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Quantum Information & Technology

“Probing entanglement entropy via randomised measurements”

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Friday, 8th November, 2019
11:00 am.
Allmandring 3
Seminar room 0.003

Entanglement is a key property to measure in engineered quantum many-body systems; for example, in order for quantum simulators and computers to provide an advantage over their classical analogues, they must generate large amounts of entanglement between their parts [1]. However, the development of new tools to probe entanglement in the laboratory is proving to be an outstanding challenge. Previous protocols to probe the entanglement structure of these systems, such as quantum state tomography or effi?cient tomographic methods (e.g. [2]), either scale unfavourably with the number of qubits, or place limitations on the quantum states which can be probed. An alternative way to probe the entanglement structure of these systems is through measuring the entropy of their partitions; in particular the second-order R?enyi entropy. If the entropy of a part A of the system is greater than the entropy of the total system, then bipartite entanglement exists between A and the rest of the system [3]. Consequently, measurements of the entropy of the system provide information about its entanglement structure.

This talk will present a protocol which uses statistical correlations between randomised measurements to measure the second order Renyi entropy [4]. The protocol not only scales more favourably than quantum state tomography, but imposes no a-priori assumption on the structure of the quantum state, and requires only a single copy of the state?. It can be implemented on any quantum platform with single-particle readout and control, applicable to systems with tens of qubits [5]. The experiments, performed on a trapped-ion quantum simulator, reveal the dynamical evolution of entanglement entropy of 10-qubit partitions of up to 20-ion strings - both in the absence and presence of disorder. The protocol represents a powerful, universal tool for both characterising engineered quantum systems and using them to tackle open questions in physics.

[1] G. Vidal, Phys. Rev. Lett. 91, 147902 (2003)
[2] B. P. Lanyon, et. al., Nat. Phys. 13, 1158 (2017)
[3] R. Horodecki, et. al., Rev. Mod. Phys. 81 865-942 (2009)
[4] A. Elben, et. al., Phys. Rev. A. 99 52323 (2019)
[5] T. Brydges, A. Elben, et. al., Science 364, 6437 (2019)