Tuning the spontaneous light emission in phoxonic cavities

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Strong acousto-optic interaction was recently predicted in appropriately designed microcavities that simultaneously localize light and elastic waves. For cavities of submicron dimensions, visible to near infrared light could be squeezed in a small volume, resonantly vibrating at GHz frequencies due to the elastic wave. When both elastic and optical fields are on resonance, multiphonon exchange mechanisms become significant, and dynamical optical frequency shift is enhanced. We investigate the influence of dual photonic-phononic resonant excitation on the spontaneous light emission of active centers. We consider a Si/SiO2 periodic multilayer structure, which operates as a Bragg mirror for both photons and phonons, with a defect layer (cavity) in the middle. Our calculation is based on the classical approach for light emission, and we solve the problem of an oscillating point dipole inside the multilayer structure using multiple-scattering Green's function techniques. The influence of the elastic wave is taken into account in a quasistatic picture, by considering both the bulk acousto-optic effect and the movement of the interfaces. Our results indicate that an elastic wave can strongly modulate light emission through a resonant acousto-optic interaction.

Nanostructures for Thermoelectric generation and waste heat recovery

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Thin film materials based on $SrTiO_3$ doped with transition metals such as Nb or La are a promising class of n-type thermoelectric materials due to its nontoxicity compared to other materials such as Bi_2Te_3 and PbTe, its stability at high temperature, as well as its large thermopower. Stacking very thin layer of Nb doped STO film into a superlattice structure has been shown to achieve giant Seebeck coefficients of about -480 μV/K, which is an improvement of about 4 times over that of bulk value obtained at 20% doping. In order to garner the full potential of such materials, concrete understanding of the effect of thin film on structural as well as thermoelectric parameters is needed. However, this study is still lacking.

Our aim is thus to conduct a thorough investigation of the influence of film thickness on structural property (lattice parameter) and more importantly on thermoelectric property. (Electrical and thermal conductivity and Seebeck coefficient). We fabricate lightly doped (2%) Nb:STO thin films fabricated by Pulsed Laser Deposition (PLD) technique. Seebeck coefficient shows a strong dependence on the film thickness and reach a value as high as -520 μV/K for 4 nm thick Nb:STO film, with a corresponding PF of about 0.02 and 0.06 W/mK^2 at temperature of 105 and 67 degrees Celsius, respectively. The estimated ZT at room temperature is about 0.05 to 0.20 W/mK based on bulk thermal conductivity. Preliminary measurement on thermal conductivity suggests a decrease in thermal conductivity of thin film as compare to bulk and shows a strong dependence on film thickness.

Quantum transport of phonons in nanostructure and at low temperature

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The objective of my PhD is to see the impact of the geometry of nanowires on thermal phonons. I am making the samples and then measuring them in a Helium 3 fridge with the 3-omega method. The first results I got was obtained by introducing a corrugated shape on silicon nanowires. The measurements I am now doing are on silicon nitride, which is amorphous. The impact of internal stress is also studied.

Measurement of the absolute absorption cross-section in individual carbon nanotubes

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Carbon nanotubes (CNTs) exhibit unique optical, mechanical and electrical properties depending on their characteristics, i.e., their nature (semiconducting or metallic) and their diameter. There are promising candidates for selective applications, e.g., in optoelectronic and in biology. In this context, the understanding of light-matter interaction processes occurring in these nano-objects is crucial, and more precisely this comprehension should occur at the individual nanotube level. A large number of studies based on resonant Raman spectroscopy and luminescence spectroscopy were performed on individualised CNTs, whereas characterisation of the absorption properties of CNTs is still challenging. Here we show direct measurements of the polarised absorption cross-section of individual CNTs obtained with the spatial modulation spectroscopy technique (SMS) [1]. This method was coupled with other existing techniques: scanning electron microscopy, atomic force microscopy, and Raman spectroscopy.

This study demonstrates the impressive capability of the SMS technique to measure the absolute absorption cross-section (σ_{abs}) of individual CNTs deposited either on transparent or opaque substrates. For a (18,5) semiconducting CNT, we estimated its resonant absorption cross-section to be σ_{abs} = 0.35 nm²/nm (corresponding to about 1.8×10^{-17} cm²/carbon atom), for incident light polarised along the nanotube axis [2]. Polarisation anisotropy of the absorption, measured for few different CVD grown CNTs, always give a contrast factor close to 2.5:1 between light polarised parallel and orthogonal to the nanotubes axes. In more recent works, we try to relate the absolute absorption cross-section with the CNTs' nature and diameter. Absorption spectra in the visible and infra-red ranges were obtained for CNTs deposited on quartz substrates.

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Calibrated real time detection of anharmonic propagating phonons

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The combination of ultrafast x-ray diffraction (UXRD) and time-resolved optical reflectivity measurements gives new perspectives in ultrafast physics. We show fluence dependent optical pump and white light probe measurements of nonlinearly propagating strain pulses in Strontium Titanate ($SrTiO_3$). The photoinduced strain amplitude was calibrated by ultrafast x-ray diffraction. Our measurement shows for high strain levels different speeds of the tensile and the compressive part of the strain pulse. This behavior is explained by an anharmonic coupling of acoustic phonons, which we have modeled with an anharmonicly coupled linear chain with hydrodynamic damping.

Picosecond acoustics

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Our work demonstrates experimentally the direct optical excitation of GHz coherent elastic vibrations in an opal-based ferromagnetic hypersonic crystal. In time-domain pump-probe measurements with applied external magnetic field we separate the elastic vibrations of SiO_2 mesoporous spheres forming the opal matrix by measuring the induced changes in the transmitted intensity on the one hand and the magnetization evolution of ferromagnetic nanoparticles embedded into the opal crystal by measuring the Faraday Effect on the other hand.

Ultrahigh Frequency Surface Acoustic Wave Devices on Silicon Fabricated by Nanoimprint Lithography

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Surface acoustic waves (SAWs) are widely used and very important in both research and industry. SAWs are mechanical vibrations propagating along the surface by confining the acoustic energy over a depth of typically one wavelength. In piezoelectric materials, they can be excited through the inverse piezoelectric effect by using interdigital transducers (IDTs). Because of the piezoelectricity of the material, a piezoelectric potential wave accompanies the mechanical wave. The unique SAW properties make them suitable not only for signal processing, but also for sensing applications, photonics, and charge transport. Among the most exciting applications of SAWs are the control of photons, electrons, and spins, and the acousto-optic modulation of semiconductors. Almost for all SAW applications, there is a strong demand for higher frequencies, for example to reach the quantum regime or to enhance processing speed. The SAW frequency is determined by the periodicity of the IDT electrodes and the acoustic velocity of the material. However, conventional photolithography resolution limits the operation frequency around a few GHz, even for high velocity substrates.

