Probing phase coherence in solid helium using torsional oscillators of different path lengths

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Long-range phase coherence is a critical signature of macroscopic quantum phenomena. To date, nonclassical rotational inertia (NCRI) of solid helium has been reported only in samples with physical dimension of at most 5 cm. We have investigated solid helium in longer path-length torsional oscillators. Samples of length ranging from 6 to 100 cm were grown inside toroids and in self-connected long capillaries. NCRI of 4×10^{-5} and 3×10^{-5} were found in cells with path length of 6 and 9 cm. In cells with path length of 30 and 100 cm, NCRI, if it exists, is less than 7×10^{-5} and 4×10^{-5}, respectively.

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I. INTRODUCTION

Evidence of nonclassical, i.e., missing, rotational inertia (NCRI) in solid helium at low temperature has been reported in torsional oscillator (TO) experiments in at least nine different laboratories.[1–11] The solid helium samples inside the TOs have dimensions of at most 5 cm. If solid helium at low temperature is a "standard"superfluid, like superconductivity and superfluidity in liquid helium, one would expect the observation of NCRI will not be limited to centimeter length scales. In this paper, we report a systematic search for NCRI in solid samples with path lengths of 6, 9, 30, and 100 cm. The 30- and 100-cm oscillators were made by winding capillaries onto bobbins like superconducting wires in a superconducting magnet in the persistent ready mode. Helium enters the cell through the fill line on the top and splits to a T-shaped junction secured at the top of the bobbin. From one end of the T, the capillary is wound down the side of the bobbin and then it is wound up along a second layer to the top and connected back to the same end of the T. The 6- and 9-cm oscillators

30 bars sample [Fig. 5(a)] in the 6-cm TO. For the 50 bars samples, the minima are found near 1.3 K [Figs. 5(b) and 5(c)]. The exact origin of this broad Q minimum is not clear. In a recent experiment, Eyal *et al.*[18] found a large drop in the period near 1.5 K. We extended the measurements for a few samples in the 6- and 9-cm TOs up to melting points. However, we could not find any period drop larger than the scatter of the data or 0.1 ns at temperatures higher than 0.5 K.

III. DISCUSSIONS

Since the observed period drops in the 6- and 9-cm TOs are only three to six times larger than that attributable to the shear modulus effect, one may wonder if it is possible that we have underestimated the effect and there is no need to invoke NCRI. It was found recently that, in a single crystal, the change in the shear modulus can be as high as 86%8.8(f0El,)-2b 4etoasf m
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