Statement of Research Interest

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May 2023

1 Research Area

My primary research interest is in the area of quantum technologies in the optical and microwave domains, both in theory and experiment. It may sound broad, but light-matter interaction and its various applications are the most intriguing research directions for me. The study of light-matter interaction in the context of cavity/circuit QED and optical quantum networks I found fascinating, as it may translate the physical concept into real-world applications.

The reach of building fault-tolerant quantum computing and a global quantum network motivates new robust designs for quantum devices that can fulfil the contradicting physical demands of quantum computing and quantum networking. I find myself capable of developing new quantum devices as well as their theoretical proposals to advance the solutions of problems. I use my experimental physical intuition, theoretical analysis, and simulation to complete a research task. Below, I describe my prior research experience.

2 Past Research

2.1 Research Scientist

During my research position at the Kazan Quantum Center (Nov. 2020- Jan. 2023) my agenda was to facilitate research in quantum networks, microwave quantum memories, and integrated quantum photonics with my skills and expertise. Part of my research was funded by private partners and government grants.

In the project devoted to microwave memory (Phys. Rev. Applied 19, 034011 2023), we experimentally demonstrated efficient and noiseless microwave multimode quantum storage based on a multiresonator scheme. Such quantum memory, being composed of linearly spectrally-spaced resonators, operates as an echo with a time delay inversely proportional to spectral spacing. The memory may be used as a cache memory in circuit QED quantum computer to increase its performance. Up to date, our result shows the highest efficiency among microwave multimode quantum memories, which is an order of magnitude more efficient than the previous experiments. My contribution to the research was performing coherent state quantum process tomography, which proved the noiseless and efficient character of the storage at the single photon level, and writing most of the manuscript.

My recent quantum network research was devoted to improving quantum key distribution (QKD) with subcarrier wave (SCW) encoding. This encoding is promising for its relative simplicity and robustness. Moreover, there is commercial interest in the development of this encoding from the telecom company (Quanttelecom LLC) in Russia that constructed and maintains the quantum communication line using this encoding between Moscow and Saint-Petersburg (700 km). The research was conducted over three projects.

In the first project (Optics Express 29 (23), 38858-38869) I, together with my colleague, proposed and experimentally demonstrated how this encoding can be simply modified such that it will lead to an increase in key generation rate twice. The proposed modification will allow the party to detect two states on a single basis while performing the BB84 QKD protocol, compared to a single state in the original scheme. My contribution was developing a theoretical model, conducting the experiment, and solely writing the paper.

In the second project (arXiv:2209.11719), I proposed how to convert information from subcarrier wave encoding into dual rail encoding. The subcarrier wave encoding, due to its spectral multimodness, is not compatible with a promising quantum repeater protocol for long-distance communication. Here I propose an ad-hoc solution for this problem by converting the information from this encoding into a single-frequency dual rail encoding that can be interfaced with entanglement generated at the quantum repeater. My contribution was proposing an idea, building a theoretical model, performing an experiment, and solely writing a manuscript.

In the third project, which is somewhat related to the second project, I took part in designing the quantum repeater for SCW encoding (arXiv:2211.03597). Together with colleagues from Quanttelecom we theoretically proposed the entanglement swapping procedure for entangled multimode states. My part of the research was proposing and analyzing a quantum teleportation procedure that may be used for connecting the remote SCW encoded QKD networks via generated entanglement.

In the project related to integrated optics (Physical Review A 107 (4), 043708), we studied laser-written waveguides in rare-earth doped crystals. The rare-earth ions are promising for several applications in quantum technologies such as optical quantum memories and optical-microwave transducers, while laser-written technology allows for the creation of optical circuits inside rare-earth doped crystals. In our study, the area theorem for a single-mode waveguide was derived, which allows us to easily describe non-linear dynamics between such a waveguide and the ions using a single non-linear ordinary differential equation. The conducted experiment with a laser-written waveguide in a YAG crystal doped with thulium ions was consistent with the developed theory. My part of the research was performing the finite difference time domain calculation of the waveguide mode, testing consistency between theory and experiment, and writing the manuscript.

2.2 PhD Research

During my PhD studies at the University of Calgary (2015–2020), I performed experimental research on cold atoms and theoretical research on quantum memories. My PhD thesis was devoted to the latter topic. I theoretically showed that an array of whispering-gallery resonators is capable of being an efficient and noise-free optical memory with an adjustable storage time. The potential for on-chip realization at room temperature makes the scheme attractive for easy implementation (Laser Physics Letters 14 (1), 015202, 2016). The effect of Raman scattering on echo memory was evaluated experimentally and theoretically. The noise performance of gradient echo memory in Λ configuration proves that the developed theory is in good agreement with an experiment.

I proposed a mechanism for extending the bandwidth of impedance-matched memories via a white-light cavity effect (New Journal of Physics 23 (6), 063071, 2021). The introduced additional dispersion compensates for a bandwidth decrease induced by the cavity and hence increases the spectral zone of impedance matching. Theoretically, the scheme allows to increase the bandwidth of highly efficient storage ($> 90\%$) several times without adding extra noise.

Finally, I have proposed an architecture of quantum random-access memory for time-bin photons (Journal of Modern Optics 63 (20), 2081-2092, 2016). The protocol allows for quantum addressing of quantum information stored in the memory with only a single control unit. It is useful for tasks in quantum machine learning and feasible for implementation in the optical and microwave domains.

In addition to my main topic of the PhD thesis, during my program I have also done research in cold atom metrology (Optics Letters 44 (7), 1678-1681), quantum enhanced optical microscopy (Optica 3 (10), 1148-1152 2016) and continuous variable quantum light generation and characterization (New Journal of Physics 22 (1), 013014 2020).