



Skolkovo Institute of Science and Technology

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. Sergey Alyatkin

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| I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict) | Date: 20-11-2024 |
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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 relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications
- The summary of issues to be addressed before/during the thesis defense

The thesis by Oksana Borzenkova after reading leaves a good impression. In my view, the sequence of chapters with content was carefully thought out, all relevant main results have been published in peer-reviewed journals. The work performed by O. Borzenkova during her PhD program and presented in her thesis is at high expected level of science. Therefore, I have no doubts that Oksana should pass to the next level of consideration - PhD defense. However, the thesis presented by Oksana in its current form is not ideal and I would like to bring to her attention some comments and/or suggestions provided below.

1) I am not sure about current technical requirements for thesis, but lack of references in Abstract section is questionable to me. Especially, I expect to find any quotations after such sentence: "Recently quantum algorithms implemented as variational models, have been proposed to accelerate such simulations."

2) It's not clear why some just introduced abbreviations in the Abstract are deciphered, but most are not?

For example: Quantum Approximate Optimization Algorithm (QAOA) is complete, at the same time for VQE, ZNE, QEM there is no clarification.

3) Are the conferences 1. and 2. at page 2 connected to the main topic of the thesis? Maybe it is better to remove them from the list. To me it looks weird to find the conference SNAIA 2018 Paris, December 10-13 with oral talk on "Cortisol Sensor Based on Metal Enhanced Fluorescence".

4) At p.5 please change "FWHM — Full width of half-maximum" to "FWHM — Full width at half-maximum" as accepted in the literature.

At p. 14 probably there is a typo "Such algorithms doesn't resemble the usual algorithms of..." Please check and correct. And here as well "travaling salesman problems".

5) Can this strong statement at p.16 be supported by the reference "Any optimization problem can be reformulated into the language of the Hamiltonian (it is not always easy, but possible)..."

6) At p.21, missing period between the sentences "Like any other quantum object, an atom can be in a superposition of these two states, which means it can work like a qubit For qubits,..."

7) At p. 21, in sentences "...the total spin of electrons and nucleons in them are fractional" it is better to replace fractional spin with half-integer spin, once for bosons "integer spin" is used in description.

8) At p.21 "Consequently, the gas of ultracold atoms is utilized as a quantum simulator for solving problems related to the modeling and study of superconductivity, as well as other strongly interacting systems." This sentence leaves the impression that ultracold atoms are strongly interacting. In context of atomic BEC, I thought that ideal Bose gas is a gas of non-interacting or weakly interacting particles.

9) At p.22, the sentence "The state of Josephson contacts is very sensitive to magnetic fields, so they are used as highly sensitive magnetic sensors (SQUID)." - the appearance of abbreviation in brackets normally refers to the words just before the brackets, here it looks strange. Do you mean magnetic sensors based on SQUID?

10) At p.22, I don't fully understand this sentence: "The perfect photon source should produce exact states — one photon at a fixed time with high frequency and well-defined properties: spatial, spectral, and temporal" What is meant here by "well-defined spatial properties of one photon" at fixed time? It is possible at all?

11) At p.30 Can the author please provide the explanation to this statement? "The most perspective platform to realize any transformation on qubits is integrated schemes." What are the advantageous of the integrated circuits compared to other platform in terms of states transformations?

12) At p. 53, "The authors showed that increasing the size of a qubit by almost three times reduces the probability of error by just over three percent. However, this does not bother the specialists from Google Quantum AI. They believe that in this way it will be possible to build a fault-tolerant quantum computer, although this will require about a million qubits." Do you mean here the number of qubits instead of the size?

13) At p.59 in experimental part the HOM visibility drops to 82% compared to 98% in experiment-with the fiber splitter. Is a non-ideality of directional coupler (DC7) the only reason of this drop? Is there a room for further optimization with integrated elements?

Overall, I like the structure of the thesis, and the way how conclusions to the chapters were written (nice summary of the results with description of the actual problems and possible routes to solution).

To sum up, I believe that presented results and achievements of Oksana Borzenkova are substantial for PhD degree. I believe that with writing this thesis Oksana has demonstrated her relatively broad expertise in novel approaches to optimization tasks, variational algorithms and their optical implementation. However, I expect to see some amendments to the text. All of the above comments do not detract from the merits of the work done.

Sergey Alyatkin

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