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# Towards Optical Wavelength Readout of Acoustic Superfluid Helium in Ultralight Dark Matter Detection (HeLiOS)

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Dark matter (DM) is an undetected form of matter whose existence is supported by numerous astrophysical observations on multiple scales. Since DM constitutes over 85% of the mass of the galaxy, its direct detection is one of the most important fundamental physics concerns today. For a broad region of sub-100KHz (peV) "ultralight" DM (UDM), mechanical sensors are predicted to set the deepest constraints on UDM-normal-matter interaction strength. Owing to its high mechanical quality (low force noise), superfluid helium is an excellent material for such acoustic UDM searches. Motivated by this, HeLIOS is a new class of sensitive small-scale UDM mechanical detectors that should place new constraints within hours of operation. Advantageously, its resonant response can be swept via pressurization, allowing it to explore more phase space than a fixed-frequency mechanical system. We propose several optimizations, including enhanced readout with a membrane-fiber-cavity optomechanical system, that should together improve sensitivity by several orders of magnitude.

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