HIGH-Q MICROMECHANICAL RESONATOR AS A PROBE OF SUPERFLUID ^{4}He IN THE BALLISTIC REGIME

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Immersed oscillating objects such as tuning forks, wires and grids have proven to be useful and multifunctional probes in studies of superfluid ^{4}He and ^{3}He. Miniaturization of these devices is desirable, since lower mass allows for more sensitive measurements of dissipative and reactive forces acting on an object moving through a fluid. To achieve this goal, we have fabricated aluminium 'vibrating-wire like' micromechanical resonators with dimensions of the order of 10 μm and rectangular cross section of 0.15×1.0 μm^2 (Fig. 1).

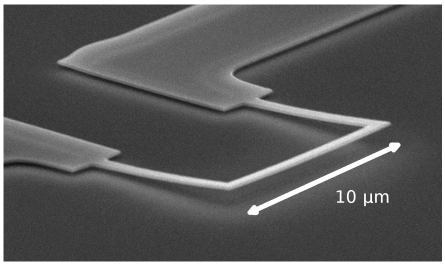

Figure 1: SEM micrograph of a studied device.

We have measured response of these devices at temperatures from 15 mK to 1 K in vacuum and superfluid ^{4}He. In this temperature range the intrinsic damping has a power-law dependence $\Delta f \propto T^{\beta}$, where $\beta \approx 0.3$. High Q-values up to 20 000 have been achieved at the lowest temperature. The drag force on a mechanical oscillator in ^{4}He-II originates from scattering of phonons and rotons. As a result, the resonance linewidth increases as $\Delta f_{ph} \propto T^4$ and $\Delta f_{rot} \propto \exp(-\Delta/T)$, respectively [1]. We have measured the linewidth as a function of temperature, and good agreement with theory has been found. The temperature dependent intrinsic width and ballistic drag make these devices sensitive thermometers in the milliKelvin/sub-Kelvin temperature range.

When the devices are driven at large oscillation amplitudes $|X|$, the resonance responses become nonlinear, showing Duffing-like behaviour (Fig. 2), and the resonance frequency f_r decreases as $f_r = f_0 - b_0|X|^2$. We observe that the value of b_0 in ^{4}He is about 4 times larger, than in vacuum. The increase in b_0 is in a qualitative agreement with results measured in ^{3}He with similiar devices [2]. At even higher drives, transition to turbulent flow is observed.

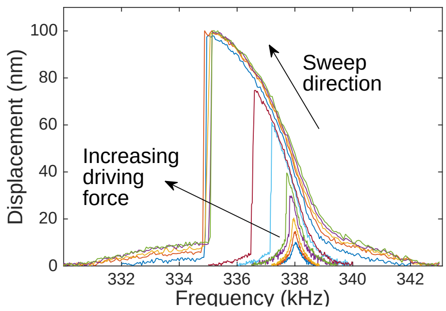

Figure 2: Frequency response measured at different driving force amplitudes.

[1] J. Jäger, B. Schuderer, W. Schoepe, Physica B: Condensed Matter **210**, 201 (1995)
[2] M. Defoort, S. Dufresnes, S. L. Ahlstrom et al. J. Low Temp. Phys. **183**, 284 (2016)