Skoltech
Skolkovo Institute of Science and Technology

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Anton Baranikov

PhD Program: Physics

Title of Thesis: Dynamic polariton condensation in organic microcavities

Supervisor: Prof. Pavlos Lagoudakis

Date of Thesis Defense: 8 November 2019

Name of the Reviewer: Prof. Simone De Liberato

I confirm the absence of any conflict of interest	**Signature:**  **Date: 20-09-2019**

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.

Reviewer's Report

In this thesis the candidate describes his work relating to the achievement of polariton condensation in an organic microcavity, and its exploitation to realize polariton-based optical amplifiers and logic gates.

The thesis starts with an introduction to the physics of organic and inorganic microcavity polaritons and condensates. The introduction is generally clear and complete, and provides most of the background material necessary to understand the research material presented in the following sections.

The manuscript then describes the achievement of a polariton condensate by single-step vibron relaxation. The results are scientifically very clear and intuitively explained, although some extra material on the nature of the vibronic transitions involved would have provided a better picture of the internal relaxation dynamics.
The last two main chapters deal with the use of the polariton condensate in order to realize an optical amplifier and, cascading multiple amplification stages, two optical logic gates. The scientific results

presented in these sections are very convincing, although the presentation, especially in the last section, is less than perfectly clear, and requires some effort to be fully understood.

The thesis concludes with a section containing conclusions and some future perspectives. A few more details in this section, would definitely help to clarify the personal views of the candidate upon the relevance of this work and its future developments.

The dissertation is topically and methodologically relevant. The results presented are of the highest importance and clearly push forward the state of the art in the study of organic polariton condensates and their practical exploitation in optical logic manipulation.

The most important results of the thesis were reported in a recent issue of Nature Photonics. A paper of which the candidate is second author, published in such a prestigious editorial collocation, is a strong proof of the importance and timeliness of the results obtained by the candidate. Together with two other publications (one under review) the amount of results is largely sufficient to justify the award of a PhD.

In the following I list a number of issues the candidate should address:

1) The description of Fig. 2.4 could be expanded. The origin of the Stoke shift of the zero-phonon-line should be explained.
2) Eq. 2.9 should be better formatted.
3) The equation in the text below Eq. 2.9, describing the condition of strong coupling is dimensionally wrong.
4) The reason Eq. 2.13 is different from Eq. 2.9 should be clearly explained (i.e. the use of RWA).
5) The scaling of the vacuum Rabi frequency with the mode volume below Fig. 2.6 seems wrong to me. Please change it or explain its origin.
6) The nature of the three vibronic modes in Fig. 3.2 c should be better discussed.
7) On page 49 the best fits for the two vacuum Rabi frequencies are provided. Can their ratio be verified with a weak coupling (free space) measurement?
8) In Fig. 3.4 what are the features in the bottom right corners?
9) On page 70, how is the pump value of 180 \muJ/cm^-2 chosen?
10) In Fig. 5.2 the control beam doesn't reach the spot A.
11) The presentation of section 5.3 should be improved. Right now it is rather difficult to follow.
12) Conclusions should be expanded, and the candidate should develop a bit more his personal vision for the future.
13) In Fig. 4.3 the probe is in resonance with the bare LP mode, while the pump+probe signal is blueshifted. Does this pose a limit to the cascadability of the platform, as each step of the cascade will be more blue-shifted than the previous one? If this is the case such a limitation should be properly discussed and its effect estimated.

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*