Supervisor's report

on doctoral thesis entitled

Ultrafast photoconductivity and charge carrier transport in semiconductor nanostructures: a study by terahertz spectroscopy

prepared by **Mgr. Vladimir Pushkarev**

This thesis deals with ultrafast dynamics and transport of photoexcited charge carriers in semiconductor nanostructures. In the literature, the terahertz conductivity spectra of nanostructures were frequently interpreted in the framework of phenomenological theories like, e.g., the Drude-Smith model. One of the aims of this work is to drive the research towards well-defined (monodisperse, ordered or uniformly aligned) nanosystems, where new peculiarities of the charge carrier confinement could have been uncovered and described on a microscopic level. The systems under study are silicon nanocrystal multilayers and quasi-uniform arrays of GaAs nanobars.

Referring to about 120 references the author covered the current state-of-the-art of the optical pump — terahertz probe spectroscopy with an extension to far- and mid-infrared (also called multi-terahertz) probing and including also terahertz local-probe techniques. The ensemble of these methods forms an ultrabroadband approach to the charge carrier transport phenomena with sub-ps time resolution. The thesis also reviews a microscopic theoretical framework for the evaluation and interpretation of ultrafast terahertz photoconductivity phenomena in inhomogeneous systems.

The work deals with sophisticated experimental methods, which require complex theoretical approaches for interpretation of results in nanosystems; namely, they involve solving the wave equation in inhomogeneous media combined with application of advanced effective medium models and quantum mechanical approach to the terahertz conductivity of confined charge carriers. In this sense the manuscript does not represent a very easy reading, especially for a non-specialist in the field. Keeping this in mind, I believe that Mr. Pushkarev has chosen the appropriate approach in the redaction of the manuscript and prepared a scientifically rigorous and understandable work.

I would like to stress the careful and systematic experimental work of Mr. Pushkarev. He mastered very well the terahertz time resolved experiments and also, during the final part of the thesis, got useful skills with near-field methods using THz-SNOM device. During his three-week stay at Goethe University in Frankfurt he obtained very useful data using time-resolved mid-infrared photoconductivity which allowed him to employ an unusually broadband approach in the case of silicon nanocrystal multilayers. He also complemented the experimental studies with various characterizations of the nanostructures using SEM, AFM and FTIR. As already mentioned, experiments in the selected systems were performed very carefully: as a function of temperature and as a function of the initial carrier concentration (by controlling the incident optical pump pulse fluence) over three orders of magnitude. This approach is necessary to attain the microscopic understanding, but it frequently involves quite long data averaging process (12h or more) and repeated series of experiments to ensure the data reliability. Besides the main focus of the thesis, Mr. Pushkarev also participated with enthusiasm to other developments of the laboratory facilities; for example, he developed a chamber for THz-SNOM operation in stable dry-air atmosphere.

The highlight of the work is the study of the charge carrier transport in GaAs nanobars. This is a combined approach involving near-field and broadband far-field THz spectroscopies, and an application of a sophisticated effective medium model and quantum theory of THz conductivity

in nanocrystals. This approach allowed him to draw important results on the enhanced charge carrier confinement due to the band bending at the GaAs surface.

The main criticism that I may express in his regard concerns the quite lengthy process of the thesis manuscript preparation, I believe that it could have been written faster.

During the doctoral studies Mr. Pushkarev has shown his skill to perform good quality scientific work and also his ability to present the results on an international level (3 publications in good quality impacted journals: Phys. Rev. B and Advanced Functional Materials, 5 oral contributions and 10 posters at international conferences and workshops). The thesis presents original results that constitute a significant contribution to the research field, and I strongly recommend accepting it for the defence.

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