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Directional dark matter detection in diamond: principles and experimental progress

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The next generation of weakly interacting massive particle (WIMP) dark matter (DM) detectors will be sensitive to coherent scattering of solar neutrinos from target nuclei, demanding an efficient background-signal discrimination tool. A directional detector would enable detection of WIMP DM below the "neutrino floor", otherwise an irreducible background. Diamond has been proposed as a next-generation DM detector because of its sensitivity to low-mass WIMP candidates, as well as its excellent semiconductor properties, making it a suitable target for sub-GeV DM detection. We are developing complementary methods for nuclear recoil directionality readout in diamond. WIMP- and neutrino-induced nuclear recoils would leave a sub-micron track of lattice damage, constituting a durable signal for the incoming particle's direction. Spectroscopy of quantum defects such as nitrogen-vacancy (NV) centers allows detection of crystal damage via the strain induced in the crystal lattice, while methods such as x-ray diffraction microscopy allow nanoscale mapping of crystal structure. An alternative method would be to detect the NV centers induced by the WIMP impact in a low-NV-density sample. We present the proposed directional detection principle as well as an overview of recent experimental results.

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