Referee report on thesis: Experimental Investigation of Quantum Turbulence in Superfluid 4He by Timofiy Chagovets, Charles University, Prague

Thesis by Timofiy Chagovets: Experimental Investigation of Quantum Turbulence in Superfluid 4He is devoted to, as the title says, very interesting, and I can say still very hot subject of the low temperature physics – quantum turbulence.

Including the introduction and conclusion, thesis consists of six chapters. Chapter 2 Theoretical background starts with a short description of the fundamental physical properties of normal and superfluid 4He, explains the origin of the second sound - main experimental tool used in this thesis. A nature of the quantum vorticity in superfluid 4He and how it can be detected by means of the second sound technique is also described here. A section about quantum turbulence gives a short background on physics of thermal counterflow and introduces the main physical quantity which determine "amount" of the turbulence – vortex line density. A following section deals with classical turbulence to remind a reader of thesis the basic information on this topic, including a classical spectral model of turbulence decay - Kolmogorov theory.

Description of the experimental setup and measurement technique is given in Chapter 3. Here, as experimental physicist, I would like to appreciate the design and home made construction of the unique experimental facility for the turbulence study. I think that this unique experimental apparatus brought the Joint Low Temperature Laboratory of Charles University and Institute of Physics Institute of Czech Academy of Sciences in Prague between the world leading laboratories in field of turbulence. Therefore I also appreciate the contribution of the applicant to development of this experimental facility.

A summary of the selected experimental results on quantum turbulence in superfluid 4He is presented in Chapter 4. The most important part here is an experimental evidence of the transition between N, A and B states of the turbulence measured as a function of the mean superfluid velocity, the temperature dependence of the critical velocities of these transitions (Fig. 4.7). The end part deals with experimental results on the dynamics of the turbulence decay.

Discussion on experimental results from point of view of physical interpretation is the object of the Chapter 5. In first part, the discussion on decaying counterflow is led in terms of kinematic effective viscosity. The author compares their results with the results of other group on turbulence generated by the grid and concludes that no matter how the turbulence is generated the late decays of the turbulence displays classical power law, including a consistency of the values of the effective kinematic viscosities. The second part is devoted to discussion on results from pure superflow experiments. Comments on steady state pure superflow, the A state and B state, including dynamics of the turbulence decay are presented step by step. The last Chapter summarizes the results.

Thesis is well organized and easy to read. There are some misprints e.g. page 40, the word believe, citation [17] is not correct, the last sentence on page 44, which continues on page 45 is misleading, etc. The English writing on some places could be different, but as I am not English native speaker either, I shall not comment them. They are only formal corrections and they do not affect the scientific value of the thesis.

As all results presented in thesis were already published in high quality international journals and therefore refereed, the questions are have should to be taken as the question for discussion and perhaps also to stimulate further work. The questions and comments are as follows:

1. Temperature of the superfluid 4He is, in principle, determined by the density of the normal component or density of the excitations. The generation of the turbulence

means the generation of the new excitations being trapped in vortex cores by super flows circulating around them. It is thermodynamically non equilibrium state. If somebody measures the temperature of the superfluid 4He in an experimental cell with turbulence by means of a thermometer, what is this temperature related to?

2. What is the sensitivity of your second sound measurement technique for turbulence measurement or also what is the lowest vortex density you can detect by this technique? What determines the maximal response time of your measurement setup when you measured time evolution of the turbulence decay?
3. Is there a physical connection between the temperature dependence of the critical velocities I and II (Fig. 4.7) and dispersion relation between energy of excitations and their moments in superfluid HeII?
4. Is there any relation between individual transitions from N to A and after that to B state with the Landau criterion of superfluidity i.e. the existence of critical velocity in superfluid systems in experiments where pure superflow was used for the turbulence generation?
5. Can you comment possible mechanisms of the turbulence generation by means of pure superflow and what possible relaxation mechanisms of the turbulence decay one can think of in your experiments?

In conclusion, based on all results presented in his thesis, according to my mind, Timofyi Chagovets has contributed to our knowledge in field of the quantum turbulence by realization of new type of experiments, especially, the experiment with pure superflow and participation on data interpretation. The results were published in prestigious international journals. Based on this, I recommend that Timofyi Chagovets deserves the defence of his work in order to obtain the degree the Doctor of Philosophy (Ph.D.).

Košice, August 6th, 2008