In this study, an alternative lithography technique “step and flash nanoimprint lithography (SFIL)” was successfully used to fabricate very high resolution IDTs on ZnO/SiO2/Si substrates. Crucial to our novel approach is the application of a hydrogen silsequioxane (HSQ) layer that provides excellent planarization combined with very high etch selectivity and critical dimension control. While this method takes the advantage of EBL resolution capability, it is a substrate independent process in contrast to EBL. Very high critical dimension control was obtained at the end of the process. The fabricated IDT devices have line widths of 125nm, 100nm, 80nm and 65nm corresponding to acoustic wave lengths of 500nm, 400nm, 320nm and 260nm wavelengths, respectively. Reflection and transmission spectra were obtained with a vector network analyzer, showing that both the fundamental and higher order Rayleigh modes were excited up to frequencies of 16 GHz. To the best of our knowledge, this is the highest frequency reported to date for piezoelectric transducers on Si. Our experimental results are well reproduced by a finite element analysis.

The implementation of functionalized silk as an useful biocompatible material for photonic applications

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Organic semiconductor lasers are a field of interest in organic photonics and this is partially due to the ability of conjugated small-molecules and polymers to demonstrate efficient optically pumped lasing in the solid state. In addition, the compatibility of organics with natural biomaterials makes organic photonic suitable to develop biocompatible and biodegradable devices.
Silk is a natural protein fiber that has recently emerged as a highly promising candidate for realizing biocompatible photonic components. In particular, silk can offer a seamless interface between the optical and biological worlds.
Indeed, silk has excellent mechanical properties, it is biodegradable and easily implantable, and can be used to fabricate biocompatible sensor for biomedical and opto-electronic applications.
Stilbene is a well-known dye with high optical emission Quantum Yield (QY) and low threshold for gain narrowing, which is also ideally compatible for blending with silk due to its water solubility.
We used the possibility to structure the surface of a silk/stilbene film to fabricate a one-dimensional Distributed FeedBack (DFB) structure, to obtain a lasing emission from the dye.

Calculation of thermal properties in silicon nanostructures

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Ultra-thin silicon membranes and nanowires have been the subject of extensive studies due to their low dimensionality that leads to enhanced thermo-electric properties and improved figure of merit, ZT, in thermoelectric modules. Recent experimental and theoretical reports point to an enhancement of the figure of merit in thin films [1], nanowires [2] and superlattices [3]. This increase of ZT is attributed to the decrease of the thermal conductivity, which is predicted to be related in part to the modification of the acoustic dispersion relation due to periodicity (superlattices) or spatial confinement of the phonon modes (thin films or nanowires). The reduced dimension of the structure leads to the confinement of acoustics modes and the discretization of the acoustic spectrum, which, in turn, results in changes in the phonon density of states, group velocity [4], and phonon-phonon interaction [5].
Our approach is to investigate the acoustic phonon dispersion in ultra-thin free-standing silicon membranes and nanowires based on the elastic continuum model. The thermal properties are calculated comparing both the modified dispersion relation and Debye dispersion relation approximation. The theoretical predictions are compared with other reported theoretical and experimental results as well as with our measurements.

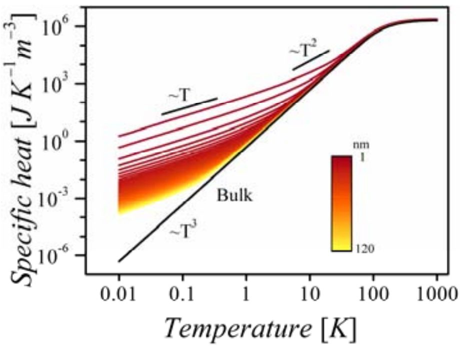

Fig. 1 Modelling of specific heat capacity in free-standing silicon membranes

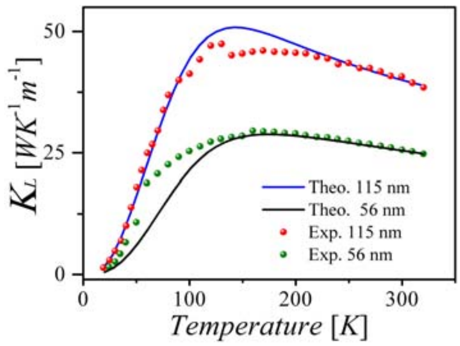

Fig. 2 Modelling and comparison of thermal conductivity of free-standing silicon nanowires [6].

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Terahertz emission from phonon coupled microcavities

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Optical phonons are important factor for the operation of Quantum Cascade Lasers (QCL), as they provide one of the dominant non-radiative relaxation channels [1]. It is known that electrons on the excited state of an intersubband transition would rather generate a phonon than a photon, it is therefore tempting to explore the giant phonon polarization inherently existing in the polar materials, like InP or GaAs, that are used to grow QCLs, for generation of light.
For this purpose, we have studied the phonon-polaritons arising from the phonon-light coupling in double-metal square patch microcavities [2]. The photonic dispersion curve of these structures, made of GaAs, has been studied in reflectivity measurements. It displays a strong anti-crossing around the Restrahlen band, with an effective Rabi splitting that is 41% of the transverse optical phonon frequency (8 THz). These structures then operate naturally in the ultra-strong light matter coupling regime. According to the Kirchoff's law, the thermal emission collected from these devices appears at the resonant phonon-polariton modes [3]. This has been verified in our poof-of-principle experiment and these structures can therefore be used as an "easy sources" of narrow-band THz radiation when thermally excited. We currently study devices where the phonon polarization is generated by electrical injection in a specially designed QC structure.

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High Frequency Bulk Acoustic Resonators for Wear Monitoring of Sharp Tips

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Measurement and nanoscale manipulation techniques, such as AFM, employ extremely sharp tips to achieve atomic resolution. Determination of tip wear is crucial to accurate and high resolution imaging. We propose an in-situ alternative to the common methods of monitoring tip wear, which use involve imaging of the tip. We fabricate a SHF transducer on the back to the tip and resonate the tip. At high frequencies, tip wear is then indicated by shifts in the resonance frequency. When thus excited, the tip can also act as a point source of ultrasonic energy. Devices demonstrated a quality factor of 443 and electromechanical coupling coefficient of 0.6% at 6.4GHz. Results show that blunting the tip results in a resonance frequency change of 0.4MHz at 6.4GHz.

Electrodynamics in plasmonic cavities coupled to semiconductor nanowires.

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The properties of excitons, electron-hole pair states stabilized by the Coulomb interaction, raise a strong interest in the prospect of applications of single-wall carbon nanotubes (SWNTs) in optical devices. As an example, non-linearities due the very efficient Auger processes control the excitonic population and lead to a sub-poissonian statistics of the photon emission, at the basis of single photon sources. The questions of the existence and stability of multi-excitonic states, in which the one-dimensional character of SWNTs induces strong Coulomb interactions, are currently the subject of an intensive debate. These states and their coupling with excitonic states play a fundamental role for the exploitation of the excitonic properties. Recently, experimental studies have led to the observation of trions (exciton-carrier bound states), which binding energy is of the order of 150 meV, typically one order of magnitude higher than in epitaxial semiconductor nanostructures. Concerning the two-excitons bound state, the so-called biexciton, theoretical works predict a slightly smaller binding energy than for the trions, ranging from 50 to 100 meV.

