



**Materials Growth and Measurement Laboratory**

**ANNUAL REPORT  
2024**

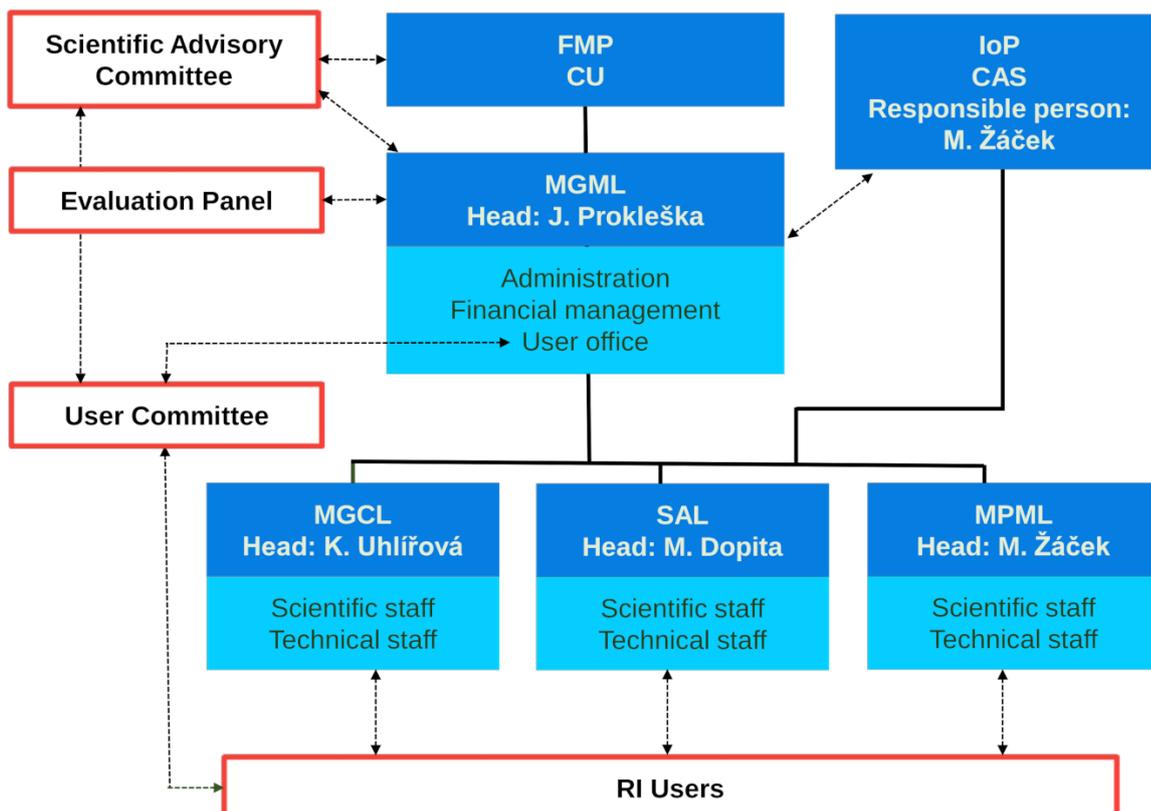
## About MGML

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 2024

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 70 user proposals under our open-access regime. These encompassed a wide range of studies, including 36 long-term research proposals, 11 standard proposals, 13 proof-of-concept proposals, and 10 test proposals.

Thanks to funding received from the Research Infrastructures I call under the [Jan Amos Komenský Operational Programme](#) (project number: CZ.02.01.01/00/23\_015/0008184), MGML will be able to renew its existing equipment and strategically develop its experimental facilities during the 2024–2026 period. This investment will enable the lab to stay at the forefront of scientific research and meet the growing demands of its user community.

The project includes the necessary expansion of frequency ranges for measuring alternating electrical and magnetic properties as well as multiferroic phenomena. Several diffractometers for detailed structural characterization will be updated, and the lab's capabilities for pressure measurements will be significantly enhanced. Furthermore, a new X-ray fluorescence spectrometer will be acquired for precise chemical analysis of prepared samples.

Collaboration with other European partner laboratories, especially within the framework of the ISABEL project (as introduced in previous 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). At the most recent ISABEL Board meeting (October 2024, Toulouse), an MGML representative participated in discussions regarding possible future projects.

