temperature can differ from the lattice temperature, and the carrier temperature in an electronic system under Joule heating depends on both electron-electron and electron-phonon scattering.[1] In this study, carrier heating induced by an ac-bias current in high mobility GaAs/AlGaAs devices was investigated using magneto-transport measurements in the regime of low field Shubnikov de Haas (SdH) oscillations. For this purpose, the background subtracted longitudinal magneto-resistance was examined at different ac-bias currents (up to 12 micro Amperes) under different bath temperatures over the span of 0.02 K to 4.2 K. Carrier heating due to the bias current was studied by observing the alteration in the SdH oscillation amplitudes by fitting them in to a semi-empirical formula based on Lifshitz-Kosevich theory.[2] According to the SdH lineshape analysis, the carrier temperature in our experiments is linearly proportional to the ac bias current, and background subtracted diagonal resistance measurements taken from a hall bar sample including different sections with different width illustrate that the carrier heating is also size dependent. Both these results appear to indicate that the electron-electron scattering is the dominant energy relaxation mechanism in the low temperature and large filling factor limit. [1] Taubert D, Tomaras C, Schinner G J, Tranitz H P, Wegscheider W, Kehrein S and Ludwig S 2011 Phys. Rev. B 83 235404 [2] Mani R G and Anderson J R 1988 Phys. Rev. B 37 4299

## P2_182 Time-resolved modeling of indirect exciton scattering: the role of the internal dynamics

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**Text** Indirect excitons (IXs) are long-lived correlated electron-hole pairs and can be optically generated in coupled quantum well devices. They can be accelerated and scattered by static or time-dependent potential patterns[1], and are an ideal playground to probe the dominant role of internal quantum correlation in the evolution of few-particle systems. We simulate the coherent dynamics of a single IX in prototypical potential landscapes by using the Split-Step Fourier method to perform the exact two-body Schroedinger propagation. Our approach, which fully takes into account the electron-hole internal degrees of freedom, allows us to expose the complex phenomenology arising in the scattering of single IXs.[2] Recent experiments are discussed in light of our calculations.[3] We show that commonly used mean-field methods -which neglect dynamical correlations by construction- are quantitatively or even qualitatively inadequate to predict transmission coefficients and diffraction patterns in experimental regimes. The shortcoming of mean-field methods are traced to the neglected internal virtual transitions during the scattering process. We also describe a recently proposed self-energy approach which includes internal virtual transition into the c.m. dynamics.[4] In spite being orders of magnitude numerically less demanding than the full quantum propagation, it proved to be able to reproduce the exact calculations with very good approximation. Finally, we perform specific simulations of IXs driven by surface acoustic waves and show that their dynamics is a sensitive probe of the scattering potentials in the devices, such as single impurities or potential landscapes generated by metallic gates. This is due to the competing length and energy scales between the SAW elastic potential, the scattering potential, and the internal level structure of the IX. Comparison between different methods in selected potential profiles show for shallow impurities, where tunneling plays a major role, that internal correlation of the electron-hole pair need to be taken into account exactly in order to correctly evaluate the IX dynamics. [1] A.A. High et al., Science 321, 229 (2008). [2] F. Grasselli, A. Bertoni, G. Goldoni, Phys.Rev.B 93, 195310 (2016). [3] C.J. Dorow, J.R. Leonard, M.M. Fogler, L.V. Butov, K.W. West, L.N. Pfeiffer, arXiv:1801.01553 [cond-mat.mes-hall] (2018). [4] F. Grasselli, A. Bertoni, G. Goldoni, Phys.Rev.B 94, 125418 (2016).

## P2_183 Shubnikov - de Haas oscillations in a wide (~20nm) HgTe quantum well with surface states

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**Text** Due to strong relativistic effects caused by large Hg mass quantum wells based on a double heterojunction CdHgTe/HgTe/CdHgTe provide a nice possibility to study new interesting physics. For today they has been already shown to be 2D topological insulator at width d > 6.3nm [1] and 3D topological insulator at d > 70nm [2]. Our work is devoted to the investigation of ~20nm HgTe quantum wells. Previously electrons of the conduction band in these wells were indirectly, by studying roughness scattering, shown to locate near well surfaces at large energies [3]. Together with the calculated spin-polarization of these states ~20nm HgTe quantum wells thus seem being a transitional case from 2D topological insulator to 3D one, when spin polarized surface states start to form but they still not well extended in space. The present work was directed to study these states more detailed. We have experimentally investigated Shubnikov - de Haas oscillations in 20-22nm HgTe quantum wells. We have observed appearance of beatings in oscillations with applying external gate voltage. This beatings can be well described by large Rashba splitting together with the appearance of the "surface" states mentioned before. [1] Bernevig et al., Science 314, 1757 (2006); Konig et al., Science 318, 766 (2007). [2] Brune et al., PRL 106, 126803 (2011). [3] Dobretsova et al., JETP Letters 104, 388 (2016); Dobretsova, et al., JETP Letters 101, 330 (2015)

