

# Experimental investigation of oscillating objects in mK superfluid $^4\text{He}$

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We present the results of an experimental investigation of oscillating bodies in superfluid  $^4\text{He}$  for temperatures in the range  $10 < T < 1500\text{mK}$ . We have studied both a 9 cm diameter vibrating grid and quartz tuning forks in ultra-pure  $^4\text{He}$ . Three standard ( $\sim 32\text{kHz}$ ) forks were used to generate and to detect the turbulence. The presence and/or generation of vortices by the moving body can be detected from the body's own oscillatory dynamics, in particular changes in frequency and width of the resonance. We studied the influence of the driving amplitude on the response (velocity). In addition, we measured the free decay of grid oscillations, observing complex behaviour with at least three different decay regimes. In more detail, our main results are –

- For low excitation, the response of tuning fork (its maximum velocity) is proportional to excitation (“laminar flow”); when the velocity  $v$  exceeds a critical velocity  $v_c$ , the damping force increases  $\propto (v - v_c)^n$ , where  $n \simeq 2$  (“turbulent” state).
- The results were different for the first measurement, in the “virgin state”, as compared to subsequent measurements – in the “excited” state (attained after excitation for  $v > v_c$ ).
- The excited state exhibited a higher damping force in the laminar flow regime than had been so in the virgin state.
- Increasing the excitation in the excited liquid was accompanied by a critical velocity lower the initial  $v_c$ ;
- While the system is in the mK range, the excited state persists for a very long time (at least weeks) but the liquid can be returned to its virgin state by warming it above  $T_\lambda$ .
- Free decay of the grid oscillations passes through three stages: (i) very fast energy-loss with a time constant of the order of few seconds; (ii) a stage where the rate of energy-loss was velocity-independent, lasting for up to 100s; (iii) exponential decay with a time constant corresponding to the quality  $Q$ -factor of the grid at low excitation ( $\tau \sim 90\text{s}$ , i.e. nuisance damping).
- The free decay exhibited variations corresponding to the prehistory of earlier measurements.

We have demonstrated the grid and forks as generators and detectors of the turbulent state. They exhibit high sensitivity in detecting changes of the turbulent state and one fork was found to respond to oscillation of a second fork at distance of 1 cm at  $T \sim 10\text{mK}$ , without any measurable time delay. We discuss possible explanations of these observations and how they bear on the problem of quantum turbulence.

Section: Quantum Turbulence

Keywords: Quantum turbulence, liquid helium-4, tuning fork, vibrating grid