Artificial gauge fields for ultracold neutral atoms

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Ultracold atoms are quantum systems under precise experimental control, ideal for the realization and characterization of novel artificial gauge fields.[1-4] Our latest experiments[3,6] with 87Rb Bose-Einstein condensates have demonstrated and explored Abelian –scalar and matrix valued– light-induced gauge potentials.

We optically dressed our BEC with a pair of far detuned “Raman” lasers[7]. The resulting dressed states are spin and momentum superpositions, and we adiabatically load the atoms into the lowest energy dressed state, which gives a new effective dispersion relation for our ultracold atoms. The nature of the dressed states is experimentally tunable via the strength of the laser coupling and the detuning from Raman resonance, thereby introducing gauge fields into the Hamiltonian.

I will discuss analogs to:

i. Electrically charged particles in electric and magnetic fields[5], which led to the nucleation of vortices in our BEC, and

ii. Spin-Orbit coupling[6], the interaction between a quantum particle’s spin and its momentum, with equal contributions of Rashba and Dresselhaus coupling, which modified the interaction between the dressed spin states and resulted in a phase transition from a spatially spin-mixed state to a phase-separated state as a function of laser power. The location of this transition is in agreement with our calculations.

Our experimental techniques for ultracold bosons have surpassed the apparent limitations imposed by their neutral charge (artificial E and B fields) and bosonic nature (SO coupling for spin–1/2 bosons), and have allowed the observation of these new and exciting phenomena. Future work might permit the observation of the bosonic quantum Hall effect, of the spin Hall effect[8,9] and topological insulators[10-12] in cold atom systems.

References: