MGML

Materials Growth and Measurement Laboratory

ANNUAL REPORT 2022

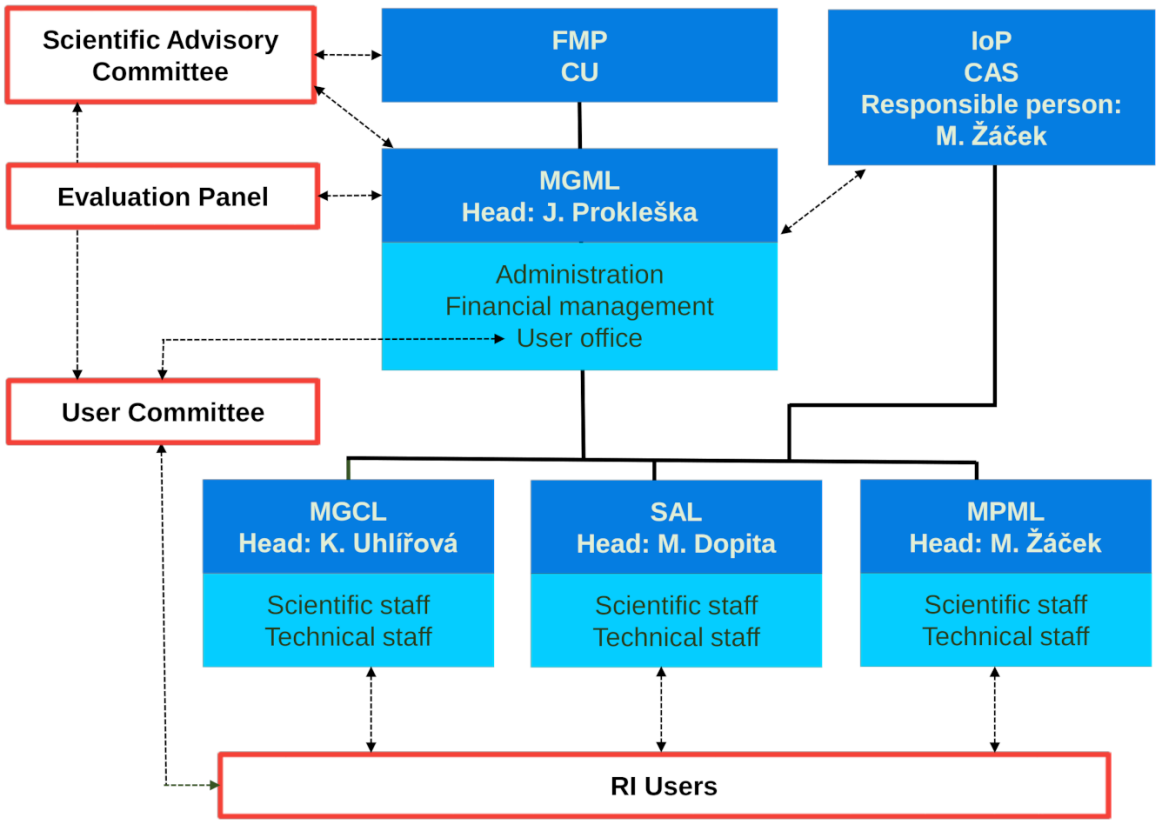
About MGML

MGML is a research infrastructure financed by the Ministry of Education, Youth and Sports within the program of Large Infrastructures for Research, Experimental Development and Innovation of CR (project No. LM2018096). It is an open access research infrastructure available to all users from Czech Republic and abroad.

The research infrastructure is hosted by the Faculty of Mathematics and Physics of Charles University with the Institute of Physics of the Czech Academy of Sciences, v. v. i. as the partner institution.

MGML provides a laboratory base for advanced material research. Within its two closely co-operating units, Material Growth and Characterization Laboratory (MGCL) and Material Properties Measurement Laboratory (MPML), MGML offers open access for external users to a vast experimental instrument suite as well as high-level expertise of its scientists. MGCL has state-of-the-art facilities for metal refinement, synthesis of new materials, and the preparation of high-quality single crystals with several different techniques. The unique combination of different crystal growth methods allows users a great deal of flexibility and optimization of the technology of producing entirely new materials. Modern X-ray diffraction and electron microscopy instruments allow detailed structural and phase characterization of samples. MPML offers the measurement of a wide portfolio of physical (magnetic, transport, thermal, acoustic and elastic) properties of materials through several complementary experimental methods. The extensive range of MGML instruments makes it possible to carry out the measurements in the temperature range from mK up to several hundred degrees Celsius, magnetic (up to 20 T) and electric (from -50V to + 50V) fields, hydrostatic and uniaxial pressures up to 15 GPa. Also important is the possibility of preparation, characterization and measurement of uranium materials, for which the institution has the appropriate license. Interconnection of this wide range of experimental techniques for the preparation, characterization and measurement of physical properties makes MGML a unique research infrastructure in the Czech Republic, fully comparable with the world's leading laboratories.