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.

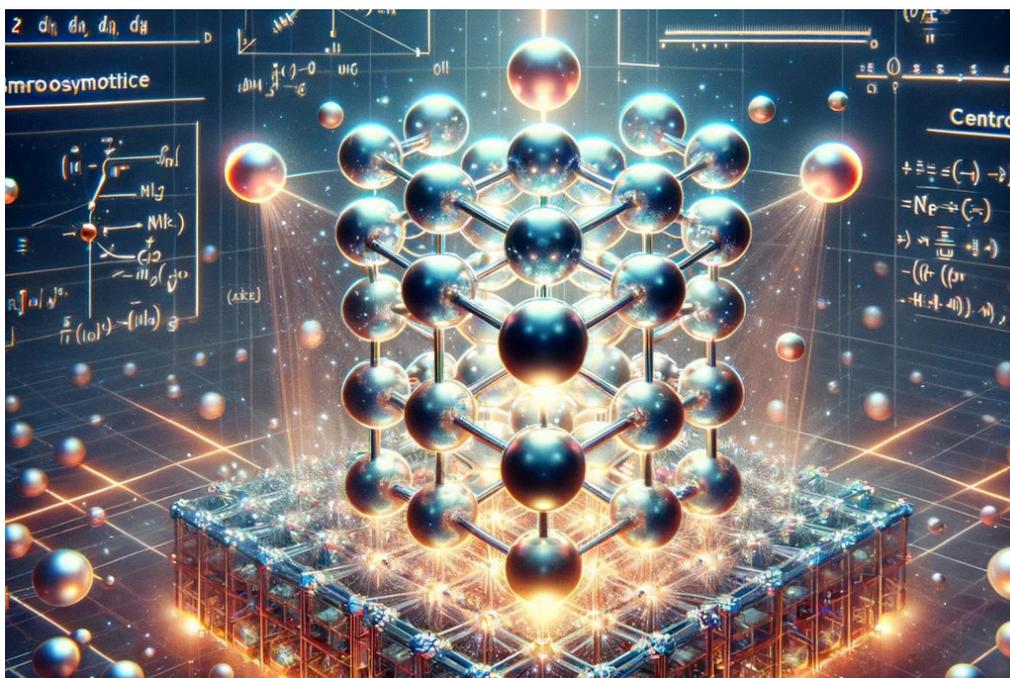
An important part of MGML's mission is to promote scientific excellence among students and co-educate the next generation of scientists, benefiting from its position within the university. Students conducting experimental work at MGML often utilize long-term proposals, allowing them access to the infrastructure's 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 Dávid Hovančík, whose achievements were highlighted in last year's report, was awarded the Milan Odehnal Prize (2nd place) for his research on two-dimensional orbital magnetism in van der Waals systems. His work has been published in high-profile journals such as Nano Letters, J. Phys. Chem. Letters, and Phys. Rev. B. Additionally, Ph.D. student Petr Král received an Honourable Mention for his study of magnetism and structure in frustrated tetragonal  $R_2T_2In$  intermetallics under pressure. He was also recognized by the Charles University Grant Agency (GAUK) Board for his project "Pressure-driven structural and magnetic transformations in 221 intermetallics," which was rated "Exceptionally good" and ranked as the third-best completed GAUK project in 2023.

MGML LRI members were heavily involved in organizing the 24th International Conference on Solid Compounds of Transition Elements and contributed to the organization of the Czech Neutron Community Meeting 2024. Both events provided opportunities to present MGML's achievements to their respective scientific communities. Additionally, MGML was represented at the EMFL Days through an invited lecture.

