. We succeeded in global modelling of all data using a single set of parameters by considering the various types of strong-coupling carriers and show the importance of a blue-green absorption of STEs, so far not been considered in literature. Financial support by the DFG (IM 37/5-2, INST 190/165-1 FUGG) is gratefully acknowledged.

DF 9.7 Tue 14:00 P1C

Enhancing the sensitivity of polymeric whispering gallery mode micro-disks by structuring notches in the outer cavity rim — •Michael Remmel, Tobias Siegle, Sarah Krämmer, Carolin Klusmann, and Heinz Kalt — Institute of Applied Physics, Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany

We present the usage of active, dye-doped, polymeric whispering gallery mode resonators as sensors. Pyrromethene 597 is embedded into PMMA (poly (methyl methacrylate)) micro-disks. If pumped optically the micro-disks exhibit sharp lasing peaks allowing easy tracking of the resonance modes via free-space excitation (fluorescence coupling) and read-out. In this way the sensors can be characterized regarding their bulk refractive index sensitivity (BRIS).

The disks are structured by electron-beam lithography on a silicon substrate. Designing notches in the outer section of the micro-disk cavities leads to enhanced interaction of the electric field with the environment due to partial free-space propagation of the cavity mode. The BRIS is determined for resonators with a varying number of notches. A sensitivity enhancement with increasing number of notches is found and compared to conventional disk cavities.

DF 9.8 Tue 14:00 P1C

Studying the interplay of plasmonic nanoparticles and polymeric whispering gallery mode resonators using a generalized Mie theory — •Carolin Klusmann[1], Steffen A. Schmid[1,2], Radius N. Suryadharma[2], Carsten Rockstuhl[2], and Heinz Kalt[1] — [1]Insitute of Applied Physics, Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany — [2]Institute of Theoretical Solid State Physics, Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany

Whispering gallery mode (WGM) resonators build a promising platform for sensing applications due to their high quality factors in combination with small modal volumes. Coupling plasmonic nanoparticles to WGM resonators has recently been suggested to further improve their sensitivity by utilizing local field enhancements around metallic nanoparticles immobilized within the evanescent field of the WGM. However, the underlying physical mechanism is not fully understood yet. Using generalized Mie theory we theoretically analyze the interplay between spherical WGM resonators and plasmonic nanoparticles to provide a deeper understanding of the physical properties of such hybrid systems. We show that the wavelength-detuning between plasmonic resonance and WGM plays a crucial role in the coupling process and deduce engineering guidelines to enhance the sensitivity of such systems.

DF 9.9 Tue 14:00 P1C

Properties of metal-coated polymeric whispering gallery mode resonators — •Patrick Forster[1], Carolin Klusmann[1], Jens Oppermann[2], Carsten Rockstuhl[2,3], and Heinz Kalt[1] — [1]Institute of Applied Physics, Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany — [2]Institute of Theoretical Solid State Physics, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [3]Institute of Nanotechnology, Karlsruhe Institute of Technology, 76021 Karlsruhe, Germany

Whispering-gallery mode resonators are characterized by high Q-factors and a small mode volume V. This renders them promising candidates for devices in biological sensing applications or in nonlinear optics. A unique quantity, the figure-of-merit defined as Q/V, is usually used to judge the suitability of a given structure for these applications. Here, we study whether the figure-of-merit can be notably improved by coating the resonator with a noble metal such as silver or gold. At the interface between the dielectric medium of the cavity and the metal coating, surface plasmon polaritons (SPP) can be sustained. They possess a high field confinement and show large field enhancements at the interface. In addition, hybrid modes occur due to the coupling of plasmonic and dielectric modes. Hybrid modes fuse the advantage of both modes and show, therefore, strong field localization while preserving fairly high Q-factors. In this study that combines theory and experiment, we investigate the influence of different cavity geometries and characteristic parameters of the resonator to obtain a fundamental understanding of the hybrid system operated at near-infrared frequencies.

