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Optically synthesized magnetic fields for ultracold neutral atoms

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Ultracold atoms hold great promise in simulating essential models in condensed matter physics. One apparent limitation is the charge neutrality of the atoms, which prevents access to a rich source of physics, for example, electrons in magnetic fields. We have circumvented this limitation by generating an effective vector potential with an optical coupling between internal states of the atoms. We have experimentally realized a synthetic magnetic field for ultracold neutral atoms, through the spatial variation of the effective vector potential. In our system, we use a two-photon Raman coupling to dress a rubidium 87 Bose-Einstein condensate (BEC), where the momentum difference between two Raman beams results in the modified energy-momentum dispersion of the dressed state, leading to an effective vector potential. We have created a synthetic magnetic field evidenced by the appearance of vortices in the BEC; this field is stable in the laboratory frame and allows for adding optical lattices with ease. Our optical approach is not subject to technical limitations of rotating systems, including the metastable nature of the rotating state, the limited maximum rotating velocity and the difficulty of applying stable rotating optical lattices. In our approach, with a suitable lattice configuration, it should be able to create sufficiently large synthetic magnetic fields in the quantum-Hall regime. Work done in collaboration with, Robert Compton, Karina Jimenez-Garcia, James Porto, and Ian Spielman, Joint Quantum Institute, National Institute of Standards and Technology, and University of Maryland.