In order to study these aspects, we have performed non-linear spectral-hole burning experiments at low temperature of an ensemble of micelle-wrapped and gelatin-frozen carbon nanotubes of several chiralities. We observe two photo-induced absorption peaks depending on the excitation power and the temperature. The resonance attributed to the trion (with the higher binding energy) is particularly sensitive to the temperature, and it becomes hardly observable above 50 K. The second peak at higher energy displays an asymmetric spectral profile, consistent with a biexcitonic transition.

Thermo-electrical modeling for GaN HFETs

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Hot spots which form in AlGaN/GaN Heterostructure Field Effect Transistors (HFETs) occur predominantly from two reasons which are 1) localized heat generation in regions with characteristic dimensions as small as 50 nm as a result of the high electrical field which impacts phonon generation from electrons and 2) the hot phonon bottleneck that limits the diffusion of thermal energy contained in the high frequency optical phonon modes in GaN. While the temperature distribution in GaN devices has been predicted using diffusion analysis, little has been done to account for the electron phonon and non-Fourier effects in HFETs. The aim of this work is to model the phonon bottleneck and account for ballistic-diffusive effects created by the localized heat generation in HFETs. This is done through thermal simulations based on the solution of the Boltzmann transport equation by taking into account of phonon interactions in GaN.

Slow-mode waveguide in honeycomb photonic crystal

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Recently, slow light has been widely investigated in the field of optics. The biggest advantage of slow light in photonic crystal waveguides is that it can produce slow light at room temperature in compact devices, and it has great prospect of applications in optical delay line, optical buffering, all-optical storage, sensor, microcavity laser, nonlinear effect enhancement and so on. In this work, we present a theoretical study and simulation to achieve slow light modes in honeycomb silicon photonic crystals (membranes and over SiO_2 susbtartate). We present and discuss different kinds of line defect to guide the slow light at 1550nm wavelength across the honeycomb photonic crystals. Experimental measurements support the numerical predictions.

Asynchronous optical sampling

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Asynchronous optical sampling (ASOPS) is a technique for high resolution ultra-fast spatiotemporal spectroscopy. We present a system which employs two mode-locked femto second pulsed Ti:Saphire lasers with a repetition frequency of 800 MHz and an offset of $\Delta fR = 5$ kHz. Consequently, the relative shift between pump and prope pulse is repetitively ramped from zero to 1250 ps in steps of 8 fs within an acquisition time of 0.2 ms. Due to the extreme short data acquisition time and the systematically conditioned avoidance of beam point instabilities and spot size variations this setup allows for far better data qualitiy than the common mechanical delay systems. With this setup we investigate the phononic properties of nanostructures, such as surface acoustic waves (SAW) on thin silicon membranes or other nano patterned structures.

Generation of an acoustic frequency comb in the GHz-Range

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An acoustic frequency comb in a silicon membrane with a thin aluminum transducer layer on top is excited and detected. The method used is asynchronous optical sampling, which is a femtosecond-laser based pump-probe technique. The generated acoustic pulse has a center frequency of 150 GHz and spans from 10 GHz to 300 GHz. The time trace shows clearly defined pulses which are detected in regular time intervals after being reflected from the bottom surface of the membrane. By analyzing the individual reflected pulses, frequency dependent damping constants can be extracted up to the high gigahertz range.

Acoustic phonon propagation in cobalt antimony skutterudites

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Cobalt antimony skutterudites are interesting due to their thermoelectric properties as they possess a large unit cell, heavy constituent atoms and large carrier mobility. Doping is considered beneficial to their thermoelectric properties. We studied undoped $CoSb_3$ samples and Co_4Sb_{12} samples with different Yb doping concentration using femtosecond pump and probe spectroscopy with an asynchronous optical sampling system. The transient reflectivity signal is strongly dependant on the doping level which should allow us to better characterize the samples. For highly doped samples fast electron-phonon coupling is observed.

Photon anti-bunching in GaAs/InGaAs nanowires driven by surface acoustic waves

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Semiconductor nanowires (NWs) offer new possibilities for low-dimensional optoelectronic devices. Their exploitation, however, demands appropriate techniques for applying electrical control fields, which typically require doping as well as the contacting of nm-sized structures with non-planar geometry. In this contribution, we demonstrate the contactless control of carriers in intrinsic NWs by using the evanescent piezoelectric potential of a surface acoustic wave (SAW). The NWs are placed on a $LiNbO_3$ SAW delay line, so that the oscillating piezoelectric potential transports photoexcited electrons and holes along the axis of the NW and can, in this way, control the spatial location of the recombination sites. We show that this approach can be exploited for the generation of pulses of anti-bunched photons based on the acoustic transport of carriers in (In,Ga)As NWs. These photon sources combine the high repetition rate provided by the acoustic pumping with the high photon extraction efficiency inherent to the NW geometry.

The experiments were carried out using GaAs NWs terminated with a short (In,Ga)As section. We excited carriers on the GaAs segment of the NW using a focused spot (diameter of approx. 1.5 μm) from a pulsed laser (pulse width of 150 ps, wavelength of 757 nm) with a repetition rate equal to 1/8 of the SAW frequency. The map of the time-integrated photoluminescence (PL) along the NW axis recorded at 20 K without SAWs applied shows weak emission lines at positions x>3 μm from the generation spot. They arise from the recombination of carriers diffusing from the laser spot to localized recombination centers in the (In,Ga)As segment. When a SAW is applied, its moving piezoelectric field transports the carriers excited in the GaAs segment to the (In,Ga)As section, leading to an enhancement of the PL intensity. Time-resolved measurements show that these centers emit short pulses (decay time of approx. 1.5 ns) with the SAW repetition period τ_{SAW}=2.95 ns. The pulsed character arise from the SAW-induced pumping of the emission center by the alternating trains of electrons and holes [1].

As a consequence of the small diameter of the NWs, the emission region has a high probability of containing only a finite number quantum emitters. In this case, the acoustic pumping is expected to induce light pulses with a finite number of photons [2]. In order to investigate the emission statistics, we analyzed the PL from the (In,Ga)As centers using a Hanbury-Brown and Twiss (HBT) autocorrelation setup. HBT histograms recorded under remote optical excitation (laser spot centered at the GaAs region) exhibit two periodicities: a short one associated with the SAW period and a longer one determined by the laser repetition rate. In contrast to the trace for local excitation (laser spot focused directly on the (In,Ga)As region), the results for remote optical excitation show a clear reduction in the coincidence rate at an autocorrelation delay τ_c=0 (photon antibunching), thereby attesting to the non-classical character of the emission.

From the reduction r_c=10 % of the coincidence rate at τ_c=0, we estimate that $1/r_c$=10 quantum emission centers are present in the detection area. Although demonstrating the concept, this number is obviously too high for applications in single-photon sources. Better degrees of antibunching are expected from the optimization of the growth conditions to create a single (In,Ga)As quantum emitter within the NW.