DF 9.10 Tue 14:00 P1C

Fabrication of silicon nano-structures for dielectric laser accelerators — •Peyman Yousefi[1], Joshua McNeur[1], Martin Kozák[1], Florentina Gannott[2], and Peter Hommelhoff[1,2] — [1]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen — [2]Max-Planck-Institut für die Physik des Lichts, Erlangen

Dielectric laser accelerators (DLA) - a novel class of accelerator in which electrons interact with laser-induced accelerating near-fields in the vicinity of dielectric nanostructures - have recently demonstrated accelerating gradients in the GeV/m regime. As such, DLAs may enable accelerator applications not available to classical RF accelerators [1,2]. However there are still major challenges in order to maintain the interaction between electrons and near-fields over longer distances (necessary for larger energy gains) and to achieve even higher accelerating gradients. Developing new nano-structures is essential to solve these issues. In this work we discuss the fabrication of different geometries of silicon such as single side gratings, dual circular pillars and sinusoidal pillars gratings that aim to achieve high gradients and energy gains. E-beam lithography and reactive ion etching (RIE) are used to fabricate the nano-structures. Future designs to address focusing and tapered structures are also discussed.

[1]England R. Joel, et al. Dielectric laser accelerators. Reviews of Modern Physics 2014, 86(4): 1337-1389.

[2]John Breuer, Peter Hommelhoff. Laser-Based Acceleration of Nonrelativistic Electrons at a Dielectric Structure. PRL 2013, 111: 134803.

DF 9.11 Tue 14:00 P1C

Sub-micrometer structuring of sapphire surface applying nanosecond IR laser irradiation — •Igor Zagoranskiy, Pierre Lorenz, Lukas Bayer, and Klaus Zimmer — Leibniz-Institut für Oberflächenmodifizierung e. V., Permoserstr. 15, 04318 Leipzig, Germany

Laser treatment of surfaces finds nowadays a lot of applications. It is also possible to fabricate various, periodic and stochastic micrometer and nanometer structures into substrate surfaces. By modifying of dielectric surfaces the IPSM-LIFE methodic (laser-induced front side etching using in situ pre-structured metal structures) was developed and optimized in applying the fiber laser with wavelength of 1064 nm and adjustable pulse duration from 1 to 600 ns. The IPSM-LIFE includes 2 steps. First step is laser induced pre-structuring of metal layer, which covered dielectric surface. In the second step the produced metal structures are transferred into dielectric substrate. As example 10 nm molybdenum covered sapphire (Al_2O_3 (1-102)) wafer was tested. Modified dielectric surfaces were analyzed by atomic force (AFM) and scanning electron microscopy (SEM) as well as contact angle measurements. Down to nanometer scale the resultant surface topography can be adjusted due to variation of follow laser parameter: number of pulses, pulse duration and fluence.

DF 9.12 Tue 14:00 P1C

Modelling electrode shape deformations of a dielectric elas-

tomer actuator with finite elements — •Philipp J. Mehner, Markus Franke, Andreas Voigt, Uwe Marschner, and Andreas Richter — Chair of Polymeric Microsystems, Technische Universität Dresden, Germany

The concept of dielectric elastomer actuators is used for tuning an optical micro-mirror for low-cost laser development. The basic elements are a flexible top electrode, a transparent dielectric elastomer based on PDMS and a fixed bottom electrode. The employed PDMS has an extremely low elastic modulus, to keep the driving voltage under $U_{\max} = 100\,\mathrm{V}$. Experimental investigations have shown that the shape of the micro-cavity under stress highly depends on the width of the top electrode and the bonding process increases the stiffness of the layer underneath. Due to the micro scale of the setup and the nanoscale thickness of the electrodes, 3d shape measurements are difficult to perform. Computer aided models, based on finite elements, will help to understand and visualize the shape deformations.

We propose a finite element method implemented in ANSYS which utilizes coupled elements for accurate and time efficient simulation runs. A concept of how to implement a depth dependent elastic stiffness will be presented. The simulated results are in accordance with the conducted experiments. This approach helps to formulate novel design parameters to optimize the developed of dielectric elastomer actuators.

DF 9.13 Tue 14:00 P1C

Water-lithium niobate interface studied from first-principles calculations — •Rebecca Hölscher, Simone Sanna, and Wolf Gero Schmidt — Universität Paderborn

Its piezoelectric, pyroelectric, and photorefractive properties make lithium niobate ($LiNbO_3$, LN) the material of choice for various optical and acoustic applications. The strong and switchable ferroelectric polarization of LN is expected to strongly influence its surface reactivity. This may open the possibility for domain-specific chemistry and the realization of molecular detectors [1].

The water-lithium niobate interface beyond the (sub)monolayer adsorption [2] is largely unexplored. Recent findings suggest, however, that the water freezing temperature is dependent on the surface polarization [3]. Here density-functional theory calculations on the adsorption of water films on both the positive and the negative Z-cut as well as the X-Cut surface of LN are presented. The temperature-dependent interface atomic structure is explored using ab-initio molecular dynamics and the influence of the surface polarity on the water layer is investigated in detail.

