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Generation of heralded entanglement between distant quantum dot hole spins

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Entanglement plays a central role in fundamental tests of quantum mechanics as well as in the burgeoning field of quantum information processing. Particularly in the context of quantum networks and communication, some of the major challenges are the efficient generation of entanglement between stationary (spin) and propagating (photon) qubits, the transfer of information from flying to stationary qubits, and the efficient generation of entanglement between distant stationary (spin) qubits. In this talk, I will present such experimental implementations achieved in our team with semiconductor self-assembled quantum dots.

Not only are self-assembled quantum dots good single-photon emitters, but they can host an electron or a hole whose spin serves as a quantum memory, and then present spin-dependent optical selection rules leading to an efficient spin-photon quantum interface. Moreover InGaAs quantum dots grown on GaAs substrate can profit from the maturity of III-V semiconductor technology and can be embedded in semiconductor structures like photonic cavities and Schottky diodes.

I will report on the realization of heralded quantum entanglement between two semiconductor quantum dot hole spins separated by more than five meters. The entanglement generation scheme relies on single photon interference of Raman scattered light from both dots. A single photon detection projects the system into a maximally entangled state. We developed a delayed two-photon interference scheme that allows for efficient verification of quantum correlations. Moreover the efficient spin-photon interface provided by self-assembled quantum dots allows us to reach an unprecedented rate of 2300 entangled spin pairs per second, which represents an improvement of four orders of magnitude as compared to prior experiments carried out in other systems.

Our results extend previous demonstrations in single trapped ions or neutral atoms, in atom ensembles and nitrogen vacancy centers to the domain of artificial atoms in semiconductor nanostructures that allow for on-chip integration of electronic and photonic elements. This work lays the groundwork for the realization of quantum repeaters and quantum networks on a chip.