## Scientific Highlights

### MGML technology: securing samples for Nature's paradigm-shifting paper

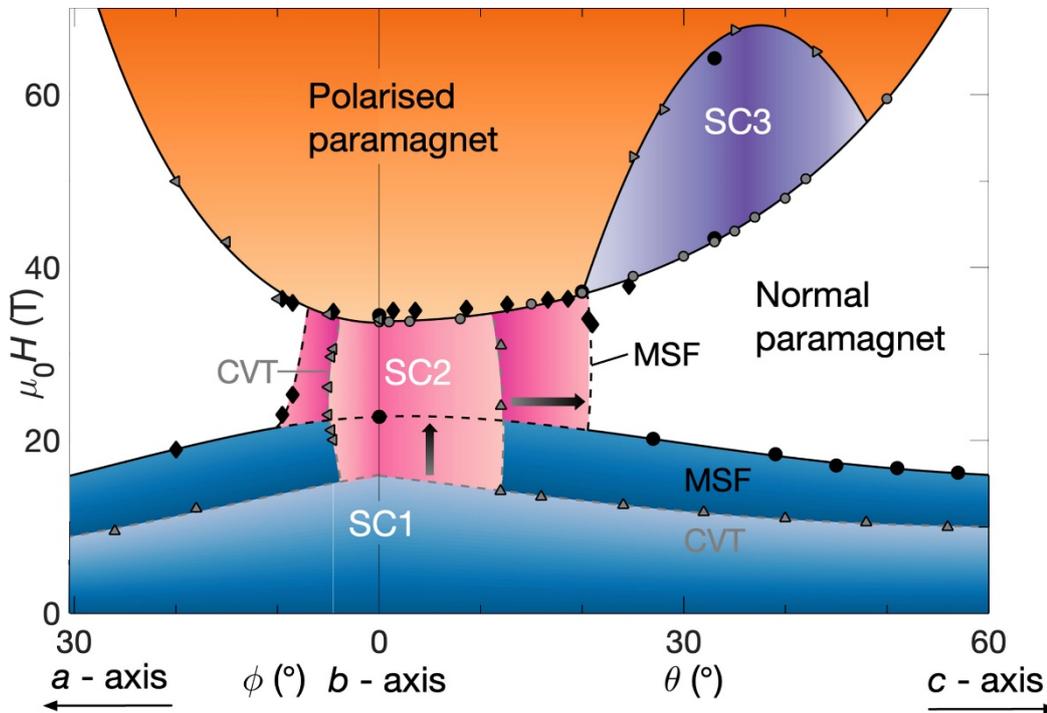


Dr. K. Uhlirova successfully prepared high-quality MnTe single crystals, a previously proposed candidate for altermagnetism. The single crystals were a cornerstone for successful spin-resolved angle-resolved photoemission spectroscopy, confirming lifted Kramer's spin degeneracy in this material.

In this paper, the authors confirm the presence of lifted Kramers spin degeneracy (LKSD) without net magnetization or inversion-symmetry breaking using photoemission spectroscopy and ab initio calculations. They identify two distinct, unconventional mechanisms of LKSD induced by the altermagnetic phase of centrosymmetric MnTe, which has no net magnetization. The study reveals that altermagnetic LKSD could significantly impact magnetism, motivating further exploration and exploitation of this

unconventional magnetic phase across a broad range of materials, including insulators, semiconductors, metals, and superconductors.<sup>1</sup>

## High-quality UTe<sub>2</sub> single crystals pave the way for breakthrough PNAS study



The unconventional superconductor UTe<sub>2</sub> exhibits numerous signatures of spin-triplet superconductivity—a rare state of matter that could enable quantum computation protected against decoherence. UTe<sub>2</sub> possesses a complex phase landscape, including two magnetic field-induced superconducting phases, a metamagnetic transition to a field-polarized state, and both pair-density and charge-density wave orders.

A recent paper published in [Proceedings of the National Academy of Sciences](#) reveals a significantly revised high magnetic field superconducting phase diagram in the ultraclean limit of single crystals. The study demonstrates a pronounced sensitivity of field-induced superconductivity to the presence of crystalline disorder. A theoretical model developed to describe the experimental results shows how critical magnetic fluctuations in high magnetic fields may drive a transition between two distinct spin-triplet superconducting phases in UTe<sub>2</sub>.

