MGML

Materials Growth and Measurement Laboratory

ANNUAL REPORT 2025

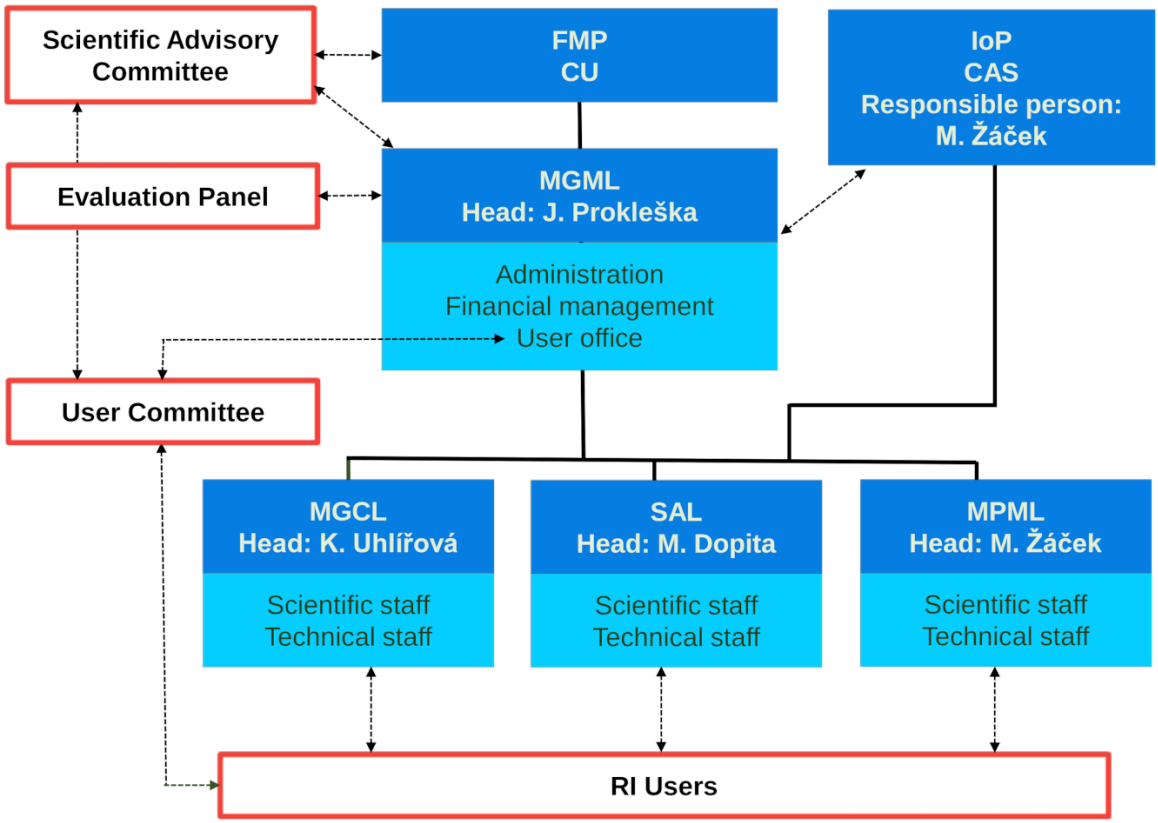
About MGML

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. LM2023065). 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 2025

The Large Research Infrastructure Materials Growth and Measurement Laboratory (LRI MGML) successfully operated all its experimental facilities throughout the past year without any notable operational disruptions. This year, we supported 58 new user proposals under our open-access regime. These encompassed a wide range of studies, including 17 long-term research proposals, 21 standard proposals, 13 proof-of-concept proposals, and 7 test proposals.

Collaboration with other European partner laboratories, especially within the framework of the ISABEL project (as introduced in past reports), has been key to our international engagement. The successful implementation of the dual-access program led to a notable overlap in the user pools of MGML and EMFL (European Magnetic Field Laboratory).

One of the most fruitful scientific endeavours stemming from the ISABEL dual-access program has been the continued investigation of superconductivity in UTe_2, a topic at the forefront of condensed matter research. LRI users successfully grew high-quality single crystals and subjected these crystals to extensive experimental investigations, utilizing the full spectrum of our laboratory's capabilities before further studies in international LRIs. The significance of this research experimentally supported by the MGML has been highlighted by Neuron price and Bernard Bolzano Endowment Fund Prize for dr. Vališka (for his research on high purity crystals of this material).

