Report on the PhD Thesis "The spin-orbit interaction of light in tunable liquid crystal microcavities" by the candidate Ms. Katarzyna Rechcińska

Introduction. In this report, I will discuss the PhD thesis titled "The spin-orbit interaction of light in tunable liquid crystal microcavities" written by Ms. Katarzyna Rechcińska. The thesis focuses on the investigation of spin-orbit interaction (SOI) of light in microcavities filled with a birefringent material, specifically liquid-crystals (LCs). By engineering microcavities having different thickness and average orientation of LC molecules, the author can implement different forms of SOI, showing a variety of effects having a direct counterpart in more familiar condensed matter systems, eg. the spin-Hall effect or the Rashba-Dresselhaus spin-orbit coupling.

Importantly, most of the presented results have been already disseminated through scientific articles published in international peer-reviewed journals, as such they have been validated by the scientific community.

Main Points. Optical microcavities presented in these thesis are formed by planar mirrors, separated by a micrometric layer of liquid-crystal material. As normal cavities, these exhibit optical modes or eigenstates, corresponding to those standing waves that, satisfying the boundary conditions at the mirrors, can exist within the cavity and couple to external waves. These modes are characterized by a given frequency, whose value dependes on the in-plane wavevector. The presence of a birefringent material inside the cavity introduces a spin-orbit coupling for the optical modes, whose dispersion becomes polarization sensitive. According to my perspective, the thesis achieves two major goals. First, the author shows that by properly selecting the LC mixture, its alignement and the cell thickness, it is possible to implement synthetic spin-orbit Hamiltonians of different kinds, each exhibiting a specif kind of SOI. Second, for each configuration, the spectral properties of the cavities can be adjusted dynamically by varying an external parameter, that is the voltage applied to the cell, determining in turn the effective birefringence.

Methodology. For each regime, the microcavities are characterized by a sufficient amount of reflection and transmission measurements, both in real and reciprocal space and for different polarization states. The presence of cavity modes, emerging experimentally as peaks/dips in the transmission/reflection spectra, is also confirmed by numerical simulations that are extensively illustrated in the thesis.

Evaluation. The thesis is extremely well written and organized, I enjoyed reading it. While an extensive introduction provides the reader with preliminary knowledge of the main physical concepts involved in the research work, a solid theoretical framework is presented before giving the details on each experiment (one per chapter). The thesis is certainly original and resulted into the publication of several articles in high-impact peer-reviewed journals, with the candidate having a major role.

Conclusion and recommendation. Based on the doctoral dissertation, I can say that the author has a strong general theoretical knowledge in physics and optics, as well as the ability to independently conduct scientific work.

The dissertation presents an original approach to the realization of optical microcavities exhibitint several regimes of tunable spin-orbit interaction, thus providing a brilliant solution to the realization of synthetic optical analogs of condensed matter effects. These enable the direct investigation of fundamental effects in simple and controlled setups.

My overall evaluation is positive, which is the best evaluation according to the list of possible ones provided by the University. I have only a few minor comments that I list below.

Finally, let me say that **the PhD thesis justifies the request for distinction** due to its significant contribution to the development of a tunable simulation platform for investigating synthetic spin-orbit interaction. The ability to switch between different regimes and associated synthetic magnetic fields will enable this platform to become widely used as a simulator of different physical systems. Moreover, the candidates publications as first author in high-impact journals like Science, Physical Review Letters, and Light: Science and Applications further demonstrate the impact and significance of her research.

List of minor corrections

- page 18. At the bottom part, when referring to Fig. 1.1, the electric field is presented with both x and y components, while in the figure it is only directed along the x axis. Perhaps the author wants to present the general case that is $\mathbf{E} \perp \mathbf{k}$, in this case it could be better making clear that in the figure there is a specific example having only the x component.
- page 19. When defining right-circular polarization (Eq. 1.5) it could be helpful to make clear which convention is adopted, that is observing a clockwise or anti-clockwise rotation of the field when seeing light coming to us, or viceversa.
- page 64. In Fig. 2.8, I feel that something is not correct in the imaging scheme. If f_2 is the focal length of the second lens, and the Fourier space of the sample is in its first focal plane (at distance f from the first lens), that in its second focal plane there cannot be the image of such Forier plane. The system would be similar to a $4f$ scheme,

with the final plane having the image of the sample. Perhaps there is some detail I am missing that makes this setup the correct one for imaging the Fourier space of the sample.

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