INTERNSHIP PROPOSAL

(One page maximum)

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Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: EU project

Hidden variable models for simulating optical quantum computing

Sampling problems are of crucial importance for demonstrating the quantum devices can efficiently perform tasks that no classical computer can efficiently simulate. Various groups have claimed the realisations of such so-called quantum advantages, both using superconducting devices and using optics [1,2], but many of these experiments have ultimately been simulated on classical computers by exploiting experimental imperfections [3]. This clearly shows the difficulty of translating highly idealised theoretical protocols to real experiments.

In our context of optical implementations, one way to address this problem is by acquiring a better understanding of the physical properties that are required to achieve a quantum computational advantage. This allows us to develop techniques to detect the presence of such properties in quantum light and to protect them against experimental noise.

In this internship, we will actively develop techniques to simulate optical sampling problems based on phase space representations of the quantum states, quantum operations, and quantum measurements. These phase space techniques are useful to explicitly construct hidden variable models for sampling problems. We will investigate which physical properties hinder us from using such hidden variables to efficiently simulate a sampling problem on a classical computer.

In the past this approach was used to identify Wigner negativity as a required physical property [4]. However, other methods have recently emphasised the role of other physical properties [5]. The goal of this internship is to either identify new necessary properties or acquire a better understanding of how the different known properties combine to make the sampling problem hard to simulate. In the subsequent PhD project, we will study these properties more rigorously using resource theories and design techniques to verify their presence in quantum optics experiments.

[1] Zhong et al. Quantum computational advantage using photons, Science 370, 1460-1463 (2020).
[2] Madsen et al. Quantum computational advantage with a programmable photonic processor, Nature 606, 75–81 (2022).
[3] Oh et al. Tensor network algorithm for simulating experimental Gaussian boson sampling, arXiv:2306.03709
[4] Mari and Eisert, Positive Wigner Functions Render Classical Simulation of Quantum Computation Efficient Phys. Rev. Lett. 109, 230503 (2012).
[5] Chabaud and Walschaers Resources for Bosonic Quantum Computational Advantage Phys. Rev. Lett. 130, 090602 (2023).

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: NO Soft Matter and Biological Physics:NO
Quantum Physics: YES Theoretical Physics: YES