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Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Oksana Borzenkova

PhD Program: Computational and Data Science and Engineering

Title of Thesis: Linear optical realization of variational quantum algorithms

Supervisor: Professor Jacob Biamonte
Co-supervisor: Dr. Stanislav Straupe

Name of the Reviewer: Dr. Alexander Korneev

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Date: 19-11-2024**

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

Reviewers report should contain the following items:

- **Brief evaluation of the thesis quality and overall structure of the dissertation.**
  The thesis by Oksana Borzenkova is written in a clear and concise language. The structure is quite traditional: *Introduction*, *Literature review*, three chapters describing the author's original research and *Conclusion*. Introduction gives an idea of the quantum variational algorithms. Literature review presents the detailed review of the state-of-the art in the field of the thesis including methods of single-photon generation and various platforms for photonic processor implementation. Chapter 3 describes the experimental realization of the Variational Quantum Eigensolver by the author of the thesis. It also addresses the influence of noise (artificially introduced in this case by liquid crystal variable retarders) on the quality of the result. Chapter 4 addresses the problem of error mitigation and zero-noise extrapolation. Finally, Chapter 5 describes several approaches to multi-photon source implementation undertaken by the author.

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

The actual content of the thesis is relevant and precisely corresponds to the goals and the topic of the research.

- **The relevance of the methods used in the dissertation**
  The experimental methods and the methods used for experimental data analysis are relevant to the goals and the topic of the research. The experimental technique is quite common for the field of linear optic quantum computing: photons are generated by the spontaneous parametric down-conversion (SPDC), CNOT gate is realized either immediately in SPDC process, or in a photonic chip prepared by femtosecond laser writing. In a classical part of the VQE optimizer a well-established simultaneous perturbation stochastic approximation algorithm is used.

- **The scientific significance of the results obtained and their compliance with the international level and current state of the art**
  The presented research is done at a high scientific level and corresponds to the best international state-of-the-art research, which is proven by the number of citations of the author's papers: *Applied Physics Letters* 118:144002 (2021) has **19** citations, *Appl. Phys. Lett.* 122:121102 (2023) has **10** citations (according to Google Scholar), *Optics Letters* 49 (15), 4453-4456 (2024) already has **2** citations since its publication on July 31, 2024!

- **The relevance of the obtained results to applications (if applicable)**
  The variational quantum algorithms are of very importance not only for quantum computing but also for a wide range of applications in chemistry, engineering and even in economics. Considering the rather limited capability of the state-of-the-art quantum computers in terms of number of qubits and their coherence time, quantum variational algorithms are among the few that promise a real practical output. The issue of noise and its influence on the accuracy of the VQE addressed in the thesis is undoubtedly of high relevance for the application of such algorithms to the real-life problems.

- **The quality of publications**
  Very good: the main results of the work are presented in Applied Physics Letters (2 papers) and Optics Letters (1 paper) and presented at 6 conferences.

- **The summary of issues to be addressed before/during the thesis defense**

(1) First of all, I would suggest giving more details concerning the experiments and the processing of the experimental results. E.g. in Chapter 3 I would recommend adding formulas describing how the value of $E(\theta)$ is calculated from photon counts. Although such things are quite clear for the experts, they will be very useful for the students who will read the thesis afterwards.

(2) In Chapter 5 there is a project of a six-photon source with Pockels cells demultiplexer (Fig. 5.5) and a source with adjustable delay (Fig. 5.6) but without any information about their performance. If they are not experimentally tested yet, I would suggest adding at least an estimation of their performance.

(3) There are a certain number of misprints:
- In author's publications list (page 2) the third paper (*Optics Letters*) is published in 2024, not 2023.
- In Fig. 3.1. mirror plane in PBS in Sagnac is in wrong direction (again, this will confuse students reading the thesis afterwards)
- There are several 'unresolved' figure numbers: '??' instead of figure number (pages 43, 63, 75).
- There are references to supplementary materials (pp 45, 57, 68).
- Duplicated references 156 and 157, 149 and 150 (also should be *O' Brien*, not *O' brien*).
- Grammer mistakes e.g. '*are stand out*' (p 51, first paragraph), '*is also helps*' (p 52, second paragraph).

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*