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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. Thanks to relative motion of the Solar System and Galactic DM halo, fluxes of solar neutrinos and DM particles have distinct anisotropic flux distributions. A directional detector hence 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 at cryogenic temperatures, 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 allow nanoscale mapping of crystal structure. We present the proposed directional detection principle as well as an overview of recent experimental results.

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