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Development of Carbon-based Dark Matter Detectors with Magnetic Phonon Sensors

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We present a novel approach for the detection of sub-GeV dark matter using carbon-based crystals integrated with paramagnetic phonon sensors for low-threshold, low-background athermal phonon sensing. The paramagnetic phonon sensors, consisting of Er-doped Ag metallic films, are directly deposited onto the surfaces of target crystals. Athermal phonons generated by dark matter interactions in the crystal are absorbed by the magnetic films, inducing spin flips that are precisely read out using DC-SQUID (Superconducting Quantum Interference Device) magnetometers. This technique offers strong versatility, enabling reliable integration of magnetic sensing films with a wide range of single-crystal detector materials, including diamond and SiC. It features fast timing resolution (<100 ns) for athermal phonon arrival, enabling precise phonon-pulse shape discrimination (P-PSD) to suppress non-nuclear recoil backgrounds and electronic noise events. Additionally, the method is highly scalable, requiring no complex superconducting circuit fabrication on the detector substrate and relying only on Ag:Er film deposition, which is broadly compatible with many crystal types. We report recent progress from our experimental development, including characterization of diamond and SiC detectors and comparison with sapphire detectors, along with preliminary studies of $PbWO_4$ crystals for potential neutrino detection applications.

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