TSF Experiment for comparision of high Reynold's number turbulence in He I and He II : first results

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Pantxo Diribarne, Julien Salort, Christophe Baudet, Benoit Belier, Bernard Castaing, et al.. TSF Experiment for comparision of high Reynold's number turbulence in He I and He II : first results. Eckhardt, B. 12th EUROMECH European Turbulence Conference, Sep 2009, Marburg, Germany. Springer-Verlag Berlin Heidelberg, 132, pp.701-704, 2009, Springer Proceedings in Physics. <10.1007/978-3-642-03085-7_169>. <hal-00430197>

TSF Experiment for comparision of high Reynold's number turbulence in He I and He II : first results.

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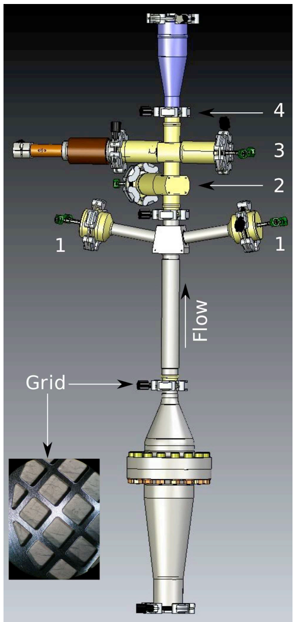
Summary. Superfluid turbulence (TSF) project uses liquid helium for the fundamental study of turbulent phenomena behind a passive grid and is able to work both in HeI and in HeII. Local and semi-local instrumentation was developed specifically for the purpose of this experiment(e.g. sub-micrometer anemometer, total head pressure tube and second sound tweezer). The difficulties encountered with this local and fragile instrumentation are discussed. Global characterization of the flow is presented including velocity, pressure, temperature stability and turbulence intensity. Finally, first results obtained with semi local measurements (total head pressure tube and second sound tweezer) both in the two phases of helium are presented.

1 Experimental facility and sensors

The experiment is a closed loop, containing three main sections : a pump, a heat exchanger and the experimental section. The helium flow is generated by the cryogenic pump. The temperature is controled by means of the heat exchanger immersed in a liquid Helium saturated bath. This experiment takes profit of the CEA Grenoble refrigerator (nominal capacity of 400 Watt at 1.8 K) to remove the heat due to the energy dissipated in this high Reynolds number experiment. Thermodynamical caracteristics of the flow are summarized in table b of fig.1.

The experimental section (see fig. 1) is made of a 27.2 mm inside diameter tube fitted with specifically designed sensor inserts. Much care was taken to avoid wall discontinuities due to the presence of the sensor mountings. The grid mesh size is $M = 3.9$ mm with 3.1mm square holes with 0.8 mm wide boundaries.



a) Sensors geometry

Sensor	**Distance to the grid x/M**	**Typical dimension**
1. Acoustic transducers	77	∅ 20 mm
2. Second sound tweezer	105	0.25×0.8×0.8 mm
3. Hot wire	123	∅ 1 μm
4. Total head pressure tube	143	∅ 1 mm

***

b)Thermal and hydrodynamical stability

Parameter	**Range**	**Standard deviation**
Temperature	1.7 - 4 K	± 1 mK
Pressure	1 - 5 bar	± 10 mbar
Velocity	0.5 - 8 m/s	± 5%

Fig. 1. Left : a sketch of the experimental section of TSF. Right : table **a** summarize position and spatial resolution of the probes, table **b** shows the thermodynamical parameters range and stability.

Four types of probes are available on TSF facility. There location and typical spatial resolution are summarized in table b of fig. 1.

Ultrasonic vorticity probe is based on scattering of ultrasonic waves by the flow vorticity at a chosen wave vector [3, 1]. In order to insure the non-invasiveness of the probe, it was necessary to add a thin wall between the transducers (transmiter and receiver) and the flow. Unfortunatly, in those conditions, the resulting signal could not be properly interpreted.

Second sound tweezer was used to measure the quantized vortex density L_0. It is based on the attenuation of a second standing wave between an emmitter (heating surface) and a very sensitive superconducting temperature probe [5].

