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Artificial Gauge Fields for Ultracold Neutral Atoms[1]

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Ultracold atoms are a versatile probe for physics at the core of the most intriguing and fascinating systems in the quantum world. Due to the high degree of experimental control offered by such systems, effective Hamiltonians can be designed and experimentally implemented on them. This unique feature makes ultracold atom systems ideal for quantum simulation of complex phenomena as important as high-temperature superconductivity, and recently of novel artificial gauge fields. Suitably designed artificial gauge fields allow neutral particles to experience synthetic- electric or magnetic fields; furthermore, their generalization to matrix valued gauge fields leads to spin-orbit coupling featuring unprecedented control in contrast to ordinary condensed matter systems, thus allowing the characterization of the underlying mechanism of phenomena such as the spin Hall effect and topological insulators. In this talk, I will present an overview of our experiments on quantum simulation with ultracold atom systems by focusing on the realization of light induced artificial gauge fields. We illuminate our Bose-Einstein condensates with a pair of far detuned "Raman" lasers, thus creating dressed states that are spin and momentum superpositions. We adiabatically load the atoms into the lowest energy dressed state, where they acquire an experimentally-tunable effective dispersion relation, i.e. we introduce gauge terms into the Hamiltonian. We control such light-induced gauge terms via the strength of the Raman coupling and the detuning from Raman resonance. Our experimental techniques for ultracold bosons have surpassed the apparent limitations imposed by their neutral charge, bosonic nature, and ultra-low energy and have allowed the observation of these new and exciting phenomena. Future work might allow the realization of the bosonic quantum Hall effect, of topological insulators and of systems supporting Majorana fermions using cold atoms.

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