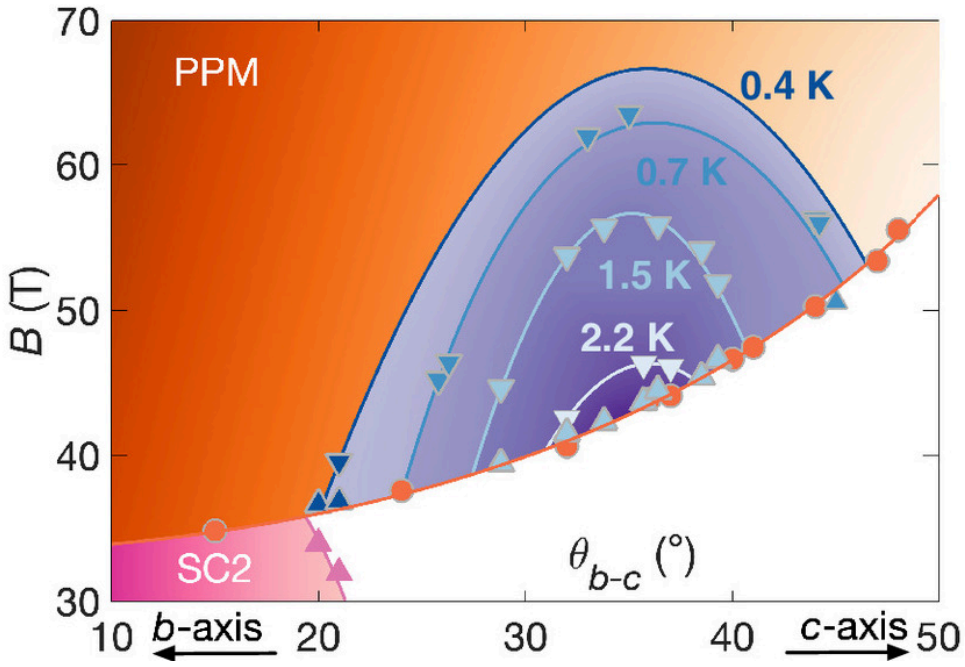
An important part of MGML's mission is to promote scientific excellence among students and co-educate the next generation of scientists, benefiting from its position within the university. Students conducting experimental work at MGML often utilize long-term proposals, allowing them access to the infrastructure's instrumentation as needed for their theses, in close collaboration with their supervisors and local contacts. Several junior users have received significant recognition for their work.

Ph.D. student Daniel Staško was recognized by the Charles University Grant Agency (GAUK) Board for his project "Electrical and magnetic properties of rare-earth iridates under extreme conditions," which was rated "Exceptionally good".

In 2024, MGML successfully secured a complementary national investment grant (CZ.02.01.01/00/23_015/0008184) for the modernisation of large research infrastructures. This year the updates/replacements of key or outdated instrumentation were started with the delivery and installations of high sensitivity magnetometer, XRF spectrometer, table-top difractometer and advancements in the field of high pressures and multiferroics, following the project's proposal. The implementation of this investment is scheduled for 2025 and 2026 and addresses the renewal of ageing instrumentation, thereby safeguarding the long-term sustainability of user services.

Scientific Highlights

Breaking Barriers: Magnetic Fields Enhance Superconductivity in UTe_2



A recent paper published in the Proceedings of the National Academy of Sciences (PNAS), titled "Superconducting critical temperature elevated by intense magnetic fields," explores how intense magnetic fields influence superconductivity in unconventional systems, shedding new light on the physics of superconductors.

The research focuses on the unconventional superconductor UTe2, a promising candidate for spin-triplet pairing. Using pulsed magnetic fields up to 70 Tesla, researchers observed that the superconducting critical temperature (Tc) increases to approximately 2.4 K under magnetic fields near 40 Tesla. This finding is counterintuitive, as magnetic fields typically suppress superconductivity; however, in this case, they appear to stabilize and enhance it under specific conditions.

While these extreme conditions are far from practical for technological applications, this work provides critical insights into the unique mechanisms driving superconductivity in UTe2 and related materials. By advancing our understanding of the interplay between magnetism and superconductivity, this study contributes to the broader effort to unravel the physics of unconventional superconductors.

The high-quality single crystals of UTe2 used in this study were prepared by Dr. M. Vališka's team at MGML. For more details, see our previous posts tagged UTe_2.

This large-scale collaboration was made possible through dual access provided by the ISABEL project.