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Coherent acoustic phonons in multilayer structures

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Asynchronous optical sampling is used to investigate layered structures where the acoustic coupling between a gold film and a silicon substrate is modified by ultrathin self-assembled organic layers. Due to the observed enhanced acoustic decoupling if an organic layer is present, the lifetime of the coherent gold film vibration is increased. We utilize this to image a patterned and buried organic layer and estimate its thickness by the time offset between the gold film vibration and the time-resolved Brillouin scattering originating from the silicon substrate. We also investigate the dependence of the gold film vibration lifetime on the organic layer thickness and on the frequency of the vibration.

Mixing of sub-terahertz phonons with microwaves using a Schottky diode

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Previously it has been shown that Schottky diodes can be used to detect high frequency coherent phonons [1]. A phonon wave packet crossing the edge of the depletion layer causes the current through the device to change. It is already well established that Schottky diodes can also be used to detect electromagnetic radiation as they are widely used in THz spectroscopy [2]. By heterodyne mixing of sub-terahertz phonons with electromagnetic radiation of a similar frequency it should be possible to detect phonons electrically.

In this poster we discuss the feasibility of using a Schottky diode for heterodyne mixing of electromagnetic and acoustic signals in the 100 GHz range of frequencies to produce an intermediate frequency in the 1 GHz range.

In the proposed experiments we use Schottky diodes fabricated from n-GaAs and Au on one side of a semi-insulating GaAs substrate. Previous work has led to a new device design, in which two layers of doped GaAs are used. A layer doped with Si to a density of 5×10^{18} cm^{-3} was grown to form good ohmic contacts with a low series resistance. On top of this a layer doped with Si to a density of 5×10^{17} cm^{-3} was grown to form the Schottky contact. The structure was processed into triangular mesas and an insulating layer was deposited to cover the edge of the mesa. The electrical contact metallization was in the form of a "bow-tie" mm-wave antenna to efficiently couple the EM radiation to the diode. A superlattice on the reverse of the substrate will be used to generate phonons at a known frequency under excitation from a pulsed laser.

The mixing experiments will be carried out in an optical access cryostat at 4 K. Burst of quasi-monochromatic phonons will be generated by exciting the superlattice with optical pulses from an amplified Ti:sapphire laser. The phonons will propagate across the substrate to the device which is illuminated by 94 GHz electromagnetic radiation from a Gunn diode. The change of current through the device will be observed and analysed for evidence of mixing.

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Liquid crystal microresonators

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Optical microresonators (also called optical microcavities) confine light in small volumes. The mechanisms of confinement of light are total internal reflection, distributed Bragg reflection and surface plasmon polaritons. The refractive index of a liquid crystal droplet is greater than that of the outer media (such as PDMS), so the light can be confined inside the sphere due to the total internal reflection. The circulating light returns to the starting point in phase, resonance occurs. These resonant modes are called whispering gallery modes (WGMs). Same as cholesteric liquid crystals, ferroelectric liquid crystals (FLCs) exhibit helical structure, consequently 3D photonic band gap (PBG) in droplets. FLCs show selective reflection and lasing at the edge of stop band. We study WGMs microresonators and Bragg microcavities.

Experimental study of heat transfer in nanodevices

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This work is part of the on-going efforts to develop materials for a more rational use of energy. It assumes that changing the material structures at the nanoscale allows creating new thermal properties at the macroscopic scale, essentially due to the interplay between the material characteristic dimensions (size, roughness parameters) and the characteristic lengthscales associated to thermal transport, i.e. the mean free path and the wavelength of the heat carriers. The physics of heat dissipation from such devices is likely to depart severely from the well-known Fourier law valid at the continuum level.

To demonstrate such effects, electrical experiments involving nanometre-scale dual heaters/thermometers are planned, as they enable to probe the thermal properties of samples and the heat conduction from sub-mean free path localized heat sources. These devices are fabricated by nanolithography means in silicon. The temperature is used as a mean to vary the average phonon mean free path and the peak of the thermal phonon spectrum, following the Wien's law for phonons.

In order to verify the results obtained with the devices, scanning thermal microscopy (SThM) experiments are planned, which will give access to the temperature field on top of the sample with high spatial accuracy. This technique is based on atomic force microscopy (AFM), with a thermal sensor added at the apex of the tip.

The goal of the work is to observe thermal rectification, when the material facilitates the heat transfer in one direction and hinders it in the opposite one, similarly to a diode.

Ultrafast excitation of magnetization precession in high-index (Ga,Mn)As induced by picosecond phonon pulses

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We use picosecond phonon pulses to manipulate the magnetization of a high-index ferromagnetic (Ga,Mn)As layer. In a pump-probe experiment, transverse acoustic strain pulses injected into a layer of (311)-(Ga,Mn)As modulate the magneto-crystalline anisotropy which leads to a precession of the magnetization. Ferromagnetic semiconductors like (Ga,Mn)As possess a strong magneto-crystalline anisotropy. Cubic magneto-crystalline anisotropy of (Ga,Mn)As in combination with the epitaxial strain fix the easy axis of magnetization along the [100] crystallographic direction. Therefore, in a (311)-(Ga,Mn)As layer the easy magnetization axis and, thus, a spontaneous magnetization are slightly turned out of the layer plane. In an external magnetic field, the orientation of the magnetization is determined by the balance of the magneto-crystalline anisotropy and the applied magnetic field. Inducing a picosecond strain pulse the direction of magnetization is tilted followed by a precession around its equilibrium orientation. The time-evolution of the magnetization is monitored by means of the magneto-optical Kerr effect. We observe a remarkable magnetization precession with an amplitude exceeding 10 % of the saturation magnetization value induced by the transverse strain pulse.

Asynchronous optical sampling (ASOPS)

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Asynchronous optical sampling (ASOPS) is a technique for high resolution ultra-fast spatiotemporal spectroscopy. We present a system which employs two mode-locked femto second pulsed Ti:Saphire lasers with a repetition frequency of 800 MHz and an offset of Δf_R = 5 kHz. Consequently, the relative shift between pump and prope pulse is repetitively ramped from zero to 1250 ps in steps of 8 fs within an acquisition time of 0.2 ms. Due to the extreme short data acquisition time and the systematically conditioned avoidance of beam point instabilities and spot size variations this setup allows for far better data qualitiy than the common mechanical delay systems. With this setup we investigate the phononic properties of nanostructures, such as surface acoustic waves (SAW) on thin silicon membranes or other nano patterned structures.

Cavity optomechanics with micromirrors

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Reaching the quantum ground state of a macroscopic mechanical object is a major experimental challenge in physics, at the origin of the rapid emergence of cavity optomechanics. We developed a new generation of optomechanical devices, either based on quartz micropillar with very high mechanical quality factor, or on low mass photonic-crystal suspended nanomembranes. Both are used as end mirror in a Fabry-Perot cavity with a high optical finesse leading to ultra-sensitive interferometric measurement of the resonator displacement. We expect to reach the ground state of such optomechanical resonators at 100 μK combining cryogenic cooling with a dilution fridge at 100 mK and radiation-pressure cooling.