## P2_184 Measurement of the electron temperature as a function of the microwave intensity in the microwave irradiated high mobility GaAs/AlGaAs 2DES

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**Text** We examined the influence of monochromatic microwave radiation on the diagonal resistance in the GaAs/AlGaAs 2DES at liquid helium temperatures both at null magnetic field, and at finite magnetic fields to determine the electron temperature as a function of microwave intensity. Thus, incident microwave radiation power, served to photo-excite a high mobility 2DES as magnetoresistance traces were obtained as a function of the microwave power P and T. Then, fits of the Shubnikov de Haas (SdH) oscillations line shape served to extract the electron temperature (Te) at finite magnetic fields as a function of P. The electron temperature Te at null magnetic field was determined as a function of microwave power by using as a temperature gauge the null magnetic field resistance variation with respect to lattice temperature. This study shows that microwave produces a small discernable increase in the electron temperature both at null magnetic field and at finite magnetic fields in the GaAs/AlGaAs 2DES. The heating effect at null field appears greater in comparison to the examined finite field interval, in line with theoretical predictions [1,2], although the increase in the electron temperature in the zero-field limit appears smaller than theoretical predictions. Also, the results indicate more heating at null magnetic field at lower microwave frequencies than at higher microwave frequencies, although in the finite magnetic field region, there is no discernable difference. Such results will be compared with theory[1,2]. [1] X. L. Lei and S. Y. Liu, Phys. Rev. B 72, 075345 (2005) [2] X. L. Lei and S. Y. Liu, Appl. Phys. Lett. 94, 232107 (2009)

## P2_185 Coulomb Interaction Effects in Partitioning of Two Hot Electrons

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**Text** Electron quantum optics using single-electron sources in solids provides important steps towards quantum information processing using a few electrons. Recently, a two-electron Hanbury-Brown Twiss experiment is demonstrated by using a quantum-dot pump [1]. In the experiment, the quantum-dot pump is formed in a quantum Hall system and emits two electrons far above the Fermi level. The two electrons propagate along a quantum Hall edge and then they are partitioned into two paths by a potential barrier. By the partitioning, the electrons are both transmitted through the barrier, both reflected by the barrier, or split. Interestingly the probabilities of the partition events obtained in the experiment deviate from those of uncorrelated tunneling events of each electron. We theoretically study how the Coulomb interaction between the two electrons changes the partitioning probabilities. We derive a two-particle scattering matrix, which takes into account of the energy exchange between the electrons in the partition events. There occurs effective bunching or anti-bunching behavior in the partitioning, depending on the tunneling time through the barrier and the interaction strength. The results are in good agreement with the experimental observations. Reference [1] N. Ubbelohde, et al., Nature Nanotechnology 10, 46 (2015)

## P2_186 Verification of Stark-ladder formation in InGaAs/GaAsP superlattice solar cell structure by a photo-reflectance

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**Text** Strain balanced InGaAs/GaAsP multiple quantum well (MQW) structure has a potential to be a suitable mid-cell of the multi-junction solar cells. Further improvement is expected by using super lattice (SL) structure where the sufficiently thin barrier layer allows the carrier to tunneling to the neighboring QWs. However, the influence of the built in electric field existing has not been well understood. We, then, experimentally verified a formation of Stark ladder states in the SL region by a photo-reflectance (PR) measurements at room temperature. The SL samples consisted of 10 stacks of QWs in the intrinsic region. The thickness of the $In_{0.21}Ga_{0.79}As$ well layer was fixed at 5.0 nm, and that of $GaAs_{0.59}P_{0.41}$ barrier layer was changed from 1.9 to 5.3 nm. The KramersKronig transformed PR modulated spectra was used for determining critical transition energies. One peak at 1.29 eV was observed for the thicker barrier layer samples. This was attributed to the hh1-e1 transition in the identical QW. In contrast, two peaks were observed for thinner barrier layers samples. For example, they were at 1.28 and 1.31 eV for 2.7-nm-thick barrier layer sample. The energy difference between these two peaks increased with decreasing the barrier thickness. When the energy state in a QW is spaced by the built-in electric field and lattice period, the Stark ladder state may appear. Electron transition occurs not only between the energy levels existing in the identical QW but those existing in the neighboring QW thanks to the extension of the envelope function. In this case, theoretical prediction shows that the wavefunction of e1 level expanded over more than three QWs. We, then, could consider that the observed two peaks were due to the transition from hh1 to e1 levels in the first nearest QWs. Since the existence probability of the Stark ladder states is expressed by a Bessel function of the first kinds, the expected intensity of the transition from hh1 to the e1 level in the identical well becomes negligible. This is why not three (-1, 0, +1) but two (-1, +1) peaks were