When Worlds Collide

Hybrid systems make quantum optics and condensed matter physics meet again

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Like in the novel *When Worlds Collide* by Edwin Balmer and Philip Wylie, two different worlds, in this case condensed matter physics and quantum optics, have in the last years come closer and closer to each other. In the field of quantum information, the search for scalable qubits with long coherence times is now taking the approach of combining the best of these two worlds in hybrid quantum systems.

Superconducting (SC) qubits and Nitrogen-vacancy (NV) centers in diamond are among the best candidates to implement a quantum computer. The former – solid-state system – has recently proven two-qubit algorithms [1], violation of Bell inequalities [2, 3], and entanglement of up to three qubits [4, 5]. The second – atomic like system – has shown very long coherence times [6, 7], as well as tripartite entanglement [8], and the possibility of using the system as a quantum register [9, 10]. In the present Physical Review Letters [11], a hybrid system combining these two has been proposed.

The system presents many of the advantages of both, solid-state and atomic qubits. For example, it is shown how the SC flux qubit, used in this proposal, can be employed as a quantum bus to couple coherently distant NV centers. Also, it is presented how the quantum state of the flux qubit can be transferred to an ensemble of NVs, and from here to the nuclear spin of Nitrogen nuclear spins, in this way using the system for long-term storage of the quantum information. Finally, the state can be transferred to optical photons for quantum communication, thereby having an interface between SC qubits and light. The different decoherence mechanisms are analyzed, giving optimistic values: the coupling between both systems is estimated to be larger than the different decoherence rates. Related experiments on hybrid systems have recently been performed [12, 13], and it may only be a matter of time until we know what happens *After Worlds Collide*.

References

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