Scientific staff achievements in MGML

Bernard Bolzano Endowment Fund Prize awarded to Michal Vališka

Michal Vališka and his team have successfully prepared ultraclean single crystals of the unconventional superconductor UTe2, which exhibits multiple hallmarks of spin-triplet superconductivity. This remarkable material features a complex and unique phase diagram, including multiple superconducting phases induced by a magnetic field and applied pressure, as well as a metamagnetic transition to a field-polarizedstate.

Recognizing the impact of these discoveries, the Bernard Bolzano Endowment Fund Prize was awarded to Michal Vališka on March 12, 2025, for his outstanding contributions. The award was presented by doc. Mirko Rokyta, Dean of the Faculty of Mathematics and Physics.

This recognition follows the publication of key findings in PNAS, Nature Communications, and other high-impact journals, which resulted from a fruitful collaboration between our department and the University of Cambridge. This partnership continues to yield significant scientific results, expanding the frontiers of research in unconventional superconductivity.

Michal Vališka was granted the Neuron Award for promising scientists in the field of physics

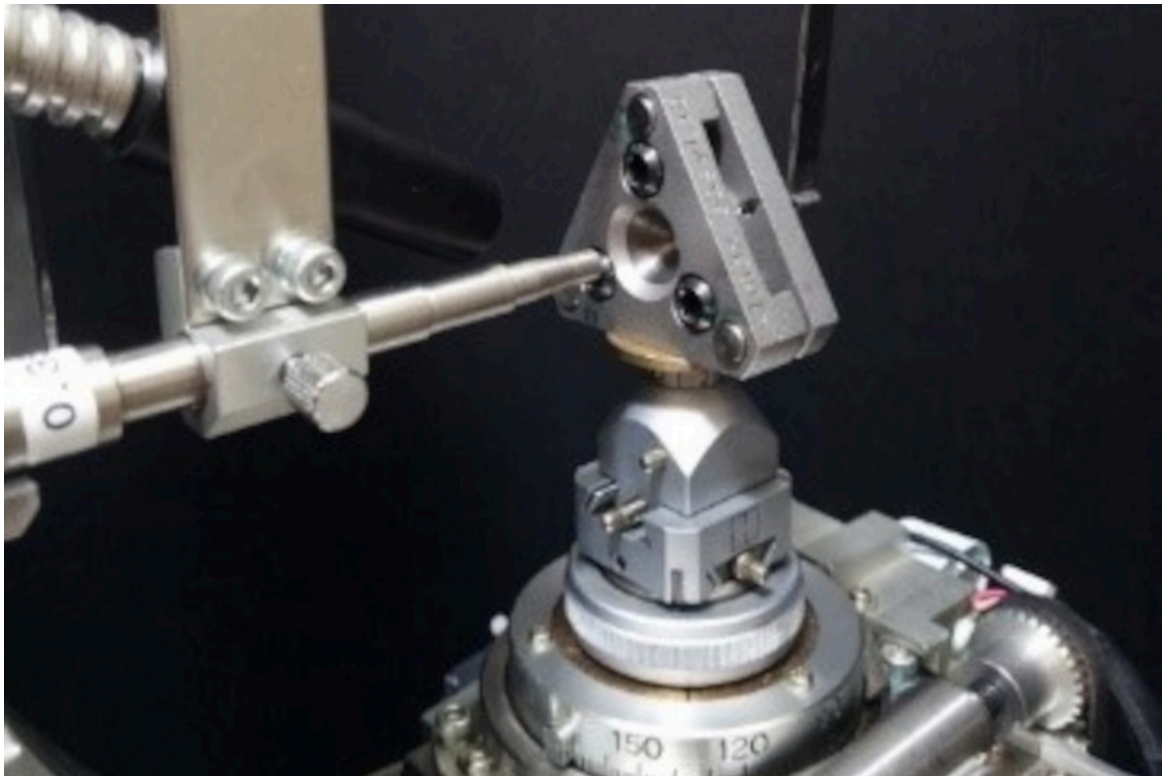
RNDr. Michal Vališka, Ph.D. member of MGML scientic staff became the laureate of the **Neuron Award** for promising scientists in the field of physics, awarded by the Neuron Foundation. He received the award at a gala evening on January 18 at the Prague Planetarium (link - in Czech only, part about MV at 49:45-57:00).

The Neuron Award in Physics is dedicated for exceptional personalities of Czech science at the beginning of their independent careers. The award reflects the scientific achievements of Michal Vališka and his team in the field of quantum materials, in particular the research of unconventional and topological superconductors based on the study of exceptionally pure single crystals.

