MAR12-2011-020155

Abstract for an Invited Paper
for the MAR12 Meeting of
the American Physical Society

Quantum simulations and artificial gauge fields with ultracold atoms

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Here I present our experimental work synthesizing gauge fields for Bose-Einstein condensates (BECs). I will first summarize our earlier work creating a scalar (abelian) gauge field (akin to the electromagnetic vector potential) and then focus in detail our current work creating a matrix valued (although still abelian) gauge field. I will discuss this gauge field in the language of spin-orbit coupling where it consists of an equal sum of Rashba and Dresselhaus couplings. Specifically, we couple two internal states of rubidium 87 with a pair of “Raman” lasers and load our BEC into the resulting adiabatic eigenstates. In agreement with theory, we observe that below a critical coupling strength our BEC has well defined spin degrees of freedom and acts like a spin-orbit-coupled spin-1/2 Bose gas. As a function of the Raman laser strength, a new exchange-driven interaction between the two dressed spins develops, which drives a (quantum) phase transition from a state where the two dressed spin states spatially mix, to one where they phase separate. Our 3D mean field theory accurately locates the critical laser strength for this transition.