Four-Dimensional Quantum Hall Effect with Ultracold Atoms

H. M. Price[1], O. Zilberberg[2], T. Ozawa[1], I. Carusotto[1], and N. Goldman[3]

[1]INO-CNR BEC Center and Dipartimento di Fisica, Università di Trento, I-38123 Povo, Italy
[2]Institute for Theoretical Physics, ETH Zürich, 8093 Zurich, Switzerland
[3]CENOLI, Faculté des Sciences, Universite Libré de Bruxelles (U.L.B.), B-1050 Brussels, Belgium

We propose a realistic scheme to detect the 4D quantum Hall effect using ultracold atoms. Based on contemporary technology, motion along a synthetic fourth dimension is accomplished through controlled transitions between internal states of atoms arranged in a 3D optical lattice. From a semi-classical analysis, we identify the linear and non-linear quantized current responses of our 4D model, relating these to the underlying topology of the Bloch bands. We then propose realistic experimental protocols, based on current or center-of-mass-drift measurements, to observe both a "fractional" Hall conductivity and to extract the topological 2nd Chern number. Our proposal sets the stage for future experiments exploring novel topological phases in higher dimensions.