Brno University of Technology
Central European Institute of Technology BUT

Supervisor's report

Academic year: **2023/2024**

Student: **Ing. Jana Dubnická Midlíková**

Doctoral programme: **Advanced materials and nanosciences**

Field of study**: Advanced nanotechnolgies and microtechnogies**

Supervisor: **doc. Dr. Ing. Petr Neugebauer, Ph.D.**

Co-Supervisor: **doc. Mgr. Adam Dubroka, Ph.D.**

Title of doctoral thesis**: Development of Fourier Transform InfraRed Spectroscopy in High Magnetic Fields**

Overall evaluation of the doctoral thesis and study period of the doctoral student:

The research in PhD studies of Jana Dubnická Midlíková was dedicated to developing a Fourier Transform Infrared (FTIR) magneto-spectroscopic setup operating in the range of 50–10,000cm^{-1}, high magnetic field up to 16 T and temperatures between 2–320 K located at the Central European Institute of Technology (CEITEC) Brno University of Technology (BUT). This setup allows for various magneto-optical measurements spanning the range from THz/far-infrared (FIR) to near-infrared (NIR). FTIR magneto-spectroscopy is a powerful spectroscopic technique that investigates many essential effects in materials, e.g., electron paramagnetic resonance, cyclotron resonance, and transitions between Landau levels. This dissertation describes in detail the design and successful implementation of a versatile FTIR magneto-spectroscopic setup and the proof-of-concept magneto-optical measurements of cobalt(II)-based single ion magnet, germanium, and graphene. The thesis is divided into four chapters, besides the Introduction, Aims of Thesis, and the Conclusion parts. The 'Introduction' chapter explains the motivation of the dissertation thesis, and Aims of Thesis states the three main aims of the thesis. The first numbered chapter 'Theoretical background' provides a theoretical framework for understanding the key concepts and phenomena that underpin our research topic, i.e., electromagnetic radiation, electromagnetic spectrum, IR spectroscopy, and FTIR spectrometer, and high magnetic fields. The second 'FTIR magneto-spectroscopy' chapter introduces the core technique of the thesis and explains the physical principles of electron paramagnetic resonance (EPR) and transitions between Landau Levels (LLs). It describes in detail the most relevant classes of materials for our research, i.e., SMMs and 2-dimensional (2D) materials. It also provides an overview of several state-of-the-art magneto-optical setups. The third chapter, "Experimental Setup," is dedicated to the design and implementation of the home-build FTIR magneto-spectroscopic setup at CEITEC BUT. It consists of sections about Beam propagation, Setup Design and Components, Methods, Testing of the setup, and Performance of the setup. The fourth chapter of the thesis, entitled "Magneto-Optical Measurements," provides results of magneto-optical measurements. The first section is devoted to data analysis and manipulation. The second section, Measurements at GHMFL, reviews the published

results of the measurements performed on the IR magneto-spectroscopic setup at Grenoble High Magnetic Field Laboratory. The third section, Measurements at CEITEC, reviews results obtained from o FTIR magneto-spectroscopic setup. These results include the magneto-optical measurements by which the functionality of the setup was demonstrated, i.e., the ZFS in cobalt(II)-based single ion magnet in the FIR region, indirect inter-band transitions between LLs in germanium in the NIR region, and inter-band transitions between LLs in graphene in the FIR region. The last chapter is 'Conclusion and Outlook', where the summary of the thesis is stated; the fulfilled tasks are described in details, and the outlook for the future developments of the FTIR magneto-spectroscopic setup are discussed. Additional sections of the thesis include 'References', a list of abbreviations, and her publications and output records. The thesis is written on 157 pages.

The PhD thesis is well structured and, overall, well written with minor comments/mistypes. While working on the design and implementation of the FTIR magneto-spectroscopic setup, she efficiently cooperated with other members of the research group and the CEITEC employees. In the first year of her PhD studies, Jana was awarded by the prestigious Brno PhD Talent 2018 scholarship. During her studies, she attended several conferences and summer schools, and she was awarded the Outstanding Poster Presentation Prize at the International Conference on Magnetic Materials (ICMM2021) in Manchester (UK). Jana had two one-month research stays in other scientific groups with a focus on the FTIR magneto-spectroscopy, namely, in Grenoble High Magnetic Field Laboratory in France (group of Dr. Milan Orlita), and Georgetown University in Washington DC in USA (group of Prof. Paola Barbara). She also taught for four semesters at the Faculty of Mechanical Engineering of BUT. She actively participated in organizing the 8th EFEPR School on advanced EPR techniques in 20219 and in numerous events for science popularisation (researchers' nights). During her Ph.D. studies, Jana considerably improved her skills in experimental science, communication, and the English language. Furthermore, she has proven to plan and execute experiments of high complexity, analyse the obtained results, and present them not only to knowledgeable professionals but to a broader audience as well. Moreover, Jana is capable of writing scientific publications with minimal guidance. Some of her ideas had not been implemented, but they can be a good starting point for future Master's and PhD students of our group.

In our opinion, the reviewed thesis **fulfils** all requirements posed on theses aimed at obtaining PhD degree. This thesis **is** ready to be defended orally, in front of the respective committee.

Brno, date:14/11/2023

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doc. Dr. Ing. Petr Neugebauer, Ph.D.

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doc. Mgr. Adam Dubroka, Ph.D.