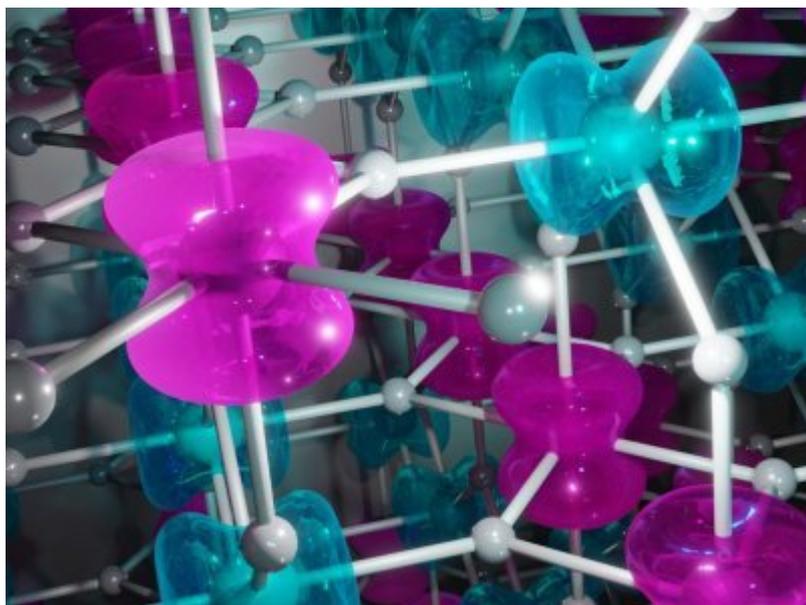
The high quality single crystals of UTe<sub>2</sub> for this study were prepared by Dr. M. Vališka's team at MGML using the molten salt flux (MSF) technique. The team used high-purity uranium metal, further refined

<sup>1</sup> Ref: J. Krempaský, L. Šmejkal, S. W. D'Souza, M. Hajlaoui, G. Springholz, K. Uhlířová, F. Alarab, P. C. Constantinou, V. Strocov, D. Usanov, W. R. Pudelfko, R. González-Hernández, A. Birk Hellenes, Z. Jansa, H. Reichlová, Z. Šobáň, R. D. Gonzalez Betancourt, P. Wadley, J. Sinova, D. Kriegner, J. Minár, J. H. Dil & T. Jungwirth, *Altermagnetic lifting of Kramers spin degeneracy*, **Nature** 626, pages 517–522 (2024).  
doi: [10.1038/s41586-023-06907-7](https://doi.org/10.1038/s41586-023-06907-7)

through the solid-state electrotransport technique available in the MGML infrastructure. The pristine quality of the resulting single crystals is evidenced by their high critical temperature ( $T_c$ ) values of up to 2.10 K, low residual resistivity down to  $0.48 \mu\Omega\cdot\text{cm}$ , and the observation of magnetic quantum oscillations.

This large-scale collaboration benefited from dual access via the [ISABEL](#) project.<sup>2</sup>

## Unveiling Altermagnets: Experimental Evidence and Spin-Symmetry Characteristics



*Altermagnetic ordering of the electronic density of states in MnTe.*

Since 2020, a new branch of magnetic materials, *altermagnets*, has been theoretically identified, in addition to the conventional ferromagnets and antiferromagnets. The exclusively distinct spin-symmetry characteristics of altermagnets are the opposite-spin sublattices connected by a real-space rotation, but not connected by a translation or [inversion](#). Such symmetry has unconventional physical consequences.

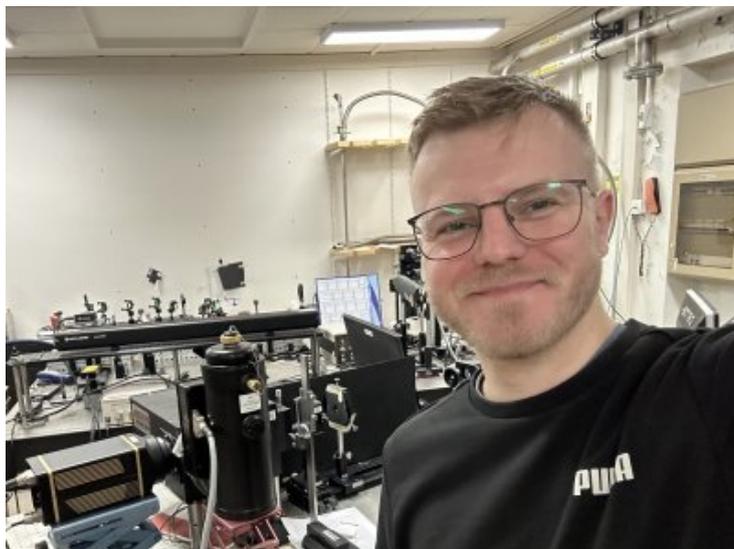
***Our colleague K. Uhlirova successfully prepared high-quality MnTe single crystals, a previously proposed candidate for altermagnetism.*** This work is the first experimental evidence of the unconventional nature and existence of altermagnets. The authors confirm the presence of lifted Kramers spin degeneracy (LKSD) without net magnetization or inversion symmetry breaking using angle-resolved photoemission spectroscopy (ARPES) and show the spin-resolved ARPES supported by *ab initio* electronic-structure calculations. Consistently with the strong LKSD, spin-resolved ARPES shows the alternating sign of the spin-polarization component along the Néel vector.

