A single-photon-based quantum computing platform

Mathias Pont[1]

Nicolas Maring,[1] Andreas Fyrillas,[1] Edouard Ivanov,[1] Petr Stepanov,[1] Nico Margaria,[1] William Hease,[1] Anton Pishchagin,[1] Aristide Lemaître,[2] Isabelle Sagnes,[2] Thi Huong Au,[1] Sébastien Boissier,[1] Eric Bertasi,[1] Aurélien Baert,[1] Mario Valdivia,[1] Marie Billard,[1] Ozan Acar,[1] Alexandre Brieussel,[1] Rawad Mezher,[1] Stephen C. Wein,[1] Alexia Salavrakos,[1] Patrick Sinnott,[1] Dario A. Fioretto,[2] Pierre-Emmanuel Emeriau,[1] Nadia Belabas,[2] Shane Mansfield,[1] Pascale Senellart,[2] Jean Senellart,[1] and Niccolo Somaschi [1]

[1] *Quandela, 7 rue Léonard de Vinci, 91300 Massy, France*

[2] *Université Paris-Saclay, CNRS, Centre de Nanosciences et de Nanotechnologies, 91120, Palaiseau, France*

mathias.pont@quandela.com

Quantum computing with light has recently been brought by several demonstrations at the edge of quantum computational advantage. These demonstrations were obtained making use of squeezed light and Gaussian Boson Sampling protocols. However, most of the roadmaps to fault-tolerant universal quantum computing are based on encoding the information on single photons.

In this work, we present the first general-purpose quantum computing platform based on single photons named *Ascella* [1]. It relies on a record efficiency monolithic bright source of pure and indistinguishable singe photons [2] that feeds a universal and reconfigurable 12-mode linear optical network with 6 photonic qubits. *Ascella,* enhanced by machine learning which corrects hardware imperfections, shows state-of-the-art performances in terms of photonic qubit quality together with unparalleled number of manipulated photons and sampling rates. The system can be operated from the Quandela Cloud with gate-based logical circuits or directly manipulating single photons.

For gate-based computation we benchmark 1-, 2- and 3-qubit gates with fidelities of 99.6±0.1%, 93.8±0.6% and 86±1.2% respectively, at the very best level all platforms considered. As a use case of the platform in the gate-based quantum computation framework we implement a variational quantum eigensolver to calculate the energy levels of H_2 with record accuracy for photonic implementations. For photon native computation, we perform the first photon-based quantum machine learning classification using a 3-photon-based quantum neural network, and report a first 6-photon Boson Sampling on-chip. Finally, we demonstrate the very first heralded generation of a 3-photon GHZ state. Such heralded entanglement schemes combined with the recent demonstration of efficient generation of linear cluster states directly from the same quantum dot source technology [3] open the path to fault tolerant quantum computing with reasonable hardware resource overheads.

Figures

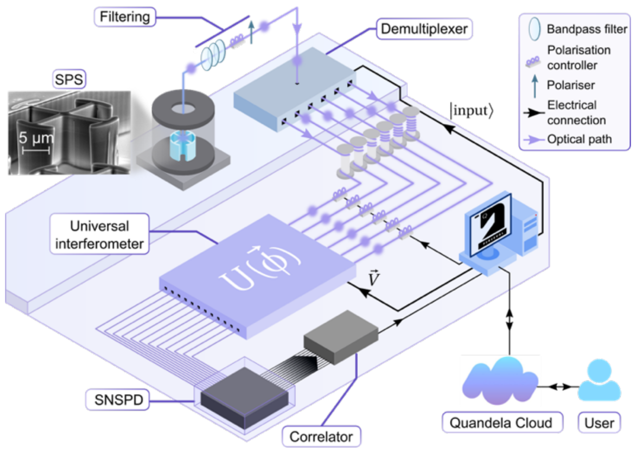

Figure 1: Sketch of the overall architecture of the 6 single-photon quantum computer.

References

[1] **Maring, Nicolas, et al. *arXiv preprint arXiv:2306.00874* (2023).**

[2] Somaschi, Niccolo, et al. *Nature Photonics* 10.5 (2016): 340-345

[3] Coste, N., et al. *Nature Photonics* (2023): 1-6.