Receiving this prestigious award represents significant recognition of the quality of research carried out at the Faculty of Mathematics and Physics of Charles University and confirms the strong position of our department in the field of physics of modern quantum materials.

Technical Development

Diamond anvil cell method successfully implemented for structural studies

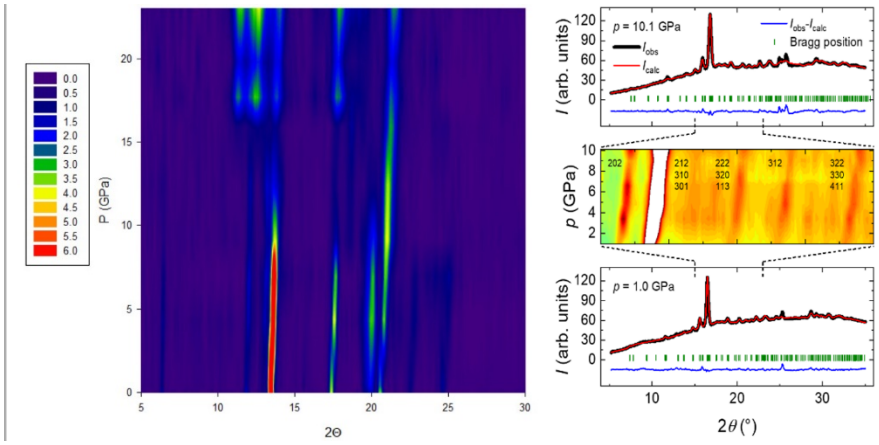


A new experimental method for measuring structural parameters under high pressure at room temperature has been successfully implemented in our laboratory. The method combines a commercial diamond anvil pressure cell (DAC) from Almax easyLab with the Rigaku Rapid II diffractometer.

The initial setup has been continuously optimized, balancing several key parameters—such as accessible sample space diameter versus beam size—to improve the quality of the collected data. The highest pressures reached so far are 23 GPa (UCu2P2) and 30 GPa (EuRu2P2), with further improvements likely possible through continued optimization and natural ageing of the pressure cell.

These developments have already contributed to multiple student projects, including a Ph.D. thesis (P. Král, 2024), a Bc. thesis (M. Jesenič, 2024), and a student faculty grant (M. Bystrický). Data from these initial experiments have been published or are currently being prepared for publication.

Despite being performed in a laboratory setting rather than at a synchrotron, the data quality is sufficient to observe the pressure dependence of lattice constants, detect pressure-induced structural transitions, and identify signs of pressure-induced valence transitions. These results have already supported successful beamtime proposals at international high-pressure facilities.



Change of crystal structure in UCu_2P_2 at 16 Gpa; xrd patter in Yb_2Pt_2Pb up to 10 GPa

Collaboration with commercial partners

Our efforts resulted in several contractual agreements, with a total turnover of 27,000 EUR. This highlights the partial economic viability of our operations while underscoring our role as a bridge between academic research and industrial application, particularly in the rapidly evolving field of pharmaceuticals.

Conferences

Annual colloquium of the Czech and Slovak Crystallographic association, **Conference Structure 2025**, Jindřichův Hradec, Czech Republic. September 8.- 12. 2025. The conference contained three courses: i) course of the program MStruct (Materials Structure analysis by powder diffraction), ii) course of program Moorhen and iii) course of the program mace-md-gui. A part of the conference was dedicated to neutron sources and neutron scattering. https://www.xray.cz/xray/csca/kol2025/

PCFES2025:
15th Prague Colloquium on f-Electron Systems, (https://pcfes.kfkl.cz), held in June 17-20, 2025 was attended by 56 (mostly foreign) participants. The PCFES is traditionally an informal forum for presentations and discussions on the current issues of magnetism, strongly correlated systems, spectroscopies, materials science, as well as progress in theory.

UAAT-ICU Workshop 2025 - International Taiwan–Czech Event on Research, Innovation, and Education https://www.kfkl.cz/cztsem/ - This workshop held in Prague during 14-17 July 2025.
This gathering marked a significant moment in the growing scientific collaboration between the Czech Republic and Taiwan - two partners united by a shared commitment to innovation, education, and the advancement of high-tech and next-generation technologies. Our partnership is built on strong foundations. Taiwan is a global leader in semiconductors and advanced electronics, while Czechia brings deep expertise in materials science, instrumentation, and condensed matter physics. Together, these complementary strengths create a powerful synergy for scientific discovery and technological innovation. The workshop was attanded 28 participants.