Photoelastic terahertz phonon detection and generation within a semiconductor superlattice

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Currently, the development of compact opto-acoustic transducer able to generate and detect acoustic wave in the terahertz wavelength is an active research subject. At the end of it all, some real advances in microscopy, spectroscopy and the study of nanostructures.
Superlattices made with a periodic stacking up of around 10 nm thick AlAs and GaAs multilayers has shown the ability to be used as high frequency acoustic generator and detector. The excitation by a femtosecond laser of a semiconductors stacking up leads to an important and a temporally short strain in the pattern which produce high frequency acoustic waves related to the multilayer period (excitation near q=0).
Lately, we have shown that a 5nm periodic stacking up can emit in its underlying substrates quasimonochromatic coherent phonons until a frequency of 1THz. This superlattice is also a very effective phonon detector since strain within superlattice cause a Refractive index shift which induces a reflectivity variation measured with a probe light.
Unfortunately, generation and detection have different spectral response, as explained above, generation is more efficient around q=0, while detection (which implies acoustic and light wave vector conservation) works with q=2k where k is the light vector. As consequence, a single superlattice cannot be used as well as detector and generator for the same acoustic wave vector.
However, equations show a rise of q=0 detection in case of light probe reflection at the rear of the superlattice. To enhance this property, we have design a sample with an optical microcavity which encircles the superlattice (this scheme is able to improve by one to two orders of magnitude detection sensitivity in picoseconds ultrasonics experiments).
The sample used is a 17nm AsGa/AlAs superlattice set in a 56/65nm Bragg reflectors microcavity. We will present experiments performed at low temperatures (10 to 80 Kelvin), this sample has been designed to generate 300GHz acoustic waves and can detect phonons until 900GHz.

Optical and vibrational properties of single gold nanobipyramids

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The peculiar properties of nanostructures and nanoparticles are currently extensively investigated because of their fundamental and industrial interest, and can now be studied at the single-particle level, avoiding spurious effects associated to shape and size dispersions. Size reduction induces resonances in the optical response of metal nano-objects, associated with a resonant oscillation of conduction electrons, known as surface plasmon resonances (SPR). Elongated gold nano-objects, such as nanorods and nanobipyramids, are particularly suitable for applications as they show a strong quasi-Lorentzian longitudinal SPR with a high quality factor, whose spectral position directly depends on their aspect ratio. Gold nanobipyramids present the additional advantage of strong electromagnetic field enhancement at the vicinity of their ends (an effect useful in many plasmonic devices).
In this context, the spectral properties (amplitude, wavelength and line width) of the longitudinal localized SPR of individual gold nanobipyramids have been quantitatively measured using the spatial modulation spectroscopy (SMS) technique. These optical measurements were combined with transmission electron microscopy (TEM) characterization of the same nano-objects. An excellent agreement was found between experimental extinction spectra and numerical simulations using the morphologies extracted from TEM analysis and including the inhomogeneous environment of nanobipyramids resulting from their deposition on a substrate. This agreement allows to theoretically predict electromagnetic field distribution in and around the nano-objects studied. Moreover, comparison with SMS experiments performed on single gold nanorods revealed marked differences in the distribution of electromagnetic field, as well as in the local environment of the nano-objects, probably as a result of different synthesis and purification procedures.
The ultrafast response of single nanobipyramids was subsequently investigated by combining the SMS microscope with a high sensitivity femtosecond pump-probe setup. The obtained time-resolved signals present multimodal oscillations induced by nanobipyramid acoustic vibrations. Finite-element modeling was then used to compute the vibration modes of a gold bipyramid, using their morphology determined in TEM together with the elastic constants of bulk gold. Experimentally observed periods were found in excellent agreement with those computed for the breathing (transverse motion) and extensional (longitudinal motion) modes of the bipyramids.

Ultrafast Optical Spectroscopy of Nanolayered Transition Metal Oxides: observing the phonon dispersion relation by time resolved optical spectroscopy

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Travelling strain waves in solids can be observed by Brillouin-scattering in backscattering condition. In superlattices, the acoustic phonon branch is backfolded into the reduced Brillouin zone. For a periodicity of approximately hundred nanometers large parts of the Brillouin zone become accessible to broadband optical spectroscopy. We show time resolved optical reflectivity measurements on a LaSrMnO3-SrTiO3 multilayer, discuss the temporal features of the signal and extract details of the superlattice acoustic and optical phonon branches by Fourier transformation.

Picosecond ultrasound spectroscopy on Ni-Mn-Ga and Co doped thin film shape memory alloys

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Shape memory alloys are characterized by a reversible and diffiusionless structural phase transition from a high-temperature austenitic phase to a low-temperature martensitic phase. Within these materials the ferromagnetic Ni-Mn-Ga system is of special interest due to an observed magnetic-field-induced strain of up to 9%. Epitaxial thin film samples deposited on MgO were investigated by femtosecond pump-probe spectroscopy using the asynchronous optical sampling technique. Strong reflectivity oscillations of up to 1.4 Thz are observed while the samples are in the martensitic phase. The temperature dependent behaviour of these high-frequency modes shows a large reduction in frequency of up to 25% when approaching the structural phase transition temperature, indicating a phonon mode, which is strongly coupled to the electronic or magnonic system. This softening bahaviour is also a characteristic phenomenon for materials, which form charge- or spin density waves.

Interaction of surface acoustic waves with Hertzian contact resonance of silica microspheres studied with laser-induced transient grating technique

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Interaction of surface acoustic waves (SAWs) with mechanical oscillators situated on a solid surface was studied theoretically [1,2] but has never been observed in experiment. We use laser-induced transient grating technique to measure SAW dispersion on a sample comprising a thin aluminum film on a glass substrate covered by a monolayer of 1 μm diameter silica microspheres. Surface acoustic waves are generated by crossed laser pulses and measured via diffraction of a probe laser beam, with both excitation and probe beams incident either on the front or back surface of the sample. The measured acoustic dispersion curves exhibit classical "avoided crossing" behavior due to hybridization of SAWs with Hertzian contact resonance of the microspheres at ~230 MHz. The measurements yield information on both the magnitude and statistical distribution of the adhesion force between the microspheres and the substrate. The experiment opens a new avenue for studying contact mechanics of micro- and nanoparticles.

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Ultrafast time resolved pump-probe spectroscopy on crossed nanobeams

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High speed asynchronous optical sampling, a pump-probe technique, was used to investigate the phonon modes of crossed nanobeams. The free-standing crossed beams are made from 157 nm thick silicon nitride with a length of 3 µm and a width varying from 200 to 400 nm. A thin gold layer of around 20 nm on top is used as an acoustical transducer. It is shown that the variation in width leads to a frequency shift in the phonon modes of the structure.

Topological defects and shape-controlled interaction in nematic liquid crystal

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We have studied topological defects around the optical micro-fiber dispersed in nematic liquid crystal, entanglement of micro-fiber with micro-sphere, and their application. The glass micro-sphere is proper spherical shape to entangle to the micro-fiber in order to study the binding of micro-fiber and micro-sphere by delocalized topological defects and entangled disclinations.

