Measuring Entanglement Entropy in Quantum Simulation

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Entanglement is a basic feature of many-body quantum systems and underlies the complexity of simulating quantum physics on a classical computer. The exponential scaling of resources to represent and propagate a general many-body quantum state on a classical device has motivated the development of quantum simulators, and significant progress has been made in building both analog and digital quantum simulators with cold atoms and ions for equilibrium and nonequilibrium dynamics [1,2,3]. Here we discuss various schemes to measure the many-body entanglement growth during quench dynamics. Specific examples include quench dynamics with bosonic and fermionic atoms, and of spin systems. By making use of a 1D or 2D setup in which two copies of the same state are prepared, we show how arbitrary order Renyi entropies can be extracted by couplings between the copies and measurement of the parity of on-site occupation numbers. We illustrate these ideas for the example of a quench in a Hubbard model, and also for hard-core bosons (spin systems), and show that the scheme is robust against imperfections in the measurements [1].

[1] A. J. Daley, H. Pichler, J. Schachenmayer, and P. Zoller, Phys. Rev. Lett. 109, 020505 (2012).
[2] D. A. Abanin and E. Demler, Phys. Rev. Lett. 109, 020504 (2012).
[3] S. J. van Enk and C. W. J. Beenakker, Phys. Rev. Lett. 108, (2012).