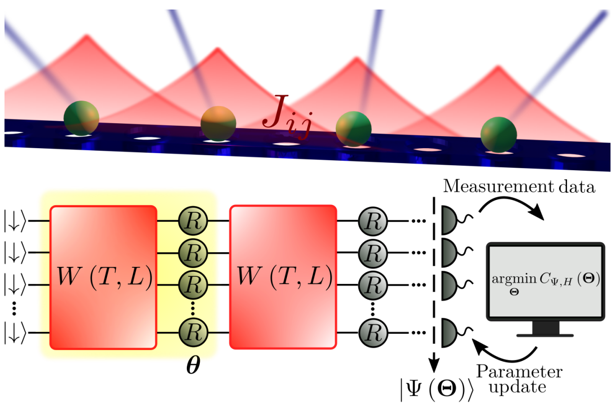
VARIATIONAL QUANTUM SIMULATORS: WAVEGUIDE-QED AND BEYOND

Cristian Tabares, Instituto de Física Fundamental IFF-CSIC
Calle Serrano 113b, 28006, Madrid
cristian.tabares@csic.es

Alberto Muñoz de las Heras, IFF-CSIC
Jan Thorben Schneider, IFF-CSIC
Luca Tagliacozzo, IFF-CSIC
Diego Porras, IFF-CSIC
Alejandro González-Tudela, IFF-CSIC

Variational Quantum Algorithms (VQAs) [1] use a classical optimizer to train a parametrized quantum circuit. These have emerged as a practical way to exploit state-of-the-art quantum computers. Currently, most VQAs have been designed for fully digital approaches, in which the error ends up accumulating for circuits with many gates. However, much less explored is the combination of analogue quantum simulators (AQS) with variational methods. This leads to new ways to exploit all the quantum resources provided by the quantum devices, and it is why they have been recently pointed out as one of the most promising directions to achieve “practical quantum advantage” [2]. However, current proof-of-principle demonstrations with trapped ions [3] or cold atoms [4], like it occurs with fully digital VQAs, are ultimately limited by the connectivities that can be achieved with these devices.



Top: scheme of a possible experimental setup, with quantum emitters addressed with lasers and coupled to a waveguide. Bottom: variational workflow using the analog waveguide-QED interactions.

In my talk I will discuss a variational AQS inspired by the tunable range interactions [5] that can be obtained in waveguide-QED platforms [6]. I will show how using the range of the interaction as a variational parameter one can design a novel class of PQCs with an optimized connectivity. This leads to an accurate preparation of the ground state of critical spin models with fewer gates and variational parameters than other state-of-the-art VQAs. FInally, I will also show how these ideas can be generalized to other types of quantum simulators. This will allow the study of complex many-body physics, like problems in quantum chemistry or quantum materials.

In summary, this talk will highlight the potential of variational methods to exploit current waveguide-QED quantum simulators, showing a practical application of their resources.

[1] M. Cerezo et al., Nature Review Physics **3**, 625-644 (2020).
[2] A. J. Daley et al., Nature **607**, 667–676 (2022).
[3] C. Kokail et al., Nature **569**, 355 (2019).
[4] C. Kaubruegger et al., Phys. Rev. X **11**, 041045 (2021).
[5] D. E. Chang, et al., Rev. Mod. Phys. **90** (2018).
[6] C. Tabares et al., arXiv:2302.01922 (2023).