[1] D. Li, et al., Nature Materials 7 (2008) 473.
[2] S. Sanna, R. Hölscher, W.G. Schmidt, PRB 86 (2012) 205407.
[3] D. Ehre et al., Science 327 (2010) 672.

DF 9.14 Tue 14:00 P1C

Oxygen exchange behaviour of implanted singles crystals $SrTiO_3$ for energy storage applications — Max Stöber[1], •Charaf Cherkouk[1], Tilmann Leiseganga[1], Matthias Schelter[2], Jens Zosel[2], Slawomir Prucnal[3], and Dirk C. Meyer[1] — [1]Institute for Experimental Physics, TU Bergakademie Freiberg, Germany — [2]Kurt-Schwabe Institute for Measuring and Sensor Technology Meinsberg, Germany — [3]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden Rossendorf,Dresden, Germany

In this work a solid-state-air battery based on thin-film technology containing an oxygen cathode is addressed. Since the efficiency of metal-air batteries is significantly limited by the activation of oxygen reduction reaction (ORR) as well as the ion and electron conductivities, an adequate porosity and a controlled metal doping is required. The ion implantation of promising transition metal oxides is a key technology to achieve this goal. The single crystal $SrTiO_3$ were implanted with Ni, Ag, O_2 and N_2 ions. The time resolved measurements of oxygen exchange behaviour by means of coloumetric titration on the ion implanted single crystal $SrTiO_3$ surface were investigated. In order to understand the defect chemistry and structure of those samples after the ion beam implantation their morphology was studied for example by TEM and sputter XPS. It was shown that the quantitative measurement of oxygen reduction rate on Ni implanted samples revealed an increase on oxygen exchange rate compared to non-treated $SrTiO_3$ single crystals. Keywords: Energy, solid-state battery, $SrTiO_3$, ORR

DF 9.15 Tue 14:00 P1C

Structural analysis of Ba_2SiO_4 thin films grown on Si(100) — •Julian Koch and Herbert Pfnür — Leibniz Universität Hannover, Inst. für Festkörperphysik, Appelstr. 2, 30167 Hannover

Crystalline Ba_2SiO_4 is a very promising candidate as a high-k dielectric. Films grown in a previous study [1] have shown a dielectric constant of 22.8 ± 0.2, band offsets to p-Si(100) of over 2 eV, a high temperature stability up to desorption at around 750 °C and an acceptable leakage current of 3 $\mathrm{mA/cm^2}$ at -1 V. Unfortunately, these films still feature a high density of interface traps. The primary cause of this is most likely the growth mode of the silicate films, which were produced by heating the Si(100) substrate during the growth of a BaO film, so that a diffusion of Si from the substrate to the film occured turning the BaO into Ba_2SiO_4. This process resulted in an atomically rough interface in a geometric and possibly also in a chemichal sense. Moreover, only the first 5 nm close to the interface turned out to be crystalline.

This study aims to improve the structural quality of the Ba_2SiO_4 films by employing a co-deposition growth method, in which Ba and Si are evaporated simultaneously in an oxygen atmosphere. This eliminates the need for the Si diffusion. The chemical composition and the crystallinity of the films are investigated using XPS and SPA-LEED, respectively. To further investigate the crystalline growth, crystal orientation and thickness HRTEM is used.

[1] S. Islam, K. R. Hofmann, A. Feldhoff, H. Pfnür, Phys. Rev. Applied **5**, 054006 (2016)

DF 9.16 Tue 14:00 P1C

Strong field scattering from lattice defects — •Lukas Medišauskas, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems Nöthnitzer Straße 38 D-01187 Dresden

Electron scattering from point defects in dielectrics driven by strong and low frequency laser fields close to the dielectric breakdown of the solid is investigated. The results reveal a strongly non-perturbative nature of the scattering process. Namely, multiphoton absorption to several bands and multiple scattering plateaus reminiscent of strong-field scattering in atoms can be observed in the energy resolved spectra. Intensity scaling of the spectra reveals band structure modification due top the strong laser field.

Kramers-Henneberger frame and Floquet approaches are employed. An efficient numerical method is developed to describe the scattering process in a regime where hundreds of Floquet states become important. This approach allows to compare scattering in different physical systems that may have very different final state.

