**Supervisor's report on the Doctoral Thesis "Quantum fluid dynamics and quantum turbulence probed using micro- and nano-resonators" by Šimon Midlik:**

Šimon Midlik has been actively involved in research in the Laboratory of Superfluidity at our faculty already since his Bachelor studies, working on various aspects of superfluidity and quantum turbulence, but also on developing techniques for advanced cryogenic applications. During his PhD studies he designed and performed several experiments at our Institution and participated in collaborative studies together with leading low-temperature laboratories in Granoble, Helsinki and Lancaster. The results of his work, summarized in the present Thesis, contributed significantly to the knowledge within this field, led to several impacted publications. As the title suggests, the focus is on development of micro-/nano- mechanical devices and their applications to the studies of quantum turbulence in helium superfluids.

Quantum turbulence (QT) differs from its classical counterpart by having a well-defined elementary building block – the quantized vortex – with a fixed value of flow circulation. This simple distinction has many profound consequences and for this QT remains an active field of research within the broader field of low temperature physics, with modern developments focused mostly either on visualization of quantum flows and investigating their statistical properties, or on the use of nanomechanical resonators to measure interaction with individual quantized vortices with the aim of finding experimental evidence for some of the underlying processes such as energy dissipation in a fluid with zero viscosity.

The Thesis presents novel results on multiple aspects of quantum turbulence falling into the second category as outlined above. Let us recall the most important ones here. First, scaling of drag forces in oscillatory flows is discussed in detail, and building upon the observed laws, the onset of turbulence in either the normal or superfluid component is treated. A temperature-induced cross-over of these instabilities is observed and identified in two different types of oscillatory flow, the first driven mechanically and the second of thermal origin. The fact that opposite directions of cross-over are explained within a single framework is remarkable.

Second, Šimon Midlik contributed greatly to the development of local probes of quantum turbulence in the form of superconducting wire loops. After calibration, the devices were successfully used by the author to locally evaluate quantized vortex line density in thermal counterflow, which was previously possible only integrally over the experimental volume using second sound attenuation. The results show the sensitivity of these local probes and are to a large extent explained by the presented boundary layer model.

Third, as high frequency devices are often limited in their performance by parasitic effects such as acoustic emission, the author has investigated this effect using tuning forks submerged in normal liquid and superfluid 3He in collaboration with the team at Lancaster University. The results showed that previously known laws valid for classical fluids remain valid in the superfluid at temperature below 1 mK, even for a special sound mode ("zeroth sound") that has no direct classical analogy.

Another collaboration, with Aalto University in Finland, led to a successful measurement of a NEMS device interacting with a single quantized vortex in superfluid $^3$He-B. This successful experiment has not only motivated the design of similar novel devices for use in our laboratory, but led to the eventual observation of Kelvin waves on the trapped vortex (under preparation for publication). The author omits in his Thesis that he has also collaborated on a similar measurement with a single trapped vortex attached to a NEMS device in $^4$He together with the Lancaster University Low temperature group.

Finally, it ought to be highlighted that Šimon Midlik took charge of the fabrication of our own MEMS devices in CEITEC Nano facilities. Several chips holding multiple goal-post oscillators were produces and tested in deep cryogenic vacuum, with first results from superfluid helium obtained very recently. I would especially like to point out that the author has devised the fabrication process fully independently, building only on our, at that time rather limited, knowledge of lithographic processes and drawing upon the expertise of the CEITEC Nano staff, as well as by independent testing. Today, several other group members benefitted from this experience. During the same time, microfluidic channels for superfluid helium were also developed and produced using a novel bonding technique. These have recently been tested with success and a report is submitted for publication.

Apart from the above mentioned work, the author has demonstrated his capabilities for independent scientific work by his participation in numerous other projects and during his presentations at top international meetings in the field of quantum fluids, or low temperature physics. As a supervisor, it has been my privilege to follow his personal and professional growth into a highly capable investigator, an experimentalist with not only a broad knowledge of the practical aspects of electronics, instrumentation and cryogenics, but also a deep understanding of the physics of superfluidity and quantum turbulence obtained through genuine scientific curiosity.

Time permitting, I would like to ask one or two rather general questions during the defence:

1. In your view, what is the most crucially missing "piece of the puzzle" in our present understanding of quantum turbulence and what lines of research may help to find the answers?
2. Of all the practical and experimental techniques that are discussed in the Thesis, which ones do you think most deserve or need future development and refinement? Why? What do you expect to re-use the most in your future research?

Summarily, I am convinced that the Thesis "Quantum fluid dynamics and quantum turbulence probed using micro- and nano-resonators" presents a substantial development in the scientific understanding of quantum turbulence, satisfies all requirements, and represents the independent work of the author to the extent outlined therein. I recommend it with pleasure for the formal defence and support awarding the candidate with the PhD degree.

Prague, August 21st, 2023

doc. RNDr. David Schmoranzer, PhD.