Organizational chart of MGML:



Our laboratories are located in three places in Prague:

The MGCL technology laboratories are located in the building of the Faculty of Mathematics and Physics – Ke Karlovu 5. You can also find the administration unit here.

The measurements of material properties are performed mostly in the cryo-pavilion of the Faculty of Mathematics and Physics in Troja, V Holešovičkách 2. The helium liquefier located in this building supplies all the cryogenic needs of the laboratory.

Some instruments for measurements of material properties and structural analysis are situated in the building of the Institute of Physics, Cukrovarnická 10.

MGML in 2022

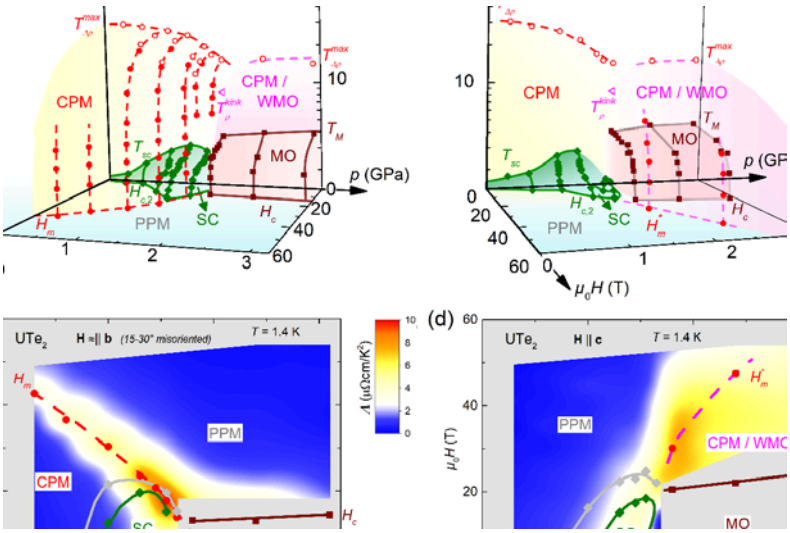
The LRI MGML runs all its experimental facilities without restrictions in 2022. In total, 60 experimental proposals were accepted, among them 45 long-term proposals, 2 standard and 13 proof of concept and test proposals.

The collaboration with other European partner laboratories continued within the ISABEL project, when MGML became a partner institution of EMFL, now it is fully engaged in the dual access program in EMFL. In practice, by submitting proposal using this dual access option, potential user(s) ask for experimental time in both – the partner institution (one of which is MGML) and the high-field facility in EMFL. The proposal is evaluated by the EMFL panel taking also into account remarks from the local contact at the partner institution. In the case of allocated time, the first experiments are performed in the partner institution and, depending on the results, continue in the EMFL laboratory

For example, a young researcher from MGML, Dr. T. Haidamak participated in the EMFL/ISABEL exchange program. The task of her stay at HZDR Dresden was to familiarise herself with the operation and research at pulsed magnetic field and transfer the obtained knowledge back to MGML. More specifically, she underwent the training and participated at experiments in the field of the measurement of elastic properties (magnetostriction and elastic constants). We also welcomed a first user within the EMFL dual access, working on UTe2 scientific case.

Scientific Highlights

Exploring superconductivity



The recent discovery of superconductivity in the heavy-fermion paramagnet UTe2 has attracted a lot of attention, particularly due to the reinforcement of superconductivity near quantum phase transitions induced by magnetic field and/or pressure. The magnetic properties of UTe2 are, thus, associated to its unusual superconducting properties.

A full description of the relationship between the two is essential to understand superconductivity in UTe2, and may well advance our understanding of magnetically-mediated superconductivity in

general. Applying pressure is the tool of choice to tune magnetism in strongly correlated systems. Often pressure can drive a system towards and through a magnetic instability, giving a direct probe of the relationship between magnetism and superconductivity.

For UTe2 it has already been shown that hydrostatic pressure induces an enhancement of the superconducting temperature by a factor 2, reaching about 3K [1]. The effect of magnetic field on the ambient pressure superconductivity of UTe2 is very unusual, with the superconducting critical exceeding 60 T for certain directions of applied field. A challenge is now to characterize the effects of combined pressure and magnetic fields applied along variable directions in this strongly anisotropic paramagnet.

In this paper the electrical resistivity of UTe2 under pressure up to 3 GPa and pulsed magnetic fields up to 58 T along the hard magnetic crystallographic directions b and c is investigated. We construct three-dimensional phase diagrams and show that the application of pressure and high magnetic field on UTe2 leads to an extremely complex phase diagram with a complete reshuffling of the magnetic anisotropy and strong associated effects on superconductivity. Near the critical pressure, a field-enhancement of superconductivity coincides with a boost of the effective mass related to the collapse of metamagnetic and critical fields at the boundaries of the correlated paramagnetic regime and magnetically-ordered phase, respectively. Beyond the critical pressure, field-induced transitions precede the destruction of the magnetically-ordered phase, suggesting an antiferromagnetic nature.

