MAR11-2010-002677

Abstract for an Invited Paper
for the MAR11 Meeting of
the American Physical Society

Entanglement of spin waves among four quantum memories[1]

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Quantum networks are composed of quantum nodes that interact coherently by way of quantum channels and open a broad frontier of scientific opportunities [1]. For example, a quantum network can serve as a 'web' for connecting quantum processors for computation and communication as well as a "simulator" for enabling investigations of quantum critical phenomena arising from interactions among the nodes mediated by the channels. The physical realization of quantum networks generically requires dynamical systems capable of generating and storing entangled states among multiple quantum memories, and of efficiently transferring stored entanglement into quantum channels for distribution across the network. While such capabilities have been demonstrated for diverse bipartite systems, entangled states have so far not been achieved for interconnects capable of "mapping" multipartite entanglement stored in quantum memories to quantum channels. In my presentation, I will describe an experiment [2] that demonstrates measurement-induced entanglement stored in four atomic memories; user-controlled, coherent transfer of the atomic entanglement to four photonic channels; and characterization of the full quadripartite entanglement by way of quantum uncertainty relations [3]. Our work thereby provides an important advance for the distribution of multipartite entanglement across quantum networks. Moreover, our entanglement verification method can be applied for the study of entanglement order for condensed matter systems in thermal equilibrium. With regard to quantum measurement, our multipartite entangled state can be applied for sensing an atomic phase shift beyond the limit for any unentangled state.

[1] "The Quantum Internet," H. J. Kimble, Nature **453**, 1023 (2008).
[2] K. S. Choi, A. Goban, S. Papp, S. J. van Enk and H. J. Kimble, Nature **468**, 412 (2010).
[3] S. B. Papp *et al.*, Science **324**, 764 (2009).

[1]Work supported by NSF PHY-0652914 and by NSSEFF.