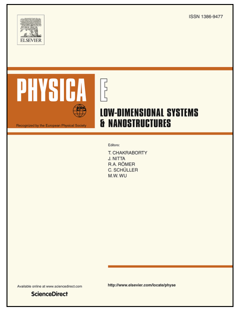
Accepted Manuscript



Magneto-optical quantum interferences in a system of spinor excitons

Wen-Hsuan Kuan, Vidar Gudmundsson

PII: S1386-9477(17)31698-3

DOI: 10.1016/j.physe.2017.12.035

Reference: PHYSE 13006

To appear in: *Physica E: Low-dimensional Systems and Nanostructures*

Received Date: 4 November 2017

Revised Date: 17 December 2017

Accepted Date: 25 December 2017

Please cite this article as: W.-H. Kuan, V. Gudmundsson, Magneto-optical quantum interferences in a system of spinor excitons, *Physica E: Low-dimensional Systems and Nanostructures* (2018), doi: 10.1016/j.physe.2017.12.035.

Magneto-Optical Quantum Interferences in a System of Spinor Excitons

Wen-Hsuan Kuan[a], Vidar Gudmundsson[b]

[a]Department of Applied Physics and Chemistry, University of Taipei, Taipei 10048, Taiwan
[b]Science Institute, University of Iceland, Dunhaga 3, IS-107 Reykjavik, Iceland

Abstract

In this work we investigate magneto-optical properties of two-dimensional semiconductor quantum-ring excitons with Rashba and Dresselhaus spin-orbit interactions threaded by a magnetic flux perpendicular to the plane of the ring. By calculating the excitonic Aharonov-Bohm spectrum, we study the Coulomb and spin-orbit effects on the Aharonov-Bohm features. From the light-matter interactions of the excitons, we find that for scalar excitons, there are open channels for spontaneous recombination resulting in a bright photoluminescence spectrum, whereas the forbidden recombination of dipolar excitons results in a dark photoluminescence spectrum. We investigate the generation of persistent charge and spin currents. The exploration of spin orientations manifests that by adjusting the strength of the spin-orbit interactions, the exciton can be constructed as a squeezed complex with specific spin polarization. Moreover, a coherently moving dipolar exciton acquires a nontrivial dual Aharonov-Casher phase, creating the possibility to generate persistent dipole currents and spin dipole currents. Our study reveals that in the presence of certain spin-orbit generated fields, the manipulation of the magnetic field provides a potential application for quantum-ring spinor excitons to be utilized in nano-scaled magneto-optical switches.

Keywords: Excitons, Magneto-optical effects, Quantum rings, Spintronics
PACS: 68.65.k, 73.21.-b, 71.35.Ji, 78.20.Ls

While the relativistic nature of a spin-orbit interaction (SOI) in atomic systems is given to be in the order of 10^{-5} eV, a large SOI field can be obtained either in the presence of a large electric field or in materials where the mass gap is reduced. Therefore, in recent decades, studies of spin-dependent effects in semiconductor nanostructures[1, 2, 3, 4] and nano-devices[5, 6, 7] have been attracted to both the experimental and the theoretical aspects and have opened up the field of spintronics.[8, 9] In narrow-gap heterostructures such as InAlAs/InGaAs, a spontaneous spin-splitting can be realized by structural inversion asymmetry (SIA).[10] The kind of asymmetry, corresponding to an inhomogeneous built-in electric field due to band-bending and discontinuity which gives rise to the 2DEG confining potential at the interface, leads to the splitting termed the Rashba effect.[11] On the other hand, in wide-gap zinc-blend structures, bulk inversion asymmetry (BIA) may induce a coupling of electronic states which is cubic in the electronic momentum **k**. The spin splitting of electron and hole states at nonzero **k**, even at zero magnetic field, is known as the Dresselhaus effect.[12] Both spin splittings can be tuned continuously by means of external gates.

Achievements in the state-of-the-art material engineering and nanofabrication techniques have successfully led to the realization of advanced semiconductor devices and made possible the investigation of quantum phenomena in these systems.[13, 14] In ring geometries, systems that undergo a slow, cyclic evolution were predicted to induce a Berry phase for the electronic states.[15] The existence of the geometric quantum phase reveals the significance of electromagnetic potentials in the quantum theory. The periodic interference effect identified by Aharonov and Bohm (AB)[16] was measured via spectroscopy of nanoscopic semiconductor rings[17] and AB oscillations of the spin components were manifested in the resistance in a GaAs 2D hole system with a strong SOI.[18] Many electronic properties, like optical absorption and transmission,[19] cyclotron-resonance,[20] Rabi oscillations,[21, 22, 23, 24, 25] and the enhancement of density deformation for electrons with different parities and symmetries under the influence of Coulomb interaction,[26] have been examined in combination with the optical AB effect, with or without SOIs. However, from the literature reviews, we find that studies of the AB effect and its relevance to another simple many-body complex, the exciton, are much fewer than research projects on many-electron systems. Therefore, although the theoretical study can be tracked back to 2000,[27] not until 2008 were AB oscillations of excitons first observed in experiment,[28] and even later in 2010, the first observation of quantum interference effects of neutral excitons was reported. [29]

Viewed as a neutral particle, the exciton was not ex-

Email addresses: wenhsuan.kuan@gmail.com (Wen-Hsuan Kuan), vidar@hi.is (Vidar Gudmundsson)