Skoltech
Skolkovo Institute of Science and Technology

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Stepan Baryshev

PhD Program: Physics

Title of Thesis: Photon correlations of optically trapped polariton condensate

Supervisor: Professor Pavlos Lagoudakis
Co-supervisor: Dr. Anton Zasedatelev

Name of the Reviewer: Simone De Liberato

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Date: 13-09-2022**

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense. *If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.*	*There*
Reviewer's Report	

- Brief evaluation of the thesis quality and overall structure of the dissertation.

In this thesis, the Candidate investigates various aspects of the optical response of two nanoscopic semiconducting platforms: one dimensional chains of carbon and inorganic microcavity polaritons.

After a first, brief introductory Chapter, the second Chapter investigates the spectral and temporal characteristics of Polyyne chains photoluminescence upon optical excitation using time-correlated single photon counting. The results on this novel system are extremely interesting and the experimental results clear, although this Chapter is rather thin in terms of microscopic explanations, for which the reader is referred to the published literature.

The third Chapter is an introduction to the thesis main research topic: polaritons in semiconductor microcavities. The basic physics of DBRs, excitons, the Hopfield polaritonic formalism, condensates, as well as the experimental setup, are very well introduced and explained in details. Other concepts important to understand the work described in the thesis, as the spinorial structure of the polaritons or the concept of Stokes vector, are instead just briefly introduced. I would suggest the Candidate to develop better these concepts in this introductory Chapter in order to make the thesis more broadly accessible.

The fourth Chapter is opened by a brief introduction to the concept of optical coherence, followed by an experimental characterization of the second order optical coherence between the various polarizations in a spinor condensate. The experimental work reported is extensive, complete, and rigorous, elucidating the non-trivial dynamics of the cross-polarization correlations under the effect of disorder and nonlinearities.

The fifth Chapter starts with an introduction to the two-photon interference effect named after Hong, Ou, and Mandel, followed by an experimental investigation of this effect using the light emitted by a polariton condensate.

The thesis is closed by a brief conclusion Chapter, which I found a bit dry. The conclusions part of a thesis is the place in which the Candidate has an opportunity to sketch his view for the future of the field and the potential impact of his research. I would suggest to develop a bit more this part with some more personal considerations.

The quality of the English could be improved, as at times it makes the manuscript difficult to understand. I strongly suggest the Candidate to have the English checked by someone, or at the very least to pass the full text through an automated spelling and grammar checking tool.

- The relevance of the topic of dissertation work to its actual content

The largest part of the thesis is extremely relevant to the topic of the dissertation work, investigating various aspects of correlations in polariton condensates. Only the second Chapter of the thesis investigates instead a rather different topic. It is normal during a thesis to work on different projects, also not related to the same core topic, and the Candidate states that expertise developed during this first work was instrumental in developing the advanced interferometric experiments on polariton condensates described in the following Chapters. Still, I would suggest the Candidate to explain this a bit better in the introduction as right now the reader could have the impression of an abrupt transition, both in the Abstract and in the main body of the manuscript, between two seemingly unrelated topics.

- The relevance of the methods used in the dissertation

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The experimental work developed in this thesis has been performed using refined spectroscopic techniques, including time-correlated single photon counting, time-resolved photoluminescence, Hanbury Brown and Twiss interferometry and measurements of the Hong Ou and Mandel effect. These methods belong to the state-of-the-art used in polaritonics and quantum optics, and they are both relevant and sufficient for the investigations performed by the Candidate.

- The scientific significance of the results obtained and their compliance with the international level and current state of the art

The quality of the results reported comply with and advance the state-of-the-art in the field of polaritonics and quantum optics.

- The relevance of the obtained results to applications (if applicable)

The work performed by the Candidate is of mainly fundamental nature. Novel applications and products in optoelectronics could eventually exploit the results presented in this thesis, but this has not been the focus of the performed research.

- The quality of publications

This thesis work led to 6 research papers and one conference proceeding. The Candidate is first author of one of them. The papers are all published in good physics journals, including one in the prestigious journal Nano Letters. Overall, the quantity and the quality of publications is more than acceptable for a PhD project.

In the following I list some specific changes the Candidate should make to the manuscript before the defence:

1) In the Abstract the transition between Chapter 2 and 3 is too abrupt. The Abstract needs to provide a narrative for the whole manuscript, not piecewise descriptions of the different Chapters.
2) In the Introduction all even-numbered Chapters are “the last Chapter”.
3) In the Introduction concepts as “HOM dip” or V are used without being defined. Being this the Introduction, a formal definition is not needed, but the reader cannot be expected to know them already.
4) The description of IRF, SER, and their relation in TCSPC in Section 2.1 is not clear and has to be expanded.
5) In Section 2.2 the origin of the dependence of the work function upon the spheres dimension has to be explained.
6) In Section 2.3 it is not clear how the peaks are correlated with specific chain lengths.
7) Equation 3.10 is inverted.
8) In Section 3.1.3 the last sentence about the Mott transition should be qualified. The Mott transition is due to saturation, not Coulomb interaction.
9) In Section 3.2.1 the sentence about “reducing the phonon density of states” should be better explained.
10) In Section 3.2.1 the sentence stating “reaching thermal equilibrium is hardly possible” should be qualified, as there are publications claiming to have done that.

11) In Section 3.2.3 the spinor nature of the polaritons, the concept of pseudospin, and the concept of Stokes vector and Poincaré sphere have to be clearly introduced.
12) The quantities in Eq. 3.20 are not defined.
13) In Section 4.1.1 the parameter eta is used before being defined.
14) In Section 4.1.1 the statement about the time-spatial domain D and its relation to the discussion has to be better explained.
15) In Section 4.2 the concept of polariton blockade has to be defined.
16) In Section 4.2.3 the link between the reservoir and the out-of-plane magnetic field could be more explicitly explained.
17) The choice of parameters in Section 4.2.5 should be justified.
18) In Section 4.2.5 the reason Theta should be understood as a quarter waveplate should be more explicitly explained.
19) In Chapter 5 what is plotted in the graphs has to be properly defined and explained. “HOM dip”, V, Coincindence, have all to be defined in the main text in terms of physical observables and clearly referenced in all the images. All colorplots need a colorbar, and all colorbars need a label.

Provisional Recommendation

☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense*

☒ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate’s thesis according to the recommendations of the present report*

☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*