Quantum interface of an electron and a nuclear ensemble

Coherent excitation of an ensemble of quantum objects underpins quantum many-body phenomena and offers the opportunity to realize a memory that stores quantum information. Thus far, a deterministic and coherent interface between a spin qubit and such an ensemble has remained elusive. Here, we first use an electron to cool the mesoscopic nuclear-spin ensemble of a semiconductor quantum dot to the nuclear sideband–resolved regime. We then implement an all-optical approach to access individual quantized electronic-nuclear spin transitions. Finally, we perform coherent optical rotations of a single collective nuclear spin excitation—a spin wave. These results constitute the building blocks of a dedicated local memory per quantum-dot spin qubit and promise a solid-state platform for quantum-state engineering of isolated many-body systems.

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Contributors: Gangloff, D. A., Éthier-Majcher, G., Lang, C., Denning, E. V., Bodey, J. H., Jackson, D. M., Clarke, E., Hugues, M., Gall, C. L., Atatüre, M.
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