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Orbital hyperfine interaction and qubit dephasing in carbon nanotube quantum dots[1] ANDRAS PALYI, Insitute of Physics, Eotvos University, Budapest, Hungary, GABOR CSISZAR, Max Planck Institute for Intelligent Systems, Stuttgart, Germany — Hyperfine interaction (HF) is of key importance for the functionality of solid-state quantum information processing, as it affects qubit coherence and enables nuclear-spin quantum memories. In this work, we complete the theory of the basic hyperfine interaction mechanisms (Fermi contact, dipolar, orbital) in carbon nanotube quantum dots by providing a theoretical description of the orbital HF. We find that orbital HF induces an interaction between the nuclear spins of the nanotube lattice and the valley degree of freedom of the electrons confined in the quantum dot. We show that the resulting nuclear-spin–electron-valley interaction (i) is approximately of Ising type, (ii) is essentially local, in the sense that an effective atomic interaction strength can be defined, and (iii) has a strength that is comparable to the combined strength of Fermi contact and dipolar interactions. We argue that orbital HF provides a new decoherence mechanism for single-electron valley qubits and spin-valley qubits in a range of multi-valley materials. We explicitly evaluate the corresponding inhomogeneous dephasing time T_2^* for a nanotube-based valley qubit.

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