DF 9.17 Tue 14:00 P1C

Implementing conductive domain walls in $LiNbO_3$ for optoelectronic applications in OLEDs — •Tillmann Stralka, Christian Godau, Alexander Haussmann, Thomas Kämpfe, and Lukas Eng — Institute of Applied Physics, Technische Universität Dresden, Germany

The research on ferroelectric domain walls (DWs) has focused for the last years on their unique property of electronic charge transport when being properly tuned. In fact, domain wall conductivity (DWC) was reported for both thin-film [1] and bulk-single-crystalline [2] ferroelectrics. In lithium niobate ($LiNbO_3$: LNO), DWC can be reversibly tuned through high-voltage treatment [3,4] or super-band-gap illumination [5], rendering this material ideal for the integration into optoelectronic devices. The present work reports on the development of such an optoelectronic device that combines conductive DWs with organic light emission diode (OLEDs). OLEDs are built in vertical stacks, with the charge-carrier mobility being optimized perpendicular to the stacks while becoming very restricted parallel to these layers [6] hence affecting the local light emission dramatically. Here, we implement conductive DWs as so-called local vias contacting the electron- and hole-transport layers in such an OLED.

[1] J. Seidel et al., Nature Mater. **8** (2009), 229. [2] T Sluka et al., Nature Comm. **4** (2013), 1808. [3] C. Godau et al., (2016), submitted. [4] T. Kämpfe et al., Phys. Rev. B **89** (2014), 035314. [5] M. Schröder et al., Adv. Func. Mater. **22** (2012), 3926. [6] Shu-Hao Wen et al., J. Phys. Chem. B **113** (2009), 8813.

DF 9.18 Tue 14:00 P1C

Raman spectroscopic investigations of domains in multiferroic $BiFeO_3$ crystals — •Jan Rix[1], Cameliu Himcinschi[1], Jens Kortus[1], Christian Röder[1], and Marin Alexe[2] — [1]TU Bergakademie Freiberg, Institute of Theoretical Physics, D-09596 Freiberg, Germany — [2]Department of Physics, University of Warwick,

Coventry CV4 7AL, United Kingdom

Multiferroic $BiFeO_3$ crystals were investigated at room temperature by means of Raman spectroscopy using the 442 nm line of a HeCd laser. Considering the direction of polarisation of the incoming and the scattered beam, characteristic spectra were revealed. These spectra can be attributed to two different types of domains, which differ in the orientation of the pseudo-cubic $<111>_{pc}$ direction. The strong intensity variation of the polar Raman mode at 175 cm^{-1} (A_1(LO) -> E(LO)) was used for domain identification by line scans and mappings. In addition, simulations by means of the Raman tensor formalism proof the experimental findings. This method is a viable alternative to polarisation microscopy and offers opportunities for further studies of ferroelastic domains in $BiFeO_3$.

DF 9.19 Tue 14:00 P1C

Real-time observations of ferroelectric switching by ultrafast x-ray diffraction — •Christelle Kwamen[2], Matthias Reinhardt[2], Wolfram Leitenberger[1], Matthias Roessle[1], Flavio Zamponi[1], Marin Alexe[3], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Uni Potsdam — [2]Helmholtz-Zentrum Berlin — [3]Department of Physics, University of Warwick

We present time-resolved x-ray diffraction experiments on the ferroelectric switching of Lead-Titanate films with a thickness of 150 nm.

The Bragg peak position directly measures the piezoelectric strain during the switching process, while the peak width derived from reciprocal space maps yields a detailed picture of the domain wall propagation dynamics. The scattering intensity yields the structure factor of the unit cells, which is a direct measure of the poling process.

We discuss how the switching speed can be increased from nanosecond to several picoseconds.

DF 9.20 Tue 14:00 P1C

Influence of ferroelectric domain walls on the dielectric permittivity of $BiFeO_3$ — Marek Pasciak, Pavel Marton, •Sabine Körbel, and Jiři Hlinka — Institute of Physics of the Czech Academy of Sciences, Prague, Czech Republic

$BiFeO_3$ with its coexistence of structural distortions (polar displacements, tilting of oxygen octahedra) and magnetic ordering has been a favourite playground for investigating structure-property relationships in multiferroics. Domain engineering adds another level of complexity, with many recent experimental and theoretical works showing rather spectacular changes in material properties. In this work we use a shell model to study how dynamics related to ferroelectric domain walls change the dielectric permittivity.

