Review

of the PhD thesis of

Felix Ludwig Schilberth

Magneto–Optical Effects from Band Topology in Kagome Magnets

The candidate investigates the magneto-optical response of kagome magnets in his thesis using experimental techniques. In conjunction with first-principles calculations, these measurements enable extracting information about the topological properties of the electronic band structure. Studies of topological phenomena have rapidly expanded over the last decades, and continue to attract great attention in various branches of contemporary condensed-matter physics. Despite its good frequency resolution and its applicability in high external magnetic fields, magneto-optical spectroscopy has seen limited application in the investigations of the electronic band topology so far. The focus of the thesis is on demonstrating the capabilities of this experimental method in this field.

The thesis is very well structured. The candidate discusses the motivations for the work, includes a detailed theoretical description of various topological phenomena in the electronic band structure, and connects these to the experimental observables. The experimental methods and setups are discussed in great detail; a remarkably high number of these devices was commissioned, rebuilt or designed by the applicant during his PhD. The results are distributed over four chapters, each of them corresponding to a separate publication or manuscript and a thesis statement. The summary at the end of each chapter is followed by a discussion of the remaining open questions, such as measurements in the presence of external magnetic field or in non-collinear spin structures, which directly ties in to the next chapter where these challenges are tackled. The main text of the thesis ends with a detailed summary of the results and the list of thesis statements.

The thesis is formulated in English, and it is exceptionally well written. The figures are of excellent quality, with many of them also appearing in the published papers or submitted manuscripts of the author. The text is very well structured, including a logical chapter structure and the main concepts being additionally highlighted at the sides of the pages. The notations in the equations and the figures are clearly explained, the discussions are detailed and easy to follow. The conclusions are well supported by the data. The candidate clearly separates his own results from those obtained by international theoretical or experimental collaborators.

Two papers connected to the thesis statements have already been published in Physical Review B, an additional manuscript is available as a preprint, while a fourth one is in preparation. The candidate is first author in all of these works. Therefore, the candidate fulfils the PhD requirements set by the Doctoral School of Physics. The candidate contributed to two further published papers not connected to the thesis statements.

I have the following questions concerning the thesis:

1. On page 10 in chapter 1.2.1, the author explains the role of the phase ϕ appearing in the tight-binding model in equation (1.17) as "[ϕ] encodes the vector potential induced by the three local moments via their scalar spin chirality". Could the author elaborate on what the scalar spin chirality is and how this vector potential looks like in a continuum Hamiltonian?
2. In chapters 3-5, the momentum-resolved topological properties or the role of interband transitions are deduced exclusively from the theoretical calculations, since the

experiments do not provide direct access to these quantities. The connection between experiment and theory is established based on the comparison between the optical conductivities (figures 3.3, 3.5, 4.3 and 5.3), but these data also contain visible differences beyond the discussed similarities. How robust are the conclusions drawn from the theory? For example, would it be possible that a spectrum which does not contain nodal lines could also reproduce the measured conductivities to the same accuracy as the results presented in chapter 3?

3. On page 55 of chapter 4.3, it is mentioned that certain interorbital matrix elements of the spin–orbit coupling prefer easy-plane or easy-axis magnetocrystalline anisotropy. Is there a general principle to deduce which matrix elements prefer which orientation? From the examples, it appears to be more complicated than in-plane (xy, x^2-y^2) orbitals preferring easy-plane alignment. Do the expectation values inside a single orbital not play a role in the preferred magnetic orientation?
4. On page 60 in chapter 5.2, it is written in the description of Fig. 5.3 that "Due to the Kramers–Kronig relationship, the derivative shape of these features [in Im σ_{xy}] appears in Re σ_{xy}." This explanation is not perfectly clear, since the Kramers-Kornig relation in equation (1.33) connects Re σ_{xy} to the integral of Im σ_{xy}. Furthermore, Re σ_{xy} does not change sign, although Im σ_{xy} has both increasing and decreasing segments. Could the author clarify the connection between the real and imaginary parts of σ_{xy}?
5. As discussed on page 67, the main difference between the HoAgGe compound in chapter 6 and the other two materials is that the former has a non-collinear magnetic ground state. Are real-space topological effects connected to the magnetic structure relevant to the optical response of HoAgGe, for example the scalar spin chirality mentioned in question 1?
6. On page 68 in chapter 6, the candidate discusses a quasisymmetry of HoAgGe. What is the definition of a quasisymmetry and how does it differ from conventional space-group symmetries?

In summary, the thesis undoubtedly satisfies the requirements of the Doctoral School of Physics. I accept the thesis statements as new scientific results. I recommend the thesis for public defense. I congratulate the author on the thesis!

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