Superconducting hot wire is designed following the principle of Castaing [2]. A bulk NbTi wire is used instead of a coated glass fiber in order to improve the spatial resolution and the sensitivity of the probe. The active part of the wire is obtained by locally reducing its cross section. This leads to a very fragile probe and few data could be acquired. Those measurements are not discussed in the present paper.
Total head pressure tube is inserted at the end of the experimental section. As in the experiment of Maurer and Tabeling [4], the pressure fluctuations at the stagnation point are assumed to be proportionnal to velocity fluctuations. This probes is thus used as an anemometer working both in He I and He II.

2 First results

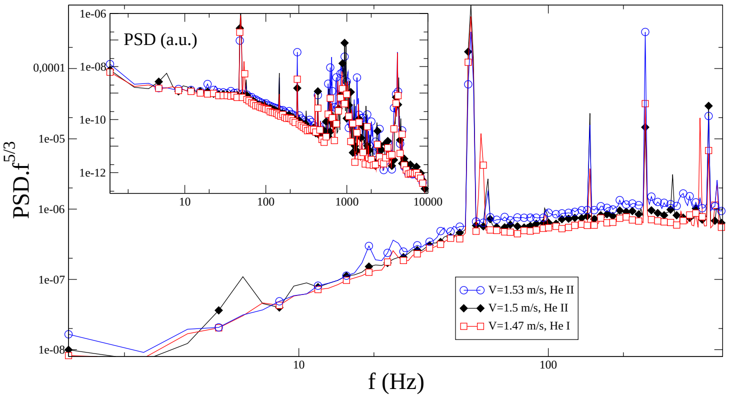


Fig. 2. Main graph : power spectral density (PSD) of the velocity compensated with $\mathtt{f}^{-5/3}$. Inset : rought PSD in arbitrary units. Above 500 Hz the signal is strongly altered by a Helmoltz resonnance in the pressure tube

In this section we show two preliminary results obtained with the total head pressure tube and the second sound tweezer.
In fig. 2 we have plotted the Power Spectral Density of the velocity. We see from the compensated spectrum that the PSD is compatible with a $\mathtt{f}^{-5/3}$ power law, both in He I and He II. The similarity between the upper inertial range in He I and II has already been reported by Maurer and Tabeling [4] in von Kármán flow with a higher turbulence intensity. Here, computed turbulence intensity is about 2%, consistent with expected values in such configurations, and does not depend on the helium phase. The geometry of the probe will now be improved to reach higher spatial and temporal resolution.

Preliminary results of the second sound tweezer are shown in fig. 3. We see that the amplitude of the temperature wave decreases with velocity. This is

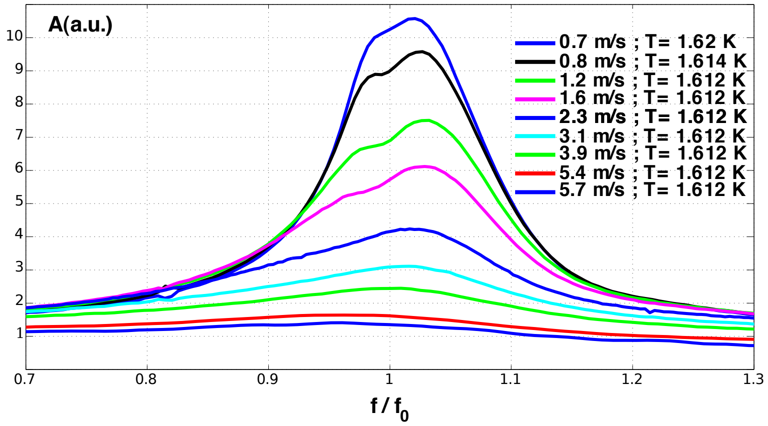


Fig. 3. Amplitude **A** of the measured temperature standing wave as a function of the driving frequency normalized with the expected resonnance frequency f_0. From top to bottom the curves correspond to increasing velocities.

due to increasing vortex lines density L_0 in the flow. Since L_0 can be viewed as the superfluid enstrophy, it provides a direct integral information about the smallest scales of the superfluid flow. Thus, the increase of L_0 versus the flow Reynolds number reflects the increase of the depth of the superfluid cascade.

3 Conclusion

We have succeeded in stabilizing a high Reynols steady superfluid flow. First results of TSF experiment tend to confirm the present understanding of superfluid turbulence and particularly the similarity with classical turbulence at large scale in a grid experiment. On-going work include quantitative analysis of the Reynolds number dependence of the superfluid cascade depth and velocity fluctuation measurements with improved space and time resolution.

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