DF 9.21 Tue 14:00 P1C

Giant resisitive switching by charged domain walls — •Thomas Kämpfe[1], Bo Wang[2], Scott Johnston[3], Eric Y. Ma[3], Alexander Haussmann[1], Hui Hu[4], Zhi-Xun Shen[3], Long-Qing Chen[2], and Lukas M. Eng[1] — [1]Institute of Applied Physics and Center for Advancing Electronics (CFAED), TU Dresden, Germany — [2]Department of Materials Science and Engineering, Pennsylvania State University, University Park, USA — [3]Department of Applied Physics and Geballe Laboratory for Advanced Materials (GLAM), Stanford University, USA — [4]School of Physics, Shandong University, Jinan, China

We investigate the application of conductive domain walls (CDWs) in exfoliated thin-film lithium niobate (LNO) for resistive switching in a standard metal-ferroelectric-metal stack. An abrupt increase over at least 5 orders of magnitude in the unidirectional conductivity is observed when the voltage sweep approaches the coercive voltage. Local-scale measurements involving AFM techniques confirm that the conductivity indeed correlates with the formation of CDWs. The high- and low-resistance-states show a retention of $> 10^4$ s and an endurance over 10^5 cycles with a resistance window of 10^4 and a high device homogeneity. The non-volatile current is tunable both by varying the writing voltage and exposure time, and indeed decreases for larger writing voltage. The transport mechanism was found to be space-charge limited, with temperature-dependent transport measurements confirming a small-electron polaron hopping. All these experiments are in good agreement with the developed phase-field modeling.

DF 9.22 Tue 14:00 P1C

Electrical current measurements at head-to-head domain walls in $LiNbO_3$ — •Manuel Becker and Elisabeth Soergel — University of Bonn, Bonn, Germany

Besides its pyroelectric, photorefractive, electrooptic and nonlinear optical properties, $LiNbO_3$ is observed to exhibit an enhanced electrical conductivity at certain domain wall configurations, although the crystal itself is an insulator. Especially head-to-head DWs show a significant conductivity which is related to a larger charge density compared to the bulk. The electrical currents at these DWs turn out to be in the order of several pA only, being difficult to detect by usual DC measurement techmiques. Therefore, low-noise AC current measurements using a lock-in amplifier are more suitable. By this means, DW currents are shown to be ohmic and an estimate for the resistance of a head-to-head DW is proposed.

DF 9.23 Tue 14:00 P1C

Creation of ferroelectric domain walls — •Cina Razzaghi[1] and Elisabeth Soergel[2] — [1]Physikalisches Institut, University of Bonn — [2]Physikalisches Institut, University of Bonn

The properties of ferroeletric domains are of great interest in modern research. In the case of $LiNbO_3$ mainly domain walls (DWs) with inclination angles of 180°, as well as head-to-head DWs, are investigated. For a deeper understanding of the properties of DWs it is necessary to study DWs that exhibit other inclination angles α. The electrical conductivity of a DW is expected to be dependent on α. Therefore, one must find techniques for a controlled creation of DWs with various inclination angles.

DF 9.24 Tue 14:00 P1C

Frequency analysis in scanning probe microscopy — •Sarmed Hussain and Elisabeth Soergel — Physics Institute of Bonn University, Bonn, Germany

Piezoresponse force microscopy (PFM) has emerged as a key-method for mapping domain patterns in ferroelectric materials with high lateral resolution an impressive sensitivity. For recording quantitatively reliable data (in terms of the magnitude of the piezomechanical response), however, a method for calibration is still missing. Besides the need for a calibration standard, there is in addition the difficulty of the frequency dependence of the data recorded, most prominent when investigating samples with small piezoelectric coefficients. Although it might eventually not be possible to get rid of this frequency dependence, its origin is of interest for a better evaluation of the, presumably quantitative PFM-data obtained.

DF 9.25 Tue 14:00 P1C

Time-resolved analysis of multiferroic switching in $Ni_3V_2O_8$, $MnWO_4$, $DyMnO_3$, and $TbMnO_3$ — Jonas Stein[1], •Sebastian Biesenkamp[1], Tobias Fröhlich[1], Tobias Cronert[1], Jeannis Leist[2], A Agung Nugroho[6], Ladislav Bohatý[5], Petra Becker[5], Navid Qureshi[4], Karin Schmalzl[3], Götz Eckold[2], and Markus Braden[1] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Institut für Physikalische Chemie, Universität Göttingen — [3]JCNS at ILL, France — [4]ILL Grenoble, France — [5]Kristallographie, Universität zu Köln — [6]Institut Teknologi Bandung, Indonesia

