Correlations of periodic structures to manipulation of photonic modes for the purposes of opto-electronics operating by quantum dots

S.A. Bugaychuk[1], V.O. Gnatovskyy[2], O.G. Kolesnyk[3]

[1] Institute of Physics, Natl. Acad. of Sci. of Ukraine, 46 Prospect Nauki, Kiev-03039, Ukraine,
E-mail: bugaich@iop.kiev.ua
[2] Taras Shevchenko National University, Physical Department, 4 Prospect Glushkova, Kiev-03127, Ukraine
[3] Taras Shevchenko National University, Radio-Physical Department, 4 Prospect Glushkova, Kiev-03127, Ukraine

Last years it was shown, that the integrating photonic circuits fabricated on silicon as a host material with individual dopants can become for an entirely new generation of devices, based on the quantum properties of charges and spins. The central theme of quantum electronics applications using single dopants is the ability to modify the dopant electron wave function using external electric fields or photons, and/or to manipulate the spin degrees of freedom using magnetic fields. The key requirement for spin quantum bits is to confine single electrons to either a quantum dot or a donor [1].

Semiconductor quantum dots (QDs) have long been considered as viable qubit candidates, as they naturally fulfill the criteria of scelability and integrability required in a quantum information technology. Single-dot coupling to light modes is in itself important for practical applications, as suggested by the possibility of nonclassical light generation, or single-photon optical switching [2]. An essential requirement of the quantum information paradigm is the possibility for two-qubits to interact coherently in a controlled fashion, in order to achieve controlled gate operations. In [2] the authors derive a general formalism to model the polariton states resulting from the radiation-matter interaction between an arbitrary number of excitonic transitions in semiconductor quantum dots and photon modes in a photonic crystal structure in which the quantum dots are embedded.

In the present work we consider the photonic modes, which can be formed by a system of sequentially arrangement of periodic diffraction converters (in the simplest case, of the phase diffraction gratings) located in a cavity. In this scheme the main idea consists in the fact, we create the coupled system between all gratings. To do that, the periods of the gratings should coincide or be multiple with each other. This way, the correlation method for the formation of field profile lies in the consistent impact of amplitude-phase convertors on a previously diffracted field [3]. In the coupled system, the photonic modes are formed as the interference of partial waves, diffracted from the gratings. The possibility to create strongly localized modes in dependence on the decreasing the periods of the gratings is considered. The experimental research can be carried out for optical interference field, which illuminates a set of phase gratings, or even a one grating of a complicated profile. The proposed method has the potential to be implemented in integral optical devices. For a system, where the QDs are embedded, a further microscopic description of light-matter coupling with a description of the polariton states and the photonic modes is needed.

1. *Zwanenburg F.A., Dzurak A.S., Morello A., Simmons M.Y., Hollengerg L.C.L., Klimenk G., Rogge S., Coppersmith S.N., Eriksson M.A.* Silicon quantum electronics // Rev. of Mod. Phys. - 2013. - **85**. - P. 961-1019.
2. *Minkov M., Savona V.* Relative coupling of quantum dots in photonic crystal structures // Phys. Rev. B . - 2013. - **87**. - P. 125306-1-16.
3. *Gnatovskyy V.O., Bugaychuk S.A., Negriyko A.M., Pryadko I.I., Sidorenko A.V.* Angular spectra of phase diffraction gratings illuminated by interference field // in: O.V. Shulika, I.A. Sukhoivanov (Eds.), IEEE Catalog Namber CFP13814-CDR, ISBN: 978-4799-0016-9 (International Conference on Advances Optoelectronics and Lasers, CAOL’2013, 9-13 September, Sudak, Crimea, Ukraine), 2013, pp. 378-380.