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Exploring the Macroscopic Quantum Physics of Motion with Superfluid He-4 LAURA DE LORENZO, AARON PEARLMAN, KEITH SCHWAB, Caltech — We demonstrate the use of superfluid helium-4 as an extremely low loss optomechanical element. We form an optomechanical system with a cylindrical niobium superconducting TE_{011} resonator whose 40 cm^3 inner cylindrical cavity is filled with ^{4}He. Coupling is realized via the variations in permittivity resulting from the density profile of the acoustic modes. Acoustic losses in helium-4 below 500 mK are governed by the intrinsic nonlinearity of sound, leading to an attenuation which drops as T^4, indicating the possibility of quality factors (Q) over 10^{10} at 10 mK. In our lowest loss mode, we demonstrate this T^4 law at temperatures down to 50 mK, realizing an acoustic Q of $1.35*10^8$ at 8.1 kHz. When coupled with a low phase noise microwave source, we expect this system to be utilized as a probe of macroscopic quantized motion, for precision measurements to search for fundamental physical length scales, and as a continuous gravitational wave detector. Our estimates suggest that a resonant superfluid acoustic system could exceed the sensitivity of current broad-band detectors for narrow-band sources such as pulsars.

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