We control multiferroic domains with electric fields in the order of several kV/mm to investigate the rise time in dependency of temperature and field strength and analyze the spatial extend and the dynamics of the chiral domains in the multiferroic phase and in vicinity of the multiferroic transition. Polarized neutrons are the ideal tool to investigate the multiferroic domains and complete the dielectric data. With our time-resolved setup it is possible to follow the reversion of chiral domains in the timescale of a few hundred microseconds to hours and record full Bragg scans for peak profile analysis in the time domain. In $TbMnO_3$ we find a clear logarithmic relation between the rise time and temperature that is fulfilled over 5 orders of magnitude. In $DyMnO_3$ the multiferroic switching is slowed down by Mn-Dy coupling.
[1] Niermann et al. **PRB 89**, 134412 (2014) [2] Baum et al. **PRB 89**, 144406 (2014) [3] Holbein et al. **PRB 91**, 014432 (2015) [4] Stein et al. **JPC 27**, 446001 (2015)

DF 9.26 Tue 14:00 P1C

Magnetic correlations in $Eu_{1-x}Ho_xMnO_3$ ($0 \leq x \leq 0.5$) probed by Raman spectroscopy — •Sebastian Elsässer[1], Anatoly M. Balbashov[2], Alexander A. Mukhin[3], and Jean Geurts[1] — [1]Exp. Phys. III, University of Würzburg, Germany — [2]Prokhorov GPI, Russian Academy of Sciences, Moscow, Russia — [3]General Physics Institute of the Russian Academy of Sciences, Moscow, Russia

The perovskite-like rare-earth manganites $R MnO_3$ are among the most widely studied compounds in multiferroics, where the magnetically in-

duced ferroelectricity of, for example, $TbMnO_3$, $DyMnO_3$ is induced via the inverse Dzyaloshinskii - Moriya (DM) interaction. The mixed stoichiometry compounds like $Eu_{1-x}Ho_xMnO_3$ allow fine-tuning of the competing ferro- and antiferromagnetic interactions to achieve the cycloidal spin order patterns needed for this mechanism. The presence of magnetic Ho^{3+} introduces an additional coupling that leads to a complete flip of the spin cycloid plane for Ho-contents of $x > 0.35$ from the *c*- to the *b*-axis (Pnma). Specific Raman-active phonon modes are prime candidates to probe the temperature- and composition dependent developement of magnetic correlations on a quasi-local level via spin-phonon coupling (SPC). Upon cooling, this is observed as a SPC-induced phonon frequency renormalization which reveals magnetic coupling effects even up to $\approx 100\,K$, despite the much lower Néel Temperature $T_N \approx 45\,K$. This is interpreted as the formation of locally correlated spin cycloids, oriented with random helicity, which explains the absence of global magnetic order.

DF 9.27 Tue 14:00 P1C

Interplay of oxygen vacancies and conductance in $SrMnO_3$ thin films under epitaxial tensile strain — •Lokamani Lokamani[1], Carina Faber[3], Peter Zahn[2], Nicola Spaldin[3], and Sibylle Gemming[1,2] — [1]Institute of Ion Beam Physics and Materials Research, HZDR, 01314 Dresden, Germany — [2]Institute of Physics, Technische Universität, 09107 Chemnitz, Germany — [3]Materials Theory, ETH, 8093 Zürich, Switzerland

Strontium manganate ($SrMnO_3$), a perovskite polymorph, exhibits cubic structure at low temperatures, which transforms under tensile strain into a G-type-antiferromagnetic (G-AFM) antiferrodistortive polar phase in the plane parallel to the substrate[1]. Recently, ferroelectric domains have been observed experimentally in 20nm thin films of $SrMnO_3$ under 1.7% tensile strain on (001)-oriented LSAT grown in an oxygen-deficient atmosphere[2]. Strikingly, the individual domains show different conductance features, whereas the domain walls were found to be electrically insulating, rendering the domains to form stable nano-capacitors with high charge rention times.

Here, we present a detailed first-principle investigation of the domain wall formation in strained $SrMnO_3$, their electronic properties and the influence of oxygen vacancies on the 2D-electron gas at the polar domain walls. Preliminary results on the migration energetics of the oxygen vacancies are expected.

