Assessment of the PhD thesis

Magnetoelectric multiferroics: From static via dynamic magnetoelectric effect to nonlinear light-matter interaction

written by Ing. Jakub Vít

I know Jakub Vít since 2012. I supervised his bachelor's and diploma thesis, which he finished in 2013 and 2015, respectively. Both theses dealt with research of multiferroics with various hexaferrite crystal structures. In 2015, I offered Jakub to continue his PhD work with me, but he is very ambitious and therefore wanted to try different research in a different group. That is why he chose PhD studies under dual supervision and started working in the Hungarian group of Dr. Bordács as well. This method of PhD study proved to be more demanding, but at the same time more beneficial for the student. He could use not only our experimental equipment in Prague, but also in Budapest as well as in collaborating groups in Tallinn, Dresden and Trieste. During his studies, he obtained a large amount of data, but not all results have been published yet, because he tried to interpret some results with his own theory and also tried to publish in journals with high-impact factors (e.g. PRL), which is of course more complicated. This is responsible for the delay of the dissertation. On the other hand, a longer and higher-quality dissertation than a classic Czech dissertation emerged.

The thesis has the following structure: After a short motivation he wrote a theoretical chapter, where he summarized our current knowledge about static and dynamic magnetoelectric coupling. This chapter is very well written and will be used by my students for their future studies.

Second chapter briefly describes used experimental methods and techniques. The third chapter deals with studies of directional dichroism in far-infrared spectra of multiferroic $Ba_2CoGe_2O_7$. In this case, Jakub was able to control THz absorption not only using external magnetic field, but also using external electric field. This was very unique observation and therefore it was published in Phys. Rev. Lett.

Fourth chapter describes results of investigation of static and mainly dynamic magnetoelectric coupling in Y-type $BaSrCoZnFe_{11}AlO_{22}$ and Z-type $(Ba_xSr_{1-x})_3Co_2Fe_{24}O_{41}$ hexaferrites. Suppression of electromagnon absorption using magnetic field was observed due to field-induced magnetic phase transitions. The electromagnons were observed also in Raman spectra and their activities in both THz and Raman spectra were analyzed from symmetry point of view. Moreover, Jakub analytically calculated infrared activities of electromagnons in six magnetic structures of the Y-type hexaferrite.

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The fifth chapter deals with studies of possible nonlinear THz absorption by electromagnons in Y-type and Z-type hexaferrite. For that purpose, intensive THz beams generated by free-electron lasers were used. The measurements were performed at large scale facilities in Trieste (TeraFERMI lab) and in Rossendorf near Dresden (TELBE beamline). Unfortunately, the changes of electromagnon absorption in dependence on fluence of THz beam, which were observed in Z-type hexaferrite, were not caused by the nonlinear absorption, but by heating of the sample using THz radiation. Nevertheless, in Y-type hexaferrite some hints of nonlinear absorption were observed. Jakub spent a lot of time with theory development explaining, why the nonlinear absorption was not observed and which conditions must be met to see the nonlinear absorption. Some details of the theory are presented in Appendix (i.e. in the seventh chapter).

The last chapter is devoted to investigation of linear magnetoelectric $LiCoPO_4$. It was demonstrated that dynamic magnetoelectric effect (in THz region) can be used for identification of various antiferromagnetic domains (published in PRL). Since the opposite domains have opposite sign of the ME tensor (manifested by different THz absorption from opposite domains), Jakub tried to use this effect for THz writing and THz reading of antiferromagnetic domains. Strong THz pulses were required, so Jakub used FELBE beamline in Rossendorf near Dresden. Although Jakub observed some THz poling effect, he could select only one of the antiferromagnetic domains, and he related his observations to the temperature gradient on the sample. Data are still analyzed and will be subject of a future publication.

What I appreciate about Jakub is that he is never satisfied with a superficial knowledge of the issue, but that he always tries to fully understand the given problem, or searches for answers in the literature. He also spent a lot of time with his own theoretical interpretation of the measured results. PhD thesis is well written, results were published in journals with mostly high impact factors. In recent years, Jakub has demonstrated the ability to do independent and creative scientific work, and therefore I propose to award him a Ph.D.

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