1 Introduction

Charge carriers in modulation–doped semiconductor quantum systems are a field of enormous and still growing research interest since they allow, in specially tailored systems, the investigation of fundamental properties, such as many–particle interactions, of electrons in reduced dimensions. Over the past decades, the experimental investigation of interacting electrons in low dimensions has led to many new and sometimes unexpected insights into many–particle physics in general. Famous examples are unique electronic transport properties as the integer and fractional quantum–Hall effects in quasi two–dimensional (Q2D) systems. Quasi one–dimensional (Q1D) electron systems, realized in semiconductor quantum wires, have been the subject of intense theoretical and experimental debates concerning the character – Fermi–liquid or Luttinger–liquid – of the interacting Q1D quantum liquid. During the past few years, tunneling–coupled electronic double–layer structures have been revisited as very interesting candidates for the realization of new quantum phases in an interacting many–particle system. A new quality came into the physics of semiconductor nanostructures by the development of quantum systems, embedded in microresonators, also called microcavities. This new inventions allowed one to investigate the light–matter interaction from an advanced point of view.

Optical spectroscopy techniques, like far–infrared (FIR) transmission [1–14] and resonant inelastic light scattering (or Raman) spectroscopy, are ideal tools to study the spectrum of elementary electronic excitations of those systems. Since the 1970's, inelastic light scattering has proven to be a very useful and powerful tool in the investigation of electrons or holes in semiconductors. Especially in the study of particle–particle interactions or coupling with other elementary excitations, inelastic light scattering experiments are extremely fruitful. In particular, also a finite quasimomentum q can be transferred to the excitations, which is in conventional backscattering geometry maximally that of the incoming laser light ($\approx 10^5$ cm^{-1}). The power of the method also results from the improvement of lasers and detectors in the visible and near–infrared spectral range where nowadays very powerful tunable lasers and detectors, such as charge–coupled–device cameras, are available. By the inelastic scattering of light, electronic elementary excitations with typical energies in the FIR spectral range can be observed in the visible range.

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The first experiments of inelastic light scattering by free electrons were performed by Mooradian and Wright in 1968 [15], who studied collective plasma oscillations (plasmons), coupled to LO phonons, in n–type bulk GaAs. Later Mooradian also observed under resonant excitation, i.e., the laser frequency is in the vicinity of the optical $E_0 + \Delta$ energy gap of the semiconductor, excitations which – at that time – were interpreted as single–particle excitations [16]. According to the experimental findings, Hamilton and McWhorter deduced in their theoretical work that this single–particle scattering, which results from so called spin–density fluctuations, can be observed in Zincblende–type semiconductors in depolarized scattering geometry, i.e., the polarization directions of incoming and scattered light are perpendicular to each others. Scattering by plasmons due to charge–density fluctuations occurs in parallel polarization configuration (polarized geometry) [17].

In contrast to light scattering by optical phonons, the electronic Raman signals are strongly dependent on resonance enhancement effects at optical energy gaps. In many cases only these enhancement effects, which occur if the laser frequency is in the vicinity of such energy gaps, allow for the observation of electronic excitations. In 1978, E. Burstein proposed that, due to these resonance enhancements, light scattering should be sensitive enough to observe electronic excitations of Q2D electron gases with densities as low as 10^{11} cm^{-2} [18]. Such Q2D electron systems can be realized today in a nearly perfect way in modulation–doped GaAs–AlGaAs heterostructures or quantum wells, grown by molecular–beam epitaxy (MBE). Soon after this proposal, the first observations of Q2D intersubband excitations were reported by A. Pinczuk [19] and G. Abstreiter [20] in their pioneering works. In the following decade, a wealth of experiments on Q2D electron systems followed, which demonstrated the versatility of the resonant light scattering technique [21]. Through all the years it was commonly accepted that the electronic excitations, which can be observed by inelastic light scattering, fall into two main categories: Spin–density excitations (SDE) which were interpreted as single–particle excitations because exchange–correlation effects were assumed to be small (observed in depolarized geometry) and charge–density excitations (CDE, plasmons) which can be observed in polarized geometry (see, e.g., [21]). The latter are depolarization shifted with respect to the corresponding SDE due to direct Coulomb interaction [22]. Very surprisingly, in contradiction to this long lasting assumption, Pinczuk et al. demonstrated in another pioneering work in 1989 that in high–mobility quantum–well samples, *additionally* to the intersubband SDE and CDE, excitations can be observed with energies in between those of the SDE and CDE and which occur in *both* polarization configurations [23]. These excitations showed all features which one expects from pure single–particle excitations. This completely changed the point of view and from there on also SDE's were regarded as *collective* excitations of the electron gas, whereas the excitations which show no polarization selection rules were interpreted as *single–particle* excitations (SPE).