[1] J. H. Lee et al., PRL 104, 207204 (2010)
[2] C. Becher et al., Nature Nanotechnology 10, 661 (2015)

Funding by VI Memriox(VH-VI-422) & Nanonet(VH-KO-606)

DF 9.28 Tue 14:00 P1C

Dielectric properties of the spin driven multiferroics linarite and $LiCuVO_4$ — •Alexander Ruff, Theresa Mack, Stephan Krohns, Peter Lunkenheimer, and Alois Loidl — Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, Germany

In the last decade, various mechanisms for coupled polar and magnetic ordering, so called multiferroicity, were discovered. Among various multiferroic systems, spin-driven ferroelectrics are especially in the scientific focus due to a close coupling of spin and charge leading to cross-link control of magnetic and electric order. These systems have noncollinear spin structures, e.g., magnetic phases with spiral or helical order. Thus, two canted neighbouring spins S_i and S_j allow for inverse Dzychaloshinskii-Moriya interaction resulting in spin-driven ferroelectric polarization P via $P \propto Q \times (S_i \times S_j)$, where Q denotes the propagation vector of the spin spiral. Those complex magnetic phases are often based on unconventional magnetic behaviour, which can be found in frustrated quantum spin systems, like $LiCuVO_4$ or the naturaly grown single crystal linarite, $PbCuSO_4(OH)_2$.

Here we present the dielectric properties as well as the ferroelectric polarization from pyro- and magnetocurrent measurements, both in external magnetic fields up to 12 T. Finally, we provide (H,T)-diagrams for the multiferroic phase of linarite and the new high-temperature phase of $LiCuVO_4$.

DF 9.29 Tue 14:00 P1C

Strong magnetoelectric coupling within ceramic core-shell structures — •Leonard Henrichs[1], Torsten Scherer[1], James Benett[2], Andrew Bell[2], Oscar Cespedes[2], and Christian Kübel[1] — [1]Karlsruhe Insitute of Technology, Karlsruhe, Germany — [2]University of Leeds, Leeds, United Kingdom

In perovskite ceramics of the composition $BiFe_{0.9}Co_{0.1}O_3)_{0.4} - Bi_{1/2}K_{1/2}TiO_3)_{0.6}$, novel nano-sized regions called multiferroic clusters (MFC) were recently discovered. These MFC belong to so-called core-shell structures as known from other relaxor ferroelectrics, where $BiFe_{1-x}Co_xO_3$-rich cores are surrounded by a $Bi_{1/2}K_{1/2}TiO_3$-rich shell within one grain. The MFC exhibit exceptionally large direct and converse local ME coupling. The observed electric-field induced switching of magnetization is especially interesting in terms of applications, since it enables in principle electrically driven magnetic memory, one of the 'holy grails' in information technology research. It is assumed that the strong magnetism stems from ferrimagnetic order of Fe and Co in MFC, which requires a superstructure of Fe and Co on the B lattice site. The main unsolved question in this system is, why the exceptional multiferroic properties occur in the $BiFe_{1-x}Co_xO_3$-rich Cores, but have never been observed in pure $BiFe_{1-x}Co_xO_3$ compounds. An explanation might be epitaxial strain originating from the core-shell structure. It is anticipated, that deeper understanding of the MFC might give valuable insights for the design e.g. of a thin-film material with similar multiferroic properties like the MFC.

DF 9.30 Tue 14:00 P1C

Exchange coupling in multiferroic $Bi_{1-x}Ba_xFeO_3$/ferromagnet heterostructures — •Sven Becker, Mehran Vafaee, Mathias Kläui, and Gerhard Jakob — Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

The $BiFeO_3$/ferromagnet interface has been target of numerous researches. The effect of exchange coupling was often weak at room temperature [1] or dies after some time because of oxidation of the interface[2]. Multiferroic $Bi_{1-x}Ba_xFeO_3$/ferromagnet heterostructures have been fabricated using pulsed laser deposition (PLD). The focus laid on $Bi_{0.75}Ba_{0.15}FeO_3$(BB15FO), which promises to have a larger magnetic moment than undoped $BiFeO_3$ (BFO).[3] As ferromagnetic layers $La_{0.7}Sr_{0.3}MnO_3$ and ferrimagnetic Sr_2FeMoO_6 have been deposited. Single crystal growth has been confirmed using XRD. Ferroelectric properties of BB15FO have been proven by piezoresponse force microscopy (PFM). Heterostructures have been investigated with regard to the exchange coupling using a SQUID magnetometer. [1] M. Vafaee Appl. Phys. Lett. **108**, 072401 (2016) [2] J. T. Heron, Nature **516**, 370 (2014) [3] R. Das, J. Magn. Magn. Mater. **324**, 1913 (2012)

DF 9.31 Tue 14:00 P1C

Tuning spin and charge orders in geometrically frustrated rare earth ferrites — •Sabreen Hammouda, Thomas Müller, Jörg Persson, and Manuel Angst — JCNS-2, Forschungszentrum ,Jülich, Germany