Optimisation of a SASER device

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It has been shown that a semiconductor superlattice (SL) structure can be used to amplify terahertz acoustic phonons [1], [2]. A population inversion can be created for phonon assisted transitions of electrons between the quantum wells in this structure. This can be used to amplify phonons in the device creating the sound equivalent of a LASER, a SASER. In this work optimisation of this device through the control of doping within the structure is investigated.

A SL was grown in which the doping is confined to a single monolayer within the barrier layers of the structure. This should lessen the impurity scattering within the device and hence reduce spontaneous transitions. The gain of the device was analysed using pump-probe and bolometer experiments. In the pump-probe experiments evidence of significant gain was seen. In the bolometer experiments the longitudinal acoustic phonon signal was obscured by a large transverse acoustic signal. The additional transverse signal is thought to be related to an additional voltage drop across the device, caused by either: a voltage being required to move the carriers into the wells or a voltage dropped over the contact layers.

Figure 1 shows the Fourier transform of the pump-probe signal obtained from the device. Two phonon frequencies are observed: the stronger peak at 490 GHz is due to folded mini-zone centre (q = 0) phonon modes and the weaker, lower frequency, peak is due to phonons of wave vector $q = 2k_{\text{laser}}$. A large increase in the 490GHz signal is observed when electrical bias is applied to the SL, which we attribute to coherent phonon amplification taking place. The acoustic gain is much higher than previously observed in a SL with uniform doping. The increase of the $q = 2k_{\text{laser}}$ peak is much less pronounced due to the weaker confinement of these modes in the SL.

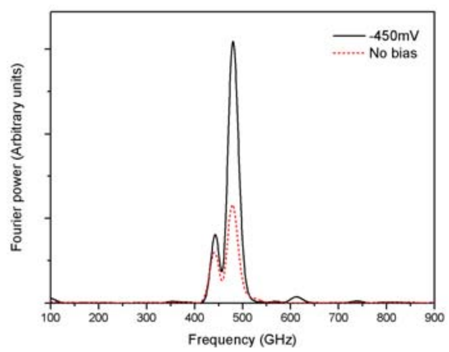

Figure 1: *Pump-Probe signal from the modulation doped sample*

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Acousto-electric control of Quantum Dots using surface acoustic waves

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Bias-controlled single electron charging of single quantum dots (QDs) can be achieved by embedding them into the intrinsic region of an n-i-Schottky diode. As a function of the applied bias voltage neutral, single and double charged excitons can be investigated. To use surface acoustic waves (SAW) as a tuning mechanism, the complete structure has to be transferred as a thin film on $LiNbO_3$ on which SAWs can be generated by interdigital transducers with frequencies up to the GHz-range. We use a stroboscopic technique to probe the dynamic modulation of the photoluminescence (PL) and an actively phase locking scheme to precisely control the phase between laser excitation and SAW. The implementation of this technique provides an additional degree of freedom for designing more complex hybrid samples with quantum dots for conditional qubit operations.

Time Resolved Vibrational Properties of Semiconductor Nano-resonators

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Phonons in nanostructures have been investigated in recent times with various techniques. Using high speed asynchronous optical sampling earlier studies have shown confined longitudinal phonons in silicon membranes. In this work we examine more complex nanostructures using the same technique. Free-standing discs and beams fabricated from Si_3N_4 with a gold layer on top, which acts as an acoustical transducer, are examined. The acoustic spectrum of a free standing 2.5µm long beam with 170nm width is compared to the spectrum of a similar beam clamped to the silicon substrate. Both spectra show several modes in the GHz range, some of them are suppressed in the spectra of the clamped beam compared to the free standing beam.
The micromechanical disk resonators have a similar thickness as the beams and are between less than a micron and a few micron in diameter. Again mechanical eigenmodes in the GHz range were found. Assuming a radial symmetry of the individual modes, simulations were carried out that agree very well with the experimental data.

Polariton mediated resonant Raman scattering of folded acoustic phonons

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We present a study of the Raman scattering efficiency by folded acoustic phonons in an acoustic cavity embedded into an optical cavity. The interaction between the multiple excitons confined in the quantum wells that form the acoustic cavity and the mode of the optical cavity produce a complex set of polariton and exciton-only branches. The studied system was grown by molecular beam epitaxy and is based in the GaAs/AlAs family of semiconductors. A wedge in the optical mirrors allows to control the detuning between the exciton and cavity energies by laterally scanning the sample. Photoluminescence experiments at temperature of liquid nitrogen show three polariton branches, with splittings of the order of 6 meV, and several purely excitonic peaks. The excellent quality of the samples allows us to perform Raman scattering experiments in almost double resonance with the three polariton branches, and to follow the scattering efficiency as the polariton changes regimes. The Raman scattering efficiency in the processes mediated by the polaritons strongly depends on the relative weight of the excitonic and photonic components, and peaks following a quadratic dependency close to the mode anticrossing. We present a factorization model to explain the results.

Energy transfer in nanostructures and in the near-field

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We study phononic heat transfer in nanoconstrictions between two bulk media using molecular dynamics simulations, focusing especially on the effects of phonon interference and phonon-phonon scattering. The results show, for example, that in the ballistic limit, the temperature and heat current profiles exhibit directional patterns in the bulk region. The patterns are washed away by increasing temperature or phonon-phonon scattering. We are also investigating the possibility of including quantum effects in the simulations by using quantum Langevin-like thermal baths for thermalization.

Collective modes detection in hypersonic phononic crystals

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Background, Motivation and Objective:
In picosecond acoustics, we use ultrashort light pulses to excite and detect very high frequency acoustic waves up to several hundred Ghz. This technique is non destructive and has been used to access to thichness or to the longitudinal sound velocity in thin films.In this technique only longitudinal waves can be emitted by the absorption of the laser pulse.

Statement of Contribution/Methods:
After realizing arrays of nanocubes on top of the sample, we can also excite and detect surface acoustic waves using the pump-probe setup. In reflectometry, we have already showed that we were able to detect some collective acoustic modes of the nanocubes only if the probe wavelength is shorter than the lattice parameter. And thus, combining the longitudinal and surface acoustic waves we can perform complete elastic measurements namely measuring the Young modulus and the Poisson ratio of thin isotropic films. Up to now, this technique was limited to films whose the thickness is greater than 200nm.

Results:
Our goal is to successfully characterize films as thin as 50nm. We realized 2D lattices of nanocubes of Platinum using e-beam lithography on top of the thin film to be characterized. In this poster, we show that thanks to an interferometric detection, we are able to detect the modes in arrays of nanocubes of Platinum irrespective of the lattice parameter. From that we show that we can access to the mechanical properties of thin film down to 50nm.

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Excitation of spin waves by picosecond strain pulses

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We study the excitation of spin waves (SW) in thin film of ferromagnetic (Ga,Mn)As layer by picosecond strain pulses. When the picosecond strain pulse travels through the ferromagnetic layer in forward and backward directions the only one SW mode can be excited.

