Review
of the Ph. D. thesis of Maria Kuznetsova
entitled "Nuclear spin effects in self-assembled quantum dots"
submitted for the degree of Doctor of Philosophy in Physics
at the St. Petersburg State University

The thesis of Maria Kuznetsova is devoted to the studies of nuclear spin effects in the self assembled quantum dots. The physics of spin dynamics in quantum dots and, in particular, the electron nuclear spin interaction is extremely rich branch of the modern physics and is in the focus of attention of the scientific community. This thesis presents a number of significant and original research results on the time resolved experimental studies of the polarization of electron spins due to the interplay of their interaction with external magnetic field and the nuclear field. The thesis is well and logically structured, it consists of an introduction, the main contents chapter, and 4 included original articles.

The first chapter is introductory, it is well written and contains a brief overview of the field and proves the high author's knowledge of the literature in the field. The goals of the work and the methods used are also clearly outlined. The main goals of the thesis is the investigation of rise and decay dynamics of the spin polarization of nuclei in quantum dots under optical excitation; experimental study and theoretical modeling of the dependence of electron spin polarization in a transverse magnetic field in the quantum dots with strong electron-nuclear spin interaction; and investigation of nuclear magnetic resonance (NMR) by resonant optical pumping of nuclear polarization in the quantum dots. The main experimental method of this work is the investigation of polarization degree of the photoluminescence from the ensemble of quantum dots excited by polarized optical pumping in external magnetic field. Behavior of the Hanle curves was studied experimentally using different temporal protocols of excitation and registration of photoluminescence of the InGaAs quantum dots. The experimental results are compared with theoretical analysis, based on two phenomenological models: the geometric model and a generalized nuclear spin cooling model. The Hanle curves are analyzed by use of an original approach based on separate consideration of the behavior of longitudinal and transverse components of nuclear polarization in quantum dots with strong quadruple splitting of nuclear spin states. The main results are also briefly summarized in this chapter and discussed in details in the next chapter and included articles.

The second chapter summarizes the methods and the results of the thesis and consists of four sections devoted to the samples and experimental setup, studies of the dynamics of nuclear polarization in a transverse magnetic field and role of nuclear spin fluctuations and the investigations of resonant nuclear spin pumping.

The spin polarization of the resident electrons has been measured through the effect of negative circular polarization of the PL of the negatively charged quantum dots. This is based on the assumption that the amplitude of negative circular polarization is proportional to the projection of electron spin onto the optical axis and is supported by a number of solid references in the thesis. I believe that, for the reader not very familiar with the subject it will be quite helpful to find a qualitative explanation for this important effect at this place of the thesis. I also was a bit confused by the different selection of the colors in two panels of Fig.5 showing the complete Hanle curve at constant excitation time (a) and its low field portion (b). Apart from these small shortcomings this part of the thesis is well written and discusses two limiting cases of the transverse magnetic field and determines the rise and decay times of each component of nuclear polarization and their dependence on transverse magnetic field. I agree with the author that opposite behavior of the rise and decay times of the dynamical nuclear polarization as a function of the magnetic field strength is an important and controversial question.

The next section outlines the modification of the Hanle curve in the presence of small additional longitudinal magnetic field. The experimental findings are analyzed within a

phenomenological model based on the widely accepted theory of the nuclear spin cooling that takes into account the effect of nuclear spin fluctuations. Within this generalized model the author has described the experimental data and has found the maximal value of the effective field of nuclear polarization created by optical pumping in quantum dots.

The last section of this chapter is devoted the observation of significant nuclear polarization in the plane perpendicular to the external magnetic field in semiconductor quantum dots due to the resonant optical pumping of the transverse component of nuclear spin polarization in the inhomogeneously broadened quantum dot. It was observed for the first time under strong excitation of quantum dots by the circularly polarized light, which polarization is modulated with the nuclear spin precession frequency about external magnetic field. This effect, has been called resonant optical pumping of nuclear spin polarization, is evidenced by several intense peaks in the Hanle curve. Nuclear spin resonances for all isotopes in the quantum dots are identified using the calculated values of quadrupole nuclear spin splitting caused by the strain-induced gradient of crystal electric field at nucleus positions.

I think that these results are very important and show high qualification of the author. All main results of this thesis were reported at many international conferences and are well published that is clear from both the included articles and the publication list.

In summary, I think this is a very good thesis covering a substantial body of work and it is well written and contains several interesting results that are important to this field. The candidate shows a high level of understanding of the physics. I am confident that the work is strong enough and satisfies the high standards of a PhD thesis and the author Maria Kuznetsova may be awarded a PhD degree.

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