From Quantized Chern Transport to Quantum Technologies: Nonlinear Topological Pumping

B.E. Castiblanco[1,2,3], **M. Fleischhauer** [2]

[1] *Department of Physics and Astronomy, Aarhus University, Ny Munkegade 120, DK-8000 Aarhus C, Denmark*

[2] Department of Physics and Research Center OPTIMAS, University of Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

[3] *Laboratoire Interdisciplinaire Carnot de Bourgogne, CNRS UMR 6303, Université Bourgogne Europe, BP 47870, F-21078 Dijon, France*

Simulations on *nonlinear bosonic* topological transport in Rice–Mele optical lattices are presented, computing *Chern number* from Zak phases of time-evolved ground states over full pump cycles to predict quantized displacement per cycle. The approach is based on soliton solutions to the Hubber model for the Thouless pump [1]. These results delineate transport/no-transport regimes versus drive frequency and interaction strength, identifying an adiabatic window with integer pumping ($C \approx 1$) and degradation under stronger nonlinearity or nonadiabatic drive, in line with recent observations of nonlinear and fractional Thouless pumping of solitons [2, 3]. Framed for quantum technology, we translate design knobs into device-level metrics and emphasize two representative applications: (i) reliable qubit/state transfer via dimerized topological chains [4]; and (ii) topologically protected memory based on surface-code architectures, from foundational proposals to recent system-level demonstrations of improving logical lifetimes with increasing code size [5].

[1] D. J. Thouless, "Quantization of particle transport," *Phys. Rev. B* **27**, 6083–6087 (1983). doi:10.1103/PhysRevB.27.6083.

[2] M. Jürgensen, S. Mukherjee, and M. C. Rechtsman, "Quantized nonlinear Thouless pumping," *Nature* **596**, 63–67 (2021). doi:10.1038/s41586-021-03688-9.

[3] M. Jürgensen, S. Mukherjee, C. Jörg, *et al.* "Quantized fractional Thouless pumping of solitons," *Nature Physics* **19**, 420–426 (2023). doi:10.1038/s41567-022-01871-x.

[4] F. M. D'Angelis, F. A. Pinheiro, D. Guéry-Odelin, S. Longhi, and F. Impens, "Fast and robust quantum state transfer in a topological Su–Schrieffer–Heeger chain with next-to-nearest-neighbor interactions," *Phys. Rev. Research* **2**, 033475 (2020). doi:10.1103/PhysRevResearch.2.033475.

[5] E. Dennis, A. Kitaev, A. Landahl, and J. Preskill, "Topological quantum memory," *J. Math. Phys.* **43**, 4452–4505 (2002). doi:10.1063/1.1499754.