---

<sup>2</sup> Ref: Z. Wu, T. I. Weinberger, J. Chen, A. Cabala, D. V. Chichinadze, D. Shaffer, J. Pospíšil, J. Prokleška, T. Haidamak, G. Bastien, V. Sechovský, A. J. Hickey, M. J. Mancera-Ugarte, S. Benjamin, D. E. Graf, Y. Skourski, G. G. Lonzarich, M. Vališka, F. M. Grosche, and A. G. Eaton, *Enhanced triplet superconductivity in next-generation ultraclean  $UTe_2$* , **Proceedings of the National Academy of Sciences** 121 (2024) e2403067121. doi: [10.1073/pnas.2403067121](https://doi.org/10.1073/pnas.2403067121)  
Supported by [GACR](#) project [22-22322S](#), [ISABEL](#) and MGML.

## Student achievements in MGML

Our students were awarded the Milan Odehnal Prize



*Dávid Hovančík*

Ph.D. student **Dávid Hovančík** was awarded the Milan Odehnal Prize (2nd place) for his contribution to the investigating two-dimensional orbital magnetism in van der Waals systems. Dávid succeeded in the competition with his work published in *Nano Letters*, *J. Phys. Chem. Letters*, and *Phys. Rev. B*.

The main outcome of David's research studies is discovering a large unquenched orbital moment of vanadium 3d states in VI<sub>3</sub>. This van der Waals material represents a 2D honeycomb magnetic lattice analogous to a graphene electronic lattice. The unfrozen orbital degree of freedom in VI<sub>3</sub> originates from a special electron occupation V<sup>3+</sup> (3d<sup>2</sup>) in combination with proper crystal field symmetry and spin-orbit coupling, as described in the publications. Apriori, its presence results in strong entanglement of the spin-orbit many-body wave function. Due to that, VI<sub>3</sub> exhibits a strong magneto-crystalline anisotropy, significant magneto-elastic coupling, and THz energy range magnons usually observed only in antiferromagnets. In addition, David's research scope has included, yet, another material VBr<sub>3</sub>, which shows Ising-like antiferromagnetism with out-of-plane magnetic moments and the unique tricriticality in metamagnetic phase diagram. The results on this subject were published in the PRB paper receiving "*PRB Editors' suggestion*", as announced in Annual Report 2023.

Honorable Mention was in addition given to our another colleague, Ph.D. **Petr Král** for his study of magnetism and structure in frustrated tetragonal R<sub>2</sub>T<sub>2</sub>In intermetallics with application of pressure.

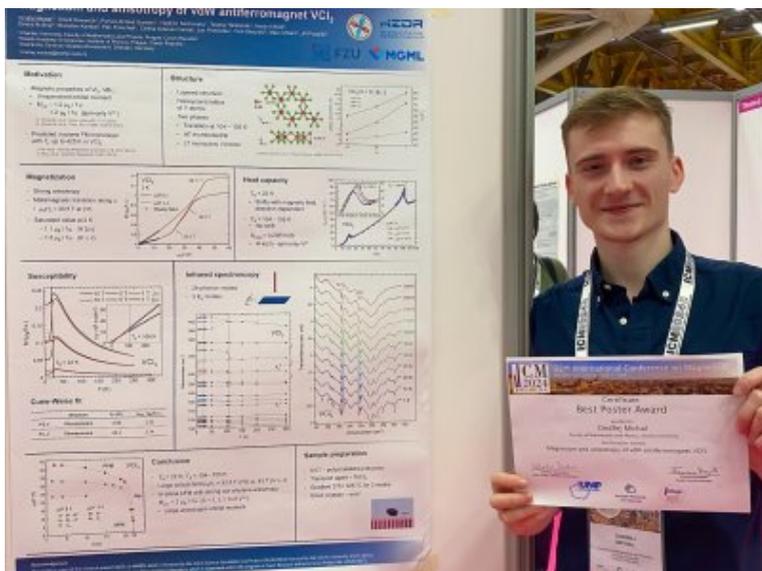
The Milan Odehnal Prize is awarded by the Czech Physical Society every two years to young authors of scientific papers from the field of physics for their exceptional contribution to their branch of physics. Dávid and Petr joined our colleagues who successfully represented our faculty and our department in this competition in the past (M.Vališka in 2018, M.Kratochvílová in 2016, J.Kaštil in 2014, J.Rusz in 2006, J.Vejpravová in 2004).