Rare earth ferrites RFe_2O_4 have attracted a lot of attention as prototypical examples of multiferroics, which have a potential use in information technology in particular due to their proposed new mechanism of ferroelectricity arising from charge ordering (CO) of Fe^{2+} and Fe^{3+} in the Fe/O bilayers [1]. The $YbFe_2O_4$ exhibits a behavior very similar to $LuFe_2O_4$ [2], consistent with the primary importance of the rare earth ion size, which is comparable for both Yb^{3+} and Lu^{3+}. Alternatively, the Y^{3+} ionic radius is much larger, and a completely different charge order was found [3].

Given the completely different CO in $LuFe_2O_4$, and YFe_2O_4, it is of high interest to study "how charge and spin orders change while tuning the relevant interactions by gradually increasing the rare earth ion radius, made by substitution", i.e. the substitution $Lu_xY_{1-x}Fe_2O_4$. However, a critical aspect have to be considered in such a study is that, for each substitution level x, the oxygen-stoichiometry needs to be fine-tuned, as otherwise O-stoichiometry changes are impossible to cleanly disentangle from the rare earth substitution.

I will present results from substituting Y (larger ion size) by the smaller Lu i.e. $Lu_xY_{1-x}Fe_2O_4$, particularly for $x = 0.5$.

[1] Ikeda et al., Nature 436, 1136 (2005). [2] Williamson et al., unpublished. [3] T. Mueller et al., J. Crystal Growth 428, 40 (2015).

DF 9.32 Tue 14:00 P1C

Synthesis and characterization of Bi - based double perovskites — •D. E. Saavedra Mesa[1,2], J. Roa-Rojas[1], A. U.B. Wolter[2], S. Aswartham[2], S. Wurmehl[2,3], and B. Büchner[2,3] — [1]Universidad Nacional de Colombia, Bogotá, Colombia — [2]Leibniz Institute for Solid State and Material Research, Dresden, Germany — [3]Institute of Solid State Physics TU Dresden, Dresden, Germany

The complex perovskite-type oxides with formula A2BB°O6 have been extensively investigated due to their wide range of physical properties. However, only four of them with Bi in the A position have been reported. Bi-based double perovskites are highly interesting because of their magneto-electric effects, where e.g. Bi2NiMnO6 has been found

to be ferroelectric below 480 K. Here, we present a systematic investigation of synthesis and characterization of new Bi-based double perovskites such as Bi2BB°O6 (B=Ho, Dy & B° = Mn, Co). Polycrystalline samples of Bi2HoMnO6 were synthesized by the conventional solid state reaction method. The structural analysis was carried out with powder X-ray diffraction (XRD) experiments. The surface morphology was studied by scanning electron microscopy (SEM), and the composition was analyzed using energy dispersive spectrometry (EDX).

DF 9.33 Tue 14:00 P1C

Directional dichroism via optical para-magnetoelectric effect in high magnetic fields — •David Szaller[1], Daniel G. Farkas[1], Vilmos Kocsis[1,4], Sandor Bordacs[1], Urmas Nagel[2], Toomas Room[2], Bence Bernath[3], Hiroshi Murakawa[4], and Istvan Kezsmarki[1] — [1]Dept. of Phys., Budapest Uni. of Tech. and MTA-BME Lendület Magn.-opt. Spect. Gr., Hungary — [2]Nat. Inst. of Chem. Phys. and Biophys., Estonia — [3]High Field Magnet Lab., Inst. for Molecules and Materials, The Netherlands — [4]RIKEN Center for Emergent Matter Science, Japan

Magnetoelectric multiferroics, i.e. materials simultaneously hosting ferroelectric and magnetic order, attract enormous interest due to their potential in IT applications. The magnetoelectric coupling present in these materials appears in the optical regime as the difference of absorption coefficients of counter-propagating light beams, which effect is termed as directional dichroism. This exotic phenomenon has been reported for spin excitations in multiferroic melilite single crystals and proposed as a new principle of directional light switches operating in the GHz-THz region. Applications seem to be limited to low temperatures where electric and magnetic order coexist. However, recent studies on melilites revealed that an external magnetic field can recover the electric polarization via the para-magnetoelectric effect far above the material's ordering temperature. Based on these static results we found strong directional dichroism in the paramagnetic phase of $Sr_2CoSi_2O_7$. The strength of the effect grows with the magnetic field, in accordance with the magnetoelectric sum rule.