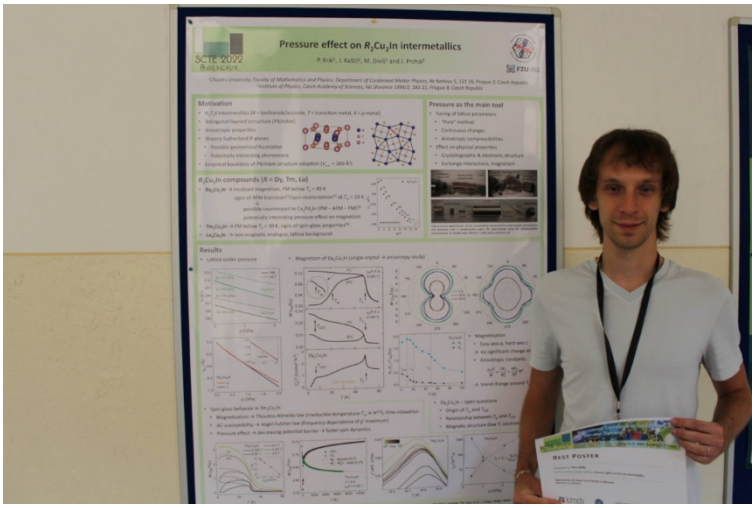
By bringing new elements about the interplay between magnetism and superconductivity, our paper appeals for microscopic theories describing the anisotropic properties of UTe2 under pressure and magnetic field.

Our MGML users succeeded to grow excellent single crystals and use all experimental capacities to investigate its properties. Further subsequent measurements were done in high magnetic field facilities (Toulouse), so it is also an example of user collaboration with large European infrastructures.

The second topic is a continuation of a series of papers that emerged from a pan-European collaboration related to the properties of spatially isolated water molecules. Recently, the users of the MGML published a paper in Nanoletters providing a clear signature of a quantum-critical behavior of the interacting water molecular dipoles. This is the first observation of “dielectric fingerprints” of quantum-critical phenomena in a paraelectric system of coupled point electric dipoles.

Student achievements in MGML

Several students were awarded for their experimental results achieved in MGML facilities.



The results of Petr Král, Ph.D. student at the Department of Condensed Matter Physics, obtained within the MGML infrastructure were presented at the International Conference on Solid Compounds of Transition Elements 2022 held in Bordeaux, France. Petr was awarded a Best Poster prize for the communication entitled “Pressure effect on R2Cu2In intermetallics”. Petr’s Ph.D. topic is focused on the R2T2X intermetallics crystallizing in the specific crystal structure type, which may result in the complex magnetism with the potential of Shastry-Sutherland frustration depending on the exchange interactions. Especially the pressure impact is investigated since mechanical pressure represents the unique tool for direct acting on the lattice and thus the related magnetic properties.

R2Cu2In compounds with R = Dy and Tm presented at SCTE conference represent the interesting members of R2T2X family. Ferromagnetic compound Dy2Cu2In was reported to exhibit the signs of spin-reorientation at lower temperatures. However, our studies signal on the origin of observed anomalies lying rather in the temperature evolution of anisotropy in this system. Tm2Cu2In is ferromagnet exhibiting glassy features probably related to the competing magnetic interactions in the Shastry-Sutherland-like Tm-planes. Pressure was found to have very weak impact on the ordering temperature, however the spin-glass properties described within the Vogel-Fulcher model are affected significantly, resulting in enhancement of the spin-glass character - three-order increase of relaxation time of single spin flip and corresponding decrease in activation energy of relaxation barrier.

Kateřina Tetalová was awarded the dean’s price for best bachelor thesis and at Czech-Slovak student conference in physics in Bratislava, she was awarded the price for second best presentation for her work done in MGML.

Collaboration with commercial partners

The collaboration with commercial partners and users is gradually developing. Besides the already existing close collaboration with the CRYTUR company (including common student projects), the measurements for Glenmark Pharmaceuticals Limited and Pharmathen were performed. The MGML User Committee (UC) has started its activities. The chair of the UC is in contact with the LRI management, communicating suggestions to improve the user environment.

Scientific Advisory Committee (SAC) meeting

The Scientific Advisory Committee (SAC) meeting took place on June 7th and 8th 2022. After the covid period of online meetings, the SAC members were able to visit our infrastructure in person. Nine SAC members came to Prague. Members of the Evaluation Panel joined the meeting as well. During the meeting, there were also brief discussions with the chairs of the Evaluation Panel (Prof. Vladimír Sechovský) and the User Committee (Dr. Ross Colman).

Conferences

Annual colloquium of the Czech and Slovak Crystallographic association, Conference Structure 2022, Tábor, Czech Republic. June 20.-23. 2022. A part of the conference was dedicated to neutron sources and neutron scattering in structural and materials sciences research. The event contained the 15th exhibition of student's works. https://xray.cz/xray/csca/kol2022/