## Our colleague Petr Král awarded by the GAUK Board



Petr Král was also recognized by the Charles University Grant Agency (GAUK) Board for his project “Pressure-driven structural and magnetic transformations in 221 intermetallics,” which was rated “Exceptionally good” and moreover obtained a Honorable mention after his work has been evaluated as the third best solved project among the GAUK projects completed in 2023.

## Best Poster prize for Ondřej Michal

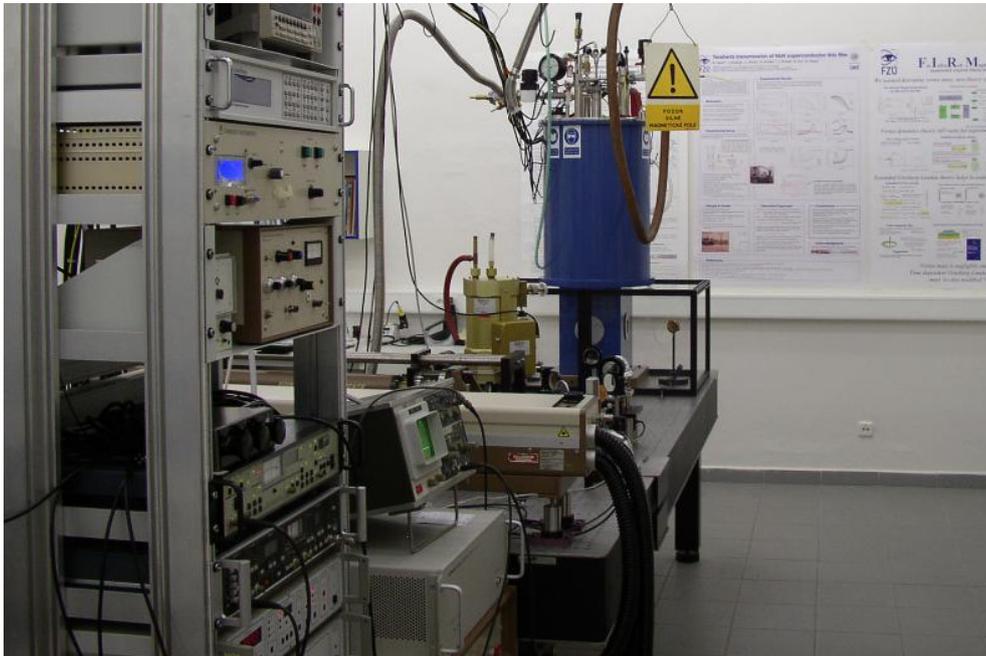


Ondřej Michal, our Mgr. student, was awarded the Best Poster Award at the 22nd International Conference on Magnetism in Bologna for his poster titled “Magnetism and anisotropy of vdW antiferromagnet VCl<sub>3</sub>”.

In his poster, Ondřej presented the results of recent bulk measurements conducted on VCl<sub>3</sub>, a member of the vanadium-based trihalides family. Other materials in this group, namely VBr<sub>3</sub> and VI<sub>3</sub>, exhibit an unquenched orbital moment due to the crystal field effect on the magnetic-moment-bearing V<sup>3+</sup> ions. This unquenched orbital moment leads, among other things, to high magnetocrystalline anisotropy. The results presented support similar behavior in VCl<sub>3</sub> but also highlight differences, such as its in-plane antiferromagnetic structure with out-of-plane anisotropy.

