

Masaryk University	Faculty of Science
Faculty	Faculty of Science
Procedure field	Condensed Matter Physics
Applicant	Mgr. Ondřej Čaha, Ph.D.
Applicant's home unit, institution	Faculty of Science, Masaryk University
Habilitation thesis	Thin films of topological insulators
<u>Board members</u>	
Chair	prof. Mgr. Dominik Munzar, Dr. <i>Faculty of Science, Masaryk University</i>
Members	prof. Mgr. Tomáš Kruml, CSc. <i>Institute of Physics of Materials of the Czech Academy of Sciences</i> prof. Ing. Eduard Hulicius, CSc. <i>Institute of Physics of the Czech Academy of Sciences</i> prof. RNDr. Jana Kalbáčová Vejpravová, Ph.D. <i>Department of Condensed Matter Physics, Faculty of Mathematics and Physics, Charles University</i> Prof. Dr. hab. Dariusz Kaczorowski <i>Institute of Low Temperature and Structure Research, Polish Academy of Sciences, Wrocław, Poland</i>

Evaluation of the applicant's scholarly/artistic qualifications

Ondřej Čaha received his Master's degree in physics from Masaryk University (MU) in 2002, his thesis was focused on small-angle x-ray scattering on self-organized quantum dots.

After completing his Master's degree, Čaha continued studying Physics at MU, under the supervision of professor Václav Holý, and in 2007, he defended his PhD thesis entitled "Lateral composition modulation in InAs/AIAs superlattices". During his PhD studies, Čaha stayed for two semesters at the University of Houston, where he worked in the team of professor Bassler, particularly on continuum simulations of self-organized growth of short-period semiconductor superlattices. This has resulted in two joint publications in the Physical Review Letters. In 2005-2021 Čaha worked as a researcher at the Department of Condensed Matter Physics (DCPM), Faculty of Science, MU, in 2011-2020 also at CEITEC MU, in 2019-2022 also at the Institute of Physics of the Czech Academy of Sciences. Since 2021, Čaha has been an assistant professor at DCPM. He is an enthusiastic experimental condensed matter physicist, an expert in X-ray structural analysis of bulk samples, thin films, multilayers, nanostructures, including defects in crystals, with considerable experience with many other experimental techniques (X-ray absorption spectroscopy, electron microscopy, ARPES, transport measurements etc.) and also with numerical simulations. Čaha contributed to studies of different classes of materials: semiconductor nanostructures, bulk semiconductors (in particular oxygen precipitates in silicon, more recently wide band gap semiconductors), transition metal oxides and their heterostructures, magnetic materials (e.g., FeRh) etc.

In 2012, Čaha began to collaborate with Springholz's group at JKU Linz in the field of topological insulators, and the latter field soon became his main area of research. So far, the collaboration has led to 19 research papers, many of them published in very high impact journals: 1 in Nature, 3 in Advanced Materials with IF of 29, 3 in Nature Communications, and 1 in Advanced Functional Materials with IF of 19. Čaha is the first author of the first paper of the series published in Crystal Growth and Design in 2013 and one of the four main authors of the Nature paper, and his contributions to other joint papers are also considered to be essential. Gunther Springholz argues in his recommendation letter that "in all these publications, Ondřej Čaha made significant contributions without which these articles could not have been published." In particular, Čaha contributed to the clarification of several unique properties of V-VI compound topological insulators, such as a self-organization of Mn dopants in Bi₂Te₃ that gives rise to the formation of the magnetic energy gap reported in the Nature paper.

Čaha is also active in applied research in collaboration with the main industrial partner of DPCM – Onsemi. Recent joint research projects focus on structural and electronic properties of wide band gap semiconductors, in particular SiC.

Čaha has authored or co-authored 85 publications listed in the WOS database that have been cited – as of March 16th 2024 – 1187 times (1120 times without direct self-citations). He has been the principal investigator of 5 research projects in collaboration with Onsemi (4 TAČR, 1 OP PIK), and he leads one work package of the OP JAK project Quantum materials for applications in sustainable technologies.

Conclusion: The applicant's scholarly/artistic capabilities **meet** the requirements expected of applicants participating in a habilitation appointment procedure in the field of Condensed Matter Physics.

Evaluation of the applicant's pedagogical experience

Ondřej Čaha has been involved in teaching at the Faculty of Science, MU since 2006. He was responsible for the class exercises of the basic physics course Oscillations, waves, optics (2006-2010) and for class exercises of several solid-state physics courses (in all cases for several years). He has been teaching three physics laboratory courses: Physics Laboratory 2 (standard course for 2nd-year bachelor students), Physics Laboratory 4 (relatively new course for 3rd-year bachelor students, involving solutions of complex experimental projects - 3 per semester), Solid State Physics Laboratory (course for 3rd-year bachelor students), and advanced laboratory courses for students

of Condensed Matter Physics. From 2011 to 2022, he taught the course Physical Properties of Materials prepared for Master's students of Physical Engineering and Nanotechnology (study programme of Brno University of Technology). The course includes lectures (2 hours per week) and class exercises (2 hours per week). Since 2011, Caha has taught specialized condensed matter physics courses: X-ray structural analysis of thin films, Modern experimental methods, and Structural analysis methods in condensed matter physics.