While the strain pulse is travelling in (Ga,Mn)As, it tilts the magnetization out of the equilibrium position with following precession [1]. In the experiment we detect the temporal evolution of the normal component of magnetization during precession. Fourier spectra of this evolution demonstrate two distinct spectral lines centered at frequencies f_l and f_h. These lines can be attributed to the SW eigenmodes of (Ga,Mn)As. The values of f_l and f_h monotoneously grow with the increase of the in-plane magnetic field. The amplitudes of spectral lines strongly depend on the magnetic field**:** in the field range $B = 225 \pm 25\, mT$ the only peak with $f_l = 12\, GHz$ presents in spectrum. This is the most important result of our work.

For theoretical analysis we need to solve the equation of Landau-Lifshitz with boundary conditions of pinning of magnetization at the interfaces. The solution for the magnetization components can be obtained as superposition of SW eigenmodes. The amplitudes of the SW eigenmodes are proportional to the overlap of wave functions of spin wave and phonons with the same frequencies [2]. The excitation of the single SW mode with number n is possible, if it has the frequency $f^{(n)} = (n+1)s/(2d)$, where d is the thickness of ferromagnetic layer, s is the sound velocity [2].

We studied the excitation of spin waves in 200-nm-thick (Ga,Mn)As film grown on GaAs substrate. According to the theoretical considerations, selective excitation of the mode with $n = 0$ in such structure is possible, if it has the frequency $f^{(0)} = 12\, GHz$. This value is in perfect agreement with experimental results. Thus, we experimentally demonstrated the excitation of the single SW mode by picosecond strain pulse with a broad acoustical spectrum. Theoretically we explained this result with Landau-Lifshitz approach and found the condition of excitation SW modes with certain number.

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Optical diffraction from opal-based photonic structures

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We report on experimental and theoretical investigations of light diffraction from opal films of different thickness. A special attention was paid to the transformation of diffraction patterns upon building up the opal structure from two-dimensional (2D) film structure towards bulk three-dimensional (3D) structure. In our setup the diffraction patterns are displayed on a narrow cylindrical screen with a specimen fixed in its center. The diffraction patterns have been studied visually and recorded in different scattering geometries with the films illuminated with white unpolarized light. With increasing number of layers, certain regions of 2D diffraction patterns fade out and finally form diffraction spots characteristic for 3D diffraction. We also found that stacking faults in bulk opals lead to formation of a 2D-like diffraction pattern, i.e. such structure demonstrate 3D to quasi-2D transition in optical properties.

1D Hybrid Bragg-Stacks: a soft model system to study hypersonic wave propagation

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Phononic crystals with their ability to mold the flow of elastic energy have attracted increasing interdisciplinary interest. As of today, no generalized full description of phonon propagation in phononic structures is available mainly due to the large number of variables determining their band diagrams. A detailed understanding is therefore necessary in order to address fundamental concepts such as heat management and strong phonon-photon interactions. While the majority of the work on phononic systems is powered by the well-developed field of semiconductor physics, we focus on phononic structures that utilize soft matter fabrication techniques. Their corresponding dispersion relation at hypersonic frequencies is directly measured using the powerful non-destructive technique of high-resolution spontaneous Brillouin light scattering (BLS).[1]
Due to the vector nature of elastic wave propagation, theoretical phononic band structures can be uniquely verified at low dimensionality [2] and hence 1D phononic crystals constitute appropriate model systems for fundamental studies. Such hybrid Bragg stacks, composed of alternating layers of porous silica (p-SiO_2) and poly(methyl methacrylate) (PMMA), respectively, exhibit clear hypersonic phononic band gaps (gap width up to 30%).[3,4] Here we report on the fabrication, characterization, and both experimental and theoretical dispersion diagrams along and normal to the periodicity direction (on-axis) of silica/PMMA. The width of the gap, the phonon frequencies, and their intensities near the edge of the first Brillouin zone are sensitive probes of the longitudinal moduli and elasto-optic constants of the individual layers and structural parameters. Mixing with sagittal modes of the individual layers under oblique incidence (off-axis) condition alters the observed dispersion and allows access to the shear moduli of the two layers. Incorporation of defects holds a wealth of opportunities to engineer the band structure. Cavity layers are capable to join additional modes which in turn modify the dispersion of the undisturbed stack.

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High frequency surface acoustic waves generated by femtosecond pulses

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Rayleigh and leaky longitudinal surface acoustic waves are generated by femtosecond pulses on bulk silicon with aluminium stripe transducers. The modes are detected in the time domain for various propagation distances and are identified by measuring on various pitches. The spectra are compared with finite element calculations and the lifetimes of the modes are determined quantitatively by spatially separating pump and probe beam, showing a significant difference in the lifetimes of both modes. Rayleigh modes with frequencies of up to 90 GHz using a 100 nm period grating were measured.

Single Circuit Parallel Computing with Phonons through Magneto-acoustics

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We analyze an alternative implementation of thermal computing inspired by optical computing. Using the acoustic Faraday effect, we design a phonon gyrator and establish that it can act like a generalized transistor (essentially a controlled gyrator). Different combinations of controlled and uncontrolled gyrators (as well as different implementations of control) are shown to implement the set of universal classical logic gates. We exploit the wave nature of phonons to demonstrate a means of performing parallel computation within a single circuit, giving an enhancement that is either infeasible or impractical in other computing architectures.

Novel scattering scheme for probing phonons in superlattices studied by Raman spectroscopy

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In this work we studied the optical generation of phonons in semiconductor superlattices of AlAs-GaAs. The samples used were characterized by photoluminescence and X-ray diffraction. The coupling efficiency between light and phonons was determined by Raman spectroscopy. These experiments were performed using in a first step the conventional standard backscattering geometry, perpendicular to the surface of growth. In a second stage we tried a novel scheme of forward scattering. Here the incoming light was set parallel to the direction of the planes of the superlattice, exploiting the waveguide geometry. This configuration allowed the access to selection rules different from the usual for the generation of phonons in the superlattice.

Vibrations of segregated and alloyed bimetallic nanoobjects

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Nanoobjects exhibit discrete low-frequency vibrations whose properties reflect their morphology and environment. They have been extensively investigated in the case of monomaterial nanoobjects[1], but, in contrast, only few studies were performed on multimaterial (or composite) nanoobjects. These are particularly promising for applications, as the association of different materials provides additional degrees of freedom for tailoring novel properties playing with their geometry, structure and composition. Here, we present time-resolved optical investigations of the acoustic vibrations of bimetallic nanoobjects (nanospheres and nanorods) in both segregated (core-shell like) and alloy conformations.

