welcome to the
European Microkelvin Collaboration
CAPACITIES

Application Form for MICROKELVIN Transnational Access Project

1. General Information

Project number:	**Lancs12**	
Project Title:	**Quantum diffusion of vacancies in Helium-4 Crystal**	
Lead scientist:[1]	**Title:**	Dr.
	First name:	Igor
	Last name:	Todoshchenko
	Home institution:	O.V. Lounasmaa Lab, Aalto University, Finland
Host scientist:[2]	**Title:**	Prof.
	First name:	Shaun
	Last name:	Fisher
	Home institution:	Lancaster University
Project scientist:[3]	**Title:**	Dr.
	First name:	Igor
	Last name:	Todoshchenko
	Scientific Field:	Quantum Liquids and Solids
	Home institution: **Is your home institution MICROKELVIN partner?**	O.V. Lounasmaa Lab, Aalto University, Finland Yes
	Business address:	O.V. Lounasmaa Lab, Aalto University
	Street:	Puumiehenkuja 2B, Otaniemi
	PO Box:	15100
	City:	Espoo
	Zip/Postal Code: Country:	00076 AALTO Finland
	Telephone:	+358 44 5458 422
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	E-mail:	todo@boojum.hut.fi
	Curriculum vitae (18 lines max): **Current Position**: 1999-present, Senior Researcher, Lounasmaa Lab, Aalto University, Finland **Resarch Interests**: **Solid Helium-4:** Equilibrium shapes, topological defects in the bulk and on the surfaces, anisotropy, supersolidity, thermodynamics. **Solid Helium-3:** Faceting transitions, surface kinetics, surface magnetism **Quantum Interfaces:** Surface fluctuations, superfluid surface bound states **Graduate Students:** 2 students graduated, 2 students currently in the lab **Publications:** 26 papers in refereed journals (30 Letters) **Invited talks at conferences:** 6	

1 The lead scientist indicated here is expected to participate in the campaign as a user of the infrastructure.
2 The host scientist is supervising the work of the visiting project scientist at the infrastructure.
3 The project scientist is the person who will be visiting the infrastructure.

	Five most recent publications:	
1	H. J. Junes, H. Alles, M. S. Manninen, A.Ya.Parshin, I. A.Todoshchenko, Stacking fault energy in ^{4}He crystals J. Low Temp. Phys., v. 153, p. 244 (2008).	
2	I. A.Todoshchenko, H. Alles, H. J. Junes, M. S. Manninen, A.Ya.Parshin, Devil's staircase of facets on the surface of ^{4}He crystals Phys. Rev. Lett., v. 101, p. 255302 (2008).	
3	M. S. Manninen, H. J. Junes, J.P. Kaikkonen, A.Ya.Parshin, I. A.Todoshchenko, and V. Tsepelin, Experimental setup for the observation of crystallization waves in ^{3}He Journal of Physics: Conference Series, v. 150, p. 012026 (2009).	
4	I. A.Todoshchenko, H. Alles, H. J. Junes, M. S. Manninen, A.Ya.Parshin, Nuclear spin ordering on the surface of a ^{3}He crystal: magnetic steps Phys. Rev. Lett., v. 102, p. 245302 (2009).	
5	I. A.Todoshchenko, M. S. Manninen, A.Ya.Parshin, Anisotropy of c facets of ^{4}He crystal Phys. Rev. B, v. 84, p. 075132 (2011).	
Other participating scientists:[4]	**Name:** **Position:**	**New User:**
	1-	
	2-	
	3-	

[4] Please list all participating user group members. Expand the table, if necessary.

2. Project Information

Name of host infrastructure:	**Lancaster University**			
Access provider / Infrastructure Director:	**Name: Prof. S.N. Fisher**		**E-mail address: s.fisher@lancaster.ac.uk**	
Planned project dates:	**Start date:**	**06.11.12**	**Completion date:**	**16.11.12**

Project description (12 lines max):

The project will be devoted to measurements on the plastic flow of helium-4 crystals at very low temperatures with a range of driving forces. We will investigate the use of new types of nucleators to create and grow good quality single crystals to avoid liquid flow along grain boundaries. We will then investigate the plasticity of the helium-4 crystals by moving a thin wire through the crystal with a wide range of driving forces. The measurements require a superconducting solenoid for high field, a system of coils for measuring the position of the wire, and a high pressure cell. These are already installed on the Lancaster Advanced Refrigerator. The cell also contains pressure sensors and an array of tuning forks which can be used to locate the solid-liquid interface when growing the crystals.

The project scientist has much experience in crystal nucleation and growth at these temperatures. We are particularly interested in investigating the crossover from thermal to quantum diffusion of vacancies, and the delocalization of vacancies at ultralow temperatures where the vacancy-phonon interaction is negligible.

Scientific objectives of the project (12 lines max):

Vacancies in quantum crystals are interesting objects which have received a lot of attention due to recent observations/speculations of possible supersolid-like behaviour and/or quantum plasticity. Vacancies have been predicted to become de-localized to form quasiparticles (vacancions), due to their high tunnelling probability and due to the periodicity of the lattice. At high temperatures delocalization is suppressed because the periodicity of the lattice is reduced by short-wavelength phonons. However, these phonons are almost completely absent at temperatures below 0.1 K. Vacancies are responsible for plastic flow at low driving forces and so are readily probed by flow measurements. Although the concentration of vacancies is very low below 0.1 K, they are easily created at the interface between the crystal and a moving object. They can diffuse through the bulk in the same direction as the object to provide mass flow in the opposite direction. Delocalization of vacancies may greatly enhance the diffusion coefficient of vacancies and hence enhance the plasticity of helium-4 crystals.

Technical description of work to be performed (20 lines max):

The superconducting wire used to produce the plastic flow forms a rectangular loop and is placed in a strong vertical magnetic field. A DC current through the wire produces a transverse Lorentz force to move it through the solid. A ~30 kHz AC current is superimposed on the DC current to induce a voltage on nearby coils which depends on the wire position. This allows the position of the wire to be calibrated from measurements in liquid He or in vacuum.

We will attempt to nucleate the He crystal by applying heat to the cell locally, or by driving the wire or a tuning fork to high velocities – this is known to nucleate vapour bubbles in liquid He at saturated vapour pressure, so we suspect that it might nucleate solid close to the melting curve. Once a seed is created, we can fix whatever temperature is required and then grow the crystal sufficiently to cover the wire completely. To maintain a good crystal, after changing the temperature the crystal must be melted to a small size and grown again, because the melting pressure is different at different temperatures. Simple cooling or warming of the existing crystal creates high stresses which will create a lot of defects in the solid and may affect the plasticity.

By preparing the crystal in different ways, we can study how defects influence the plastic properties. We can also generate extra defects by driving the wire at higher velocities, and we can study polycrystalline samples by growing the crystal at higher temperatures.

3. Joint Proposals / Funding

Is this project in collaboration with other (concurrent) projects at the infrastructure?	**Yes**
If yes, please specify: The sample cell was built for both turbulence experiments in superfluid helium and for experiments on solid helium 4. The former experiments were conducted earlier using the same cell, but are otherwise entirely separate from the current project. Preliminary studies of plastic flow in solid helium, and the development of the essential experimental techniques, were performed in an earlier TNA project with Emil Polturak.	

Is this proposal submitted to any funding programmes?	**No**
If yes, please specify:	

The completed Application Form should be submitted to MICROKELVIN Management Office (**Sari.Laitila@aalto.fi**, fax +358-9-47022969)