Caha supervised eight Bachelor's theses (all successfully defended) and five Master's theses (all successfully defended), and at the moment, he supervises one doctoral candidate.

Conclusion: The applicant's pedagogical capabilities **meet** the requirements expected of applicants participating in a habilitation appointment procedure in the field of Condensed Matter Physics.

Habilitation thesis evaluation

Caha's habilitation thesis entitled "Thin films of topological insulators" is based on Caha's papers addressing (i) properties of Bi_2Te_3 , Bi_2Se_3 and $\text{Bi}_2(\text{S}_{1-x}\text{Te}_x)_3$ topological insulator thin films, (ii) magnetically doped topological insulators, and (iii) properties of Bi-doped topological crystalline insulators $(\text{Pb},\text{Sn})\text{Se}$ and $(\text{Pb},\text{Sn})\text{Te}$. The thesis consists of an introduction into the physics of topological insulators (chapter 2), a brief description of experimental techniques used by the applicant (chapter 3) and nine reprinted papers. The thesis has been reviewed by three experienced scientists: Professor Ulrich Pietsch (University of Siegen, Germany), Professor Tomasz Story (Institute of Physics, Polish Academy of Sciences, Warsaw, Poland) and Dr. Martin Veis (Faculty of Mathematics and Physics, Charles University). All reviewers conclude that the habilitation thesis fulfils the requirements expected of a habilitation thesis in the field of Condensed Matter Physics. In their reports they stress the top quality of Caha's results.

Professor Story appraises the applicant as follows:

"Candidate proved his status of a world-class specialist in developing and application of various X-ray diffraction and spectroscopy experimental tools to study new electronic materials, in both the form of bulk crystals and epitaxial thin films. Importantly, it was done in very close collaboration with leading European laboratories in the field: Johannes Kepler University in Linz (Professors Gunther Bauer and Gunther Springholz) and Helmholtz Zentrum Berlin (Professor Oliver Rader). It provided O. Caha regular access to new materials and advanced synchrotron experimental techniques and resulted in important scientific observations identifying the real space arrangement of constituent atoms in topological films. For several topological layered heterostructures, in particular magnetic ones, it constituted an important step towards understanding the electronic properties of these new electronic materials."

Dr. Veis describes the role played by Caha in the research teams as follows:

"Although it might look that the experimental methods which applicant used are just common characterization tools without no real impact on the discussion of topological properties of materials, this is not the case. Proper analysis of structural order is absolutely crucial for correct discussion of the experimental results from subsequent experiments. This makes applicant's contributions extremely valuable. The quality, originality of the results, and the level of their comprehensive analysis and discussion reflects to the applicant's ability to contribute to cutting-edge scientific research in the field of condensed matter physics."

The reports contain questions, eight in total. Caha responded to all of them and the reviewers confirmed that they considered his response satisfactory. One question raised by professor Pietsch, concerning Caha's contributions to the publications, should be addressed in this report. Pietsch argues "It is obvious that the publication record is a result of a strong collaboration and intense discussion among collaborators. However, considering the aim of a habilitation thesis it would be important to know by which ideas or particular new experimental solutions the candidate did contribute to the final achievement beyond the x-ray service." In his response, Caha stresses that he participated in the research focused on topological insulators since the beginning: "I participated in the research from the beginning together with Prof. Gunther Springholz, prof. Günther Bauer, prof. Václav Holý and prof. Oliver Rader. The experiments' planning, design, evaluation, interpretation, and manuscript planning were joint work over more than ten years. A lot of this work was made during joint discussions, and I cannot honestly remember which of the ideas were mine." Professor Springholz confirms, in his recommendation letter cited above, that Caha's contributions were indeed essential, and the role of Caha in the team has also been highlighted in the other two reports.

Conclusion: The applicant's habilitation thesis **meets** the requirements expected of habilitation theses in the field of Condensed Matter Physics.

Secret vote results

Voting took place: electronically

Number of board members		5
Number of votes cast		5
of which	in favour	5
	against	0

Board decision

Based on the outcome of the secret vote and following an evaluation of the applicant's scholarly or artistic qualifications, pedagogical experience and habilitation thesis, the board hereby submits a proposal to the Scientific Board of the Faculty of Science of Masaryk University to **appoint the applicant associate professor** of Condensed Matter Physics.

In Brno on 22.03.2024

prof. Mgr. Dominik Munzar, Dr.