The vibrations of segregated spherical bimetallic nanoparticles were investigated in Pt-Au and Ni-Ag systems. The breathing modes of these nanoobjects were coherently excited after absorption of a pump pulse by the the electrons of the metals. Their vibration is subsequently detected in the time-domain by a probe pulse monitoring the induced modulation of the sample transmission. Their measured periods are in agreement with those computed using a model based on continuum elasticity, assuming a perfect core-shell configuration and good mechanical contact at the interface between the core and shell metals[2]. Similar experiments were performed on bimetallic Au-Pd core-shell nanorods formed by deposition of Pd on gold nanorods. Both the extensional and breathing modes were excited and detected. Their periods were found to decrease and increase with the amount of deposited palladium respectively[3]. These opposite behaviors reflect changes of both the nanorod dimensions and mechanical properties, in excellent agreement with numerical simulations. Using this approach the amount of deposited material can be determined even for very low quantities, difficult to estimate by other means.

The acoustic vibrations of alloy nanoparticles were analyzed in the case of chemically synthesized Au-Ag alloys with different compositions. The measured breathing periods are in agreement with those calculated averaging the elastic properties of the constituting materials, but only leads to small deviation as compared to those computed for Au-Ag core-shell structures. In the future, these results may be complemented by new experiments involving alloy nanoparticles formed by metals with more dissimilar elastic properties, allowing for a more quantitative study of the effect of alloying on the acoustic response.

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Photogeneration of coherent acoustic phonons by Photoinduced Dember field

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The poster deals with the study of the microscopic mechanisms of opto-acoustics transformations. We discuss in particular the processes of generation of acoustic phonons by the interaction between a femtosecond laser and a piezoelectric semiconductor. While thermoelastic process (phonon pressure), deformation potential (electronic pressure) and inverse piezoelectric effect are already known mechanisms, we present here a first observation of the generation of coherent acoustic phonons by photo-induced Dember electric field. The experiments are conducted according to the classical pump and probe scheme. We report that the electric field (Dember field), caused by the separation of the photo-generated electrons and holes in the process of the supersonic diffusion at the femtosecond-picosecond time scales in non-doped semiconductor, is indeed sufficient for the dominance of the piezoelectric mechanism of the optoacoustic transformation over the mechanism of the electron-hole-phonon deformation potential. To clearly establish our claims, we have performed experiments on non-piezo active GaAs sample (GaAs [100]) as well as on several piezoactive samples with different crystallographic orientations (GaAs [111] and [-1-1-1]).

Raman scattering in optical microcavities

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The inelastic scattering of light by phonons can be strongly modified by the confinement and amplification of the light field in optical microcavities [1]. We present a model that fully takes into account in a transparent way the details of the light and phonon fields in the evaluation of the Raman efficiency in these structures [2]. A comprehensive experimental study of the Raman scattering by acoustic phonons in GaAs/AlAs M QWs embedded in optical microcavities with high and low Q-factor is presented and compared with the predictions of the model. Both the conditions of full cavity confinement in resonance with the cavity-mode, and of «slow light » in resonance with the edge-mode of the distributed Bragg reflectors are considered. The application of these results to optomechanical resonators with confinement of both light and sound are also discussed.

Indirect Excitons transport in confined acoustic potentials - Towards an integrated optical multiplexer

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A spatially indirect exciton (IX) is a bound state of an electron and a hole localized in different quantum wells of a double quantum well structure (DQW). IX are formed by applying an electric field across the DQWs in order to drive the electrons and holes to the different QWs and, hence, to increase the IX lifetime while still maintaining the Coulomb interaction between them. Due to their long lifetimes and strong non-linear properties arising from dipole-dipole interactions [1, 2] IXs are particularly interesting for applications in optoelectronic devices. During the last years, different concepts have been put forward for the transport and manipulation of IXs, including electric, magnetic, optical and strain fields. Moreover, IXs fluids have been shown to undergo a spontaneous phase transition to a macroscopically ordered state (a condensate) thus opening the the way for their use in quantum devices [3].

In this contribution, we demonstrate that a high degree of control of IX fluids can be obtained by combining their electrostatic manipulation via electrostatic gates with the long - range IX transport achieved by Surface Acoustic Waves (SAW). The experiments were carried out in (Al,Ga)As DQW samples grown by molecular beam epitaxy. SAWs with a wavelength λSAW = 2:8 μm propagating along a non-piezoelectric <100> surface direction were electrically generated using interdigital transducers deposited on a piezoelectric ZnO-island. The spatial and energetic distributions of IXs as well as the IX dynamics during acoustic transport was investigated using spatially and spectrally resolved photoluminescence (PL). The moving type-I band-gap modulation induced by the SAW strain field traps and transports the long-living IXs [4] over distances up to one mm. Our results show that, since the transport efficiency is high (exceeding 50% over a distance of 500 μm), the maximum transport distance is limited only by the length of the transport channels. Moreover, we demonstrate that IXs can be transferred between orthogonal SAW beams, thus opening the way for the control of the transport direction of exciton fluids. The transfer is mediated by a moving array of potential dots created by the interference of two orthogonal SAW beams, which captures the IXs from the incoming beam and transfers them to the other. The mechanisms for the acoustic transport as well as for the IX transfer between beams have been investigated by PL and supported by numerical simulations based on a theoretical model for hydrodynamics of interacting dipolar excitons. These functionalities are combined to realize an IX acoustic multiplexer (EXAM), a device which controls IX flow between different input and output ports. namely, the EXAM combines several optoelectronic functionalities on a single chip including photon to exciton and exciton to photon conversion, on/off switching using Exciton Optoelectronic Transistors EXOTs, IX (information) transport in moving acoustic potentials, signal multiplexing and logic operations. The EXAM not only delivers a proof-of-concept for all exciton optoelectronic device but also offers a controllable way for artificially producing cold IX gases confined in zero-dimensional moving strain dots. It, therefore, provides a promising platform to investigate the dipole-dipole interactions as well as collective phenomena of IXs.

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Near-field dynamic study of the nanoacoustic effect on the extraordinary transmission in gold nanogratings

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In this work we report that nanoacoustic pulses can modulate the extraordinary optical transmission (EOT) in nanogratings with a high frequency bandwidth. This study was performed on gold nanogratings on top of a GaN crystal by combining a near-field scanning optical microscope with a femtosecond nanoultrasonic system. Experimental results indicate that the propagating longitudinal nanoacoustic pulses changed the refractive index of a GaN crystal and therefore modulated the near-field cavity mode behavior. Our finding suggests that the temporal modulation with a >11GHz bandwidth can be achieved, with a high potential for future temporal and high speed control on the EOT behavior in nanostructures.

Ion beam synthesis of nanothermochromic diffraction gratings with giant switching contrast at telecom wavelengths

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We present two different routes to define switchable diffraction gratings realized by vanadium dioxide nanoclusters in a SiO_2 matrix. These VO_2 nanocrystals as synthesized by ion beam implantation followed by a raid thermal anneal. The reversible metal-insulator-transition (MIT) of the VO_2-clusters close to room temperature comes with a change of the refractive index and is most pronounced at telecom wavelengths. The diffraction gratings studied were either defined by spatially selective ion beam synthesis or by selective deactivation of the MIT by Ar-ion bombardment. The observed broad thermal hysteresis makes this system suitable for switchable optical storage and photonic devices.