## Technical Development

### Far-infrared magnetospectroscopy



[The Far-Infrared Magnetospectroscopy](#) system is equipped with an optically pumped THz gas laser, a cryomagnetic cryostat, and a bolometer. This unique experimental setup enables the measurement of optical properties of materials in the far-infrared region at temperatures as low as 3 K and magnetic fields up to 11 tesla.

## Collaboration with commercial partners

Our efforts resulted in several contractual agreements, with a total turnover of 25,000 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

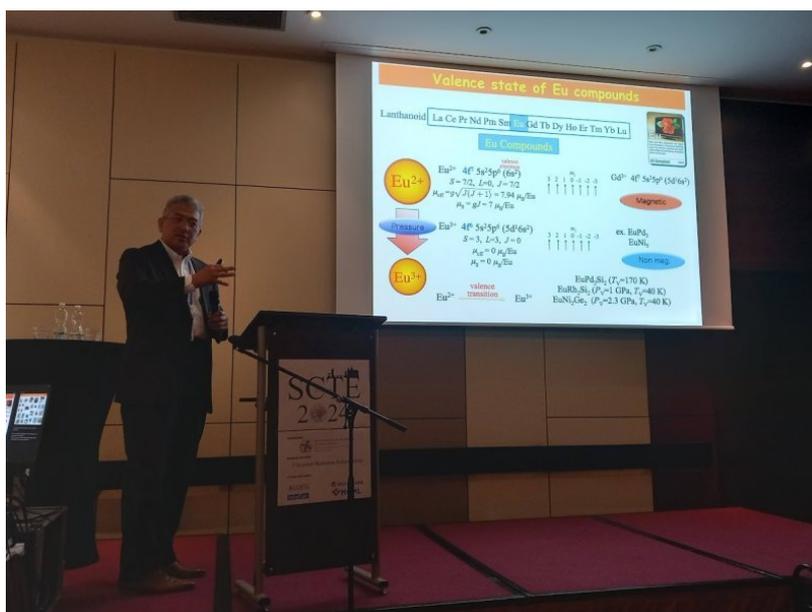


**The 24th International Conference on Solid Compounds of Transition Elements (SCTE24).** The conference took place from June 17 to June 21, 2024, at the Hotel Duo in Prague. Dr. Ross H. Colman is honored to serve as the conference chair.

The SCTE conferences, held biennially, are a premier forum for discussing the latest advancements in the chemistry and solid-state physics of compounds and materials based on *d* and *f* electron elements. Key topics include crystal structure, chemical bonding, and the diverse physical properties of intermetallics and their derivatives such as hydrides, borides, carbides, silicides, pnictides, chalcogenides, oxides, and halides.

This year's conference continues a tradition of excellence, following successful meetings in Bordeaux (2022), Wrocław (2020 and 2021), Vienna (2018), Zaragoza (2016), Genoa (2014), Lisbon (2012), Annecy (2010), Dresden (2008), and Krakow (2006).

We anticipate the participation of over 100 experts from Europe, Asia, and beyond. For more details, visit the official [conference website](#).





**The 11th European Conference on Residual Stresses** was held for the first time in the Czech Republic. Residual stresses, which arise in materials during manufacturing and subsequent processes, can exert either positive or negative effects on products. Understanding these stresses in both bulk materials and thin films is crucial. Effective management of residual stresses can lead to enhanced material and structural properties, including improved fatigue life and geometric stability. The analysis and targeted control of residual stresses, a parameter highly sensitive to micro/nano-structural changes, offers valuable insights into the history of materials and the relationship between their microstructure and properties. Primary method of determination of residual stresses is X-ray or neutron diffraction measuring the dependence of interplanar spacing of atoms on their inclination with respect to the sample surface.

About 200 experts in the field from European and Asian countries should meet at the conference. We also have a record number of 15 sponsors and exhibitors. More <https://www.xray.cz/ecrs11/>



Annual colloquium of the Czech and Slovak Crystallographic association, **Conference Structure 2024**, Loučná nad Desnou, Czech Republic. November 18.- 22. 2024. The event contained the 16th exhibition of student's works and course of Computational Crystallography Toolbox - CCTBX.

<https://xray.cz/xray/csca/kol2024/>