welcome to the European Microkelvin Collaboration

# Application Form for MICROKELVIN Transnational Access Project

## 1. General Information

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| **Project number:** | Lancs11 | |
| **Project Title:** | **Study of Plastic flow in solid Helium-4** | |
| **Lead scientist:**[1] | **Title:** | Prof. |
| | **First name:** | Emil |
| | **Last name:** | Polturak |
| | **Home institution:** | Technion-Israel Institute of Technology |
| **Host scientist:**[2] | **Title:** | Prof. |
| | **First name:** | Shaun |
| | **Last name:** | Fisher |
| | **Home institution:** | Lancaster University |
| **Project scientist:**[3] | **Title:** | Prof. |
| | **First name:** | Emil |
| | **Last name:** | Polturak |
| | **Scientific Field:** | Low Temperature Physics, Superfluidity |
| | **Home institution:** | Technion-Israel Institute of Technology |
| | **Is your home institution MICROKELVIN partner?** | No |
| | **Business address:** | |
| | Street: | Department of Physics, Technion-Israel Institute of Technology, |
| | PO Box: | - |
| | City: | Haifa |
| | Zip/Postal Code: | 32000 |
| | Country: | Israel |
| | Telephone: | |
| | Fax: | - |
| | E-mail: | emilp@physics.technion.ac.il |
| | **Curriculum vitae (18 lines max):**<br>**Current Position**: 1999-, Professor, Faculty of Physics., Technion- Israel Institute of Technology<br>**Resarch Interests**:<br>**Solid Helium** Inelastic neutron scattering, Torsional oscillator studies searching for "Supersolid-like" effects at high temperatures.<br>**Superconductivity**, Proximity effect, Andreev reflections, nonequilibrium superconductivity ( the Kibble-Zurek effect).<br>**Melting of solids** MD simulations of melting of Fcc, Bcc and Hcp metals.<br><br>**Graduate Students** – 24 students graduated, 2 students currently in the lab<br>**Grants**- continuously supported by Israel Science Foundation since 1981<br>**Publications –** > 100 papers in refereed Journals, (30 Letters)<br>**Invited talks at conferences > 50** | |

[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.

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| | **Five most recent publications:** | | |
| 1 | A.Eyal, O. Pelleg, L. Embon, and E. Polturak, "Evidence for a High-Temperature Disorder-Induced Mobility in Solid $^4$He", *Phys. Rev. Lett*. **105**, 025301 (2010). | | |
| **2** | D. Golubchik, E. Polturak, and G. Koren, B. Ya. Shapiro, and I. Shapiro,"Experimental determination of correlations between spontaneously formed vortices in a superconductor" *Jour. Low Temp. Phys*. 2011 | | |
| **3** | P. Bavli, J. Adler, and E. Polturak, "Molecular dynamics study of melting of the HCP metal Mg", Phys. Rev. B 84, 235442 (2011). | | |
| **4** | A. Eyal and E. Polturak, "BCC vs. HCP - The Effect of Crystal Symmetry on the High Temperature Mobility of Solid 4He"**,** *Jour. Low Temp. Phys.( 2012).* | | |
| **5** | D. Golubchik, E. Polturak, and G. Koren "Mass of a vortex in a superconducting film measured via magneto-optical imaging plus ultrafast heating and cooling", PRB **85**, 060504 (Rapid Communications) (2012) | | |
| **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

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| **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:** | **28/10/2012** | **Completion date:** | **2/11/2012** |

**Project description (12 lines max):**

This project will study plastic flow in solid Helium-4 over a broad range of temperatures, from around 1.5K to well below 10mK. We will study the motion of a wire through the solid under an applied force. The device was developed in an earlier TNA project. It was previously used to study quantum turbulence in superfluid 4He over a wide range of temperatures, from the superfluid transition temperature (~2K) to below 3mK. We now wish to use the device (and the same cell) to study solid 4He. The experiments will be performed on the Lancaster Advanced Refrigerator.

The project will investigate the plastic properties of solid helium, including plastic flow (creep) at low drive forces, the yield stress and the plastic response at higher driving forces. We are particularly interested in what happens at lower temperatures where there has been a great deal of recent interest in possible "super-solid" and/or "quantum plasticity" behaviour.

Substantial amounts of data, analysis and modelling will be required to interpret the experiments. The project scientist has much experience in similar experiments at higher temperatures.

**Scientific objectives of the project (12 lines max):**

There has been much interest in the anomalous properties of solid 4He at low temperatures. In 2004 Kim and Chan reported mass decoupling below ~100mK in a torsional oscillator which was interpreted as evidence for "super-solid" behaviour. In 2007, Beamish et. al. found that the shear modulus increases below a similar temperature, and there is much debate whether the apparent super-solid response is in fact just a consequence of the shear modulus change. It is now commonly believed that the crystal is unusually soft above ~100mK due to high defect mobility, the behaviour has been called "quantum plasticity". This project will address this issue by directly measuring the plastic properties by forcing a wire through the solid. The wire should be particularly sensitive at measuring plastic flow (creep) at very low velocities. It could also be used to study plastic properties close to the yield stress of the solid.

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

The wire is formed into a square loop. The sideways driving force arises from the Lorentz force exerted on the wire when a current is passed through it in a vertical magnetic field.

The position of the wire is measured using two near-by pick-up coils. A high frequency (~30 kHz) probe current is superimposed on the drive current. This induces voltages in the nearby coils. The magnitude of the voltage depends on the wire position. The position measurements are calibrated by measuring the elastic displacement of the wire in liquid 4He.

In the solid phase at high temperatures the wire should slowly move through the solid when a sufficient drive force is applied. The resultant plastic flow of the solid around the wire is thought to be facilitated by the diffusion of vacancies – an effect previously investigated by the project scientist. Here we aim to investigate the behaviour at lower temperatures and at higher driving forces. A large range of driving forces can be applied by varying the current (up to ~ 1 Amp) and/or the magnetic field (up to ~ 7 Tesla). The Lancaster Advanced Refrigerator has a base temperature of well below 3mK, so it should allow measurements over the full range of temperatures where anomalous behaviour has been observed.

## 3. Joint Proposals / Funding

**Is this project in collaboration with other (concurrent) projects at the infrastructure? Yes**

**If yes, please specify:**

The cell was built for both turbulence experiments and for experiments on the possible supersolidity of 4He.

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| The former experiments were conducted earlier and used the same device, but are otherwise entirely separate from the current project. |

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| **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)