

Quantized Angular Momentum in Topological Optical Systems

Mário Silveirinha¹

¹ University of Lisbon, Instituto Superior Técnico and Instituto de Telecomunicações, Avenida Rovisco Pais, 1, 1049-001 Lisboa, Portugal

Topological materials and topological effects have elicited significant interest, first in the condensed-matter community [1-3] and more recently in the photonics community [4-10]. The only systems with a robust topological protection in optics are those with a broken-time reversal symmetry [11, 12]. The topological phases of such systems are usually classified by a topological integer: the Chern number.

In condensed-matter systems, the Chern number has a clear physical interpretation: it is the quantum of the Hall conductivity of a 2D electron gas [2, 13], and hence it determines the electronic transport for very low temperatures. In contrast, in optics the Chern index has not been linked to any physical entity, except that it is known that it gives the net number of gapless unidirectional edge states supported by an interface with a trivial material.

In this talk, I will show that the photonic Chern number is the quantum of the light-angular momentum in a closed photonic insulator cavity. I prove that for a sufficiently large cavity, the spectral density of the quantum or thermal fluctuation-induced angular momentum is precisely quantized in the band-gaps of the bulk modes. The nontrivial value the light angular momentum expectation is due to a circulation of a heat current in closed orbits, which may occur even when a system is in a thermodynamic equilibrium with a large reservoir [14, 15, 16]. Interestingly, the proposed theory also applies to systems without a topological classification, and in such a context the angular momentum “quantum” is given by the net number of unidirectional edge modes supported by the cavity walls [17, 18].

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[1] F. D. M. Haldane, “Model for a Quantum Hall Effect without Landau Levels: Condensed-Matter Realization of the “Parity Anomaly”, *Phys. Rev. Lett.*, **61**, 2015, (1988).

[2] B. A. Bernnervig, T. Hughes, *Topological Insulators and Topological Superconductors*, Princeton University Press, 2013.

[3] F. D. M. Haldane, “Nobel lecture: Topological quantum

matter,” *Rev. Mod. Phys.* **89**, 040502, (2017).

[4] L. Lu, J. D. Joannopoulos, M. Soljačić, “Topological photonics”, *Nat. Photonics*, **8**, 821, (2014).

[5] Z. Wang, Y. Chong, J. D. Joannopoulos, M. Soljačić, “Observation of unidirectional backscattering immune topological electromagnetic states”, *Nature*, **461**, 772 (2009).

[6] A. B. Khanikaev, S. H. Mousavi, W.-K. Tse, M. Kargarian, A. H. MacDonald, G. Shvets, “Photonic topological insulators”, *Nat. Mater.*, **12**, 233, (2013).

[7] A. Slobozhanyuk, S. H. Mousavi, X. Ni, D. Smirnova, Y. S. Kivshar, A. B. Khanikaev, “Three-Dimensional All-Dielectric Photonic Topological Insulator”, *Nat. Photonics*, **11**, 130, (2017).

[8] M. G. Silveirinha, “Chern Invariants for Continuous Media”, *Phys. Rev. B*, **92**, 125153, (2015).

[9] M. G. Silveirinha, “Bulk edge correspondence for topological photonic continua”, *Phys. Rev. B*, **94**, 205105, (2016).

[10] M. G. Silveirinha, “PTD Symmetry Protected Scattering Anomaly in Optics”, *Phys. Rev. B*, **95**, 035153, (2017).

[11] F. D. M. Haldane, S. Raghu, “Possible realization of directional optical waveguides in photonic crystals with broken time-reversal symmetry”, *Phys. Rev. Lett.*, **100**, 013904, (2008).

[12] S. Raghu, F. D. M. Haldane, “Analogues of quantum-Hall-effect edge states in photonic crystals”, *Phys. Rev. A*, **78**, 033834, (2008).

[13] D. J. Thouless, M. Kohmoto, M. P. Nightingale, and M. den Nijs, “Quantized Hall Conductance in a Two-Dimensional Periodic Potential”, *Phys. Rev. Lett.*, **49**, 405, (1982).

[14] M. G. Silveirinha, “Topological Angular Momentum and Radiative Heat Transport in Closed Orbits”, *Phys. Rev. B*, **95**, 115103, (2017).

[15] M. G. Silveirinha and S. I. Maslovski, “Exchange of momentum between moving matter induced by the zero-point fluctuations of the electromagnetic field”, *Phys. Rev. A* **86**, 042118 (2012).

[16] L. Zhu and S. Fan, “Persistent Directional Current at Equilibrium in Nonreciprocal Many-Body Near Field Electromagnetic Heat Transfer”, *Phys. Rev. Lett.* **117**, 134303 (2016).

[17] M. G. Silveirinha, “Quantized Angular Momentum in Topological Optical Systems”, arXiv:1803.07121, (2018).

[18] M. G. Silveirinha, “Proof of the bulk-edge correspondence through a link between topological photonics and fluctuation-electrodynamics”, arXiv:1804.02190, (2018).