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Acoustically driven transport and manipulation of excitons and spins in semiconductor structures

Surface acoustic waves (SAWs) have been used to control different types of electronic excitations in semiconductors. Photon control via the acousto-optic interaction – the strain-induced changes of the optical properties - forms a traditional area of application. Approaches have also been introduced to use the mobile SAW potentials to control and transport electrons and spins in semiconductor structures. More recently, the moving spatial modulation of the bandgap provided by the SAW strain field has been applied to control more complex structures, such as indirect excitons and exciton polari-tons.

In this contribution, we review recent results on the acoustic control and transport of electron spins and excitons by acoustic fields in semiconductor nanostructures. Excitons are neutral composite particles consisting of an electronhole pair bound by the Coulomb interaction. These composite particles play a fundamental role in the absorption and emission of light in semiconductor structures: their storage and transport provide, therefore, a direct way of manipulating optical information. We have recently developed a novel concept for information processing based on the transport and manipulation of excitons by the moving strain field produced by a SAW. Here, information bits encoded in photons are first converted into long-living excitons in GaAs QWs, which are then transported and manipulated using SAW fields and subsequently reconverted to photons for further information transmission. We use for that purpose spatially indirect excitons (IX), which consist of a bound state of an electron and a hole localized in a double quantum well structure subjected to an electric field F_E One of the main advantages of IXs is the electrical control via F_E of the recombination lifetime and, therefore, of the photon to IX inter-conversion process. In particular, the IX lifetime can be extended to the s range, thus allowing acoustic transport over long distances. We show that the moving band-gap modulation induced by a SAW can confine IXs at the locations of minimum energy and transport them with the acoustic velocity over several hundreds of micrometers [1, 2]. The acoustic IX transport is used to demonstrate devices concepts including an IX transistor [3, 4] as well as an IX multiplexer [4]. In the latter, a network of SAW beam is used to controllably transfer IXs between multiple remote locations, thus opening the way for the realization of scalable excitonic circuits. In addition, we will demonstrate the feasibility of exciton spin transport and manipulation in GaAs QWs by electric and magnetic fields. When combined with acoustic transport, exciton-based structures thus provide a pathway for the realization of scalable quantum electro-optic devices using the conventional planar technology. Approaches for the implementation of these concepts using exciton-exciton interactions will be discussed.

References:

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