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Experimental Design and Construction for Critical Velocity Measurement in Spin-Orbit Coupled Bose-Einstein Condensates

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ABSTRACT

Quantum simulation using ultra-cold atoms, such as Bose-Einstein Condensates (BECs), offers a very flexible and well controlled environment to simulate physics in different systems. For example, to simulate the effects of spin orbit coupling (SOC) on electrons in solid state systems, we can make a SOC BEC which mimics the behavior of SOC electrons. The goal of this project is to see how the superfluid property of BECs change in the presence of SOC. In particular, we plan to measure the critical velocity of an ^{87}Rb BEC with and without SOC by stirring it with a laser. This laser needs to be blue-detuned for generating a repulsive potential as an obstacle. For this purpose, we build an external cavity diode laser (ECDL) at 776.47nm, which is blue-detuned to the D_1 and D_2 transition of ^{87}Rb. To drive the ECDL, temperature and current controllers are designed and built. Since we need to focus the laser beam to the center of a BEC (about 20 by 55 micron), we set up a telescope to shrink the beam size to less than 10 micron. The optical design is accomplished by OSLO (optical system simulation software) with simulation results consistent with the Ray