EXPERIMENTAL SETUP FOR PROBING A VON KARMAN TYPE FLOW OF NORMAL AND SUPERFLUID HELIUM

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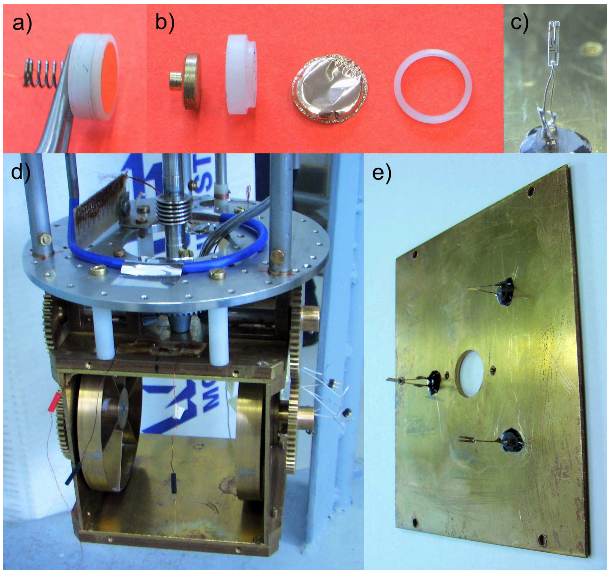
Introduction

Quantum turbulence (QT) as well as its classical counterpart represent a challenging field of investigation. Although QT in superfluid He II at finite temperature must differ significantly from that in normal He I, which is a classical fluid, while He II exhibits two-fluid behaviour and flow of its superfluid component (superflow) is subject to severe quantum restrictions, in some cases one observes surprising similarities, such as the existence of an inertial part of Kolmogorov form in their energy spectra [1, 2]. In order to study these similarities and differences experimentally, it is desirable to choose a type of flow that can be generated in the same way both in He I and in He II and probed simultaneously *in situ* using various complementary techniques. We have chosen a mechanical probe – a vibrating quartz fork [3] and a piezoelectric pressure sensor, similar as was successfully used by previous investigators [1]. Additionally, the vortex line density in a von Karman superflow can be sensed by attenuation of second sound, a technique which has been utilized in our Laboratory over recent years. This publication is a progress report reflecting current state of development.

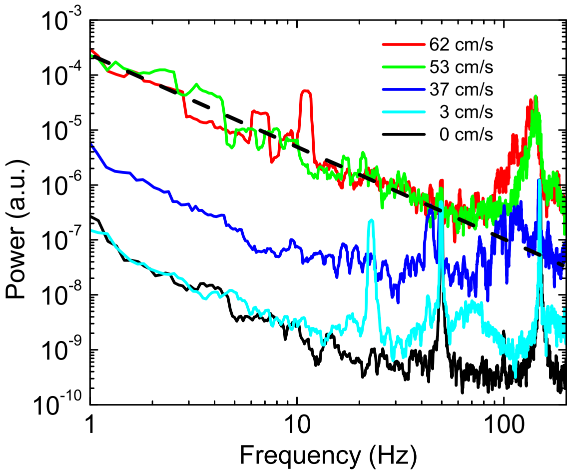


Obrázek 1: An assembled (a) second sound sensor based on the gold-plated nuclepore membrane, mechanically stretched over a delrin ring, forming a capacitor with the opposite brass electrode (b) pressed against it by a spring. Detailed view of one of the bare quartz tuning forks sealed with Stycast 1860 to the brass wall (c) and the geometric configuration (e) of three forks. The photograph of the lower part of the cryogenic insert showing the brass cell (d).

Experimental setup and preliminary results

Von Karman flow is generated by rotating the two discs of diameter 8.5 cm, each fitted with five blades, located at opposite sides of the $9 \times 9 \times 9$ cm^3 brass cell, see Fig. 1. Both discs are driven simultaneously to rotate in mutually opposite directions by a Maxon engine placed at the top flange of the cryogenic insert and connected to the cell via a hollow stainless steel shaft fitted with soft bellows. The gears located on the box ensure sufficient rotation speeds (up to 1 m/s) of the discs (corresponding to $Re \approx 4 \times 10^6$ at 4.2 K based on the perimeter velocity of the discs and their mutual distance).

Classical turbulence can be probed by three different quartz tuning forks [4] (forks oscillating at 32 kHz, 77.5 kHz and 100 kHz are installed) as well as by a PCB Piezotronics low temperature piezoelectric pressure probe. These sensors provide us with complementary information, because while the forks measure directly the force acting on a body oscillating at a single frequency, the dynamical pressure sensor allows us to construct the power spectrum of turbulent fluctuations by Fourier transforming its time domain signal. The pressure sensor is located on the outside of the cell and connected to its interior by a thin z-shaped tube. The orifice of the tube is positioned about 1 cm away from one of the two rotating discs and oriented so that it faces the incoming mean flow. The sensor is operated using a PCB charge amplifier and signal conditioner to provide maximum accuracy.



Obrázek 2: Energy spectra in He I as detected by the piezoelectric pressure sensor. The bottom line shows the spectrum measured with discs at rest; other spectra correspond to ascending velocities as indicated. The dashed line illustrates the Kolmogorov roll-off exponent of -5/3.

Fig. 2 shows the preliminary power spectra obtained using the pressure sensor in He I at rest and at various values of perimeter velocity of the counter-rotating discs. It is evident that the pressure sensor is capable of probing the flow as the background data measured with the discs at rest (due to extremely low kinematic viscosity it takes long time of order 1/2 hour for the flow inside the box to decay) lie several orders of magnitude lower than those measured at finite velocities. Moreover, the upper two spectra seem consistent with the famous Kolmogorov -5/3 roll-off exponent up to about 70 Hz. Present higher frequency data are unreliable, most likely due to combined effect of electrical noise, mechanical vibrations, and acoustic resonances occurring along the entry tube of the sensor.

Our attempts to acquire similar spectra in He II have so far been less successful. Although some of them do display features consistent with the inertial range of Kolmogorov type with -5/3 roll-off exponent, their quality is generally worse, probably because of temperature gradients and overheating of the interior of the box. QT can be additionally probed by second sound attenuation. Two second sound transducers with gold-plated nuclepore membranes (see detail in Fig. 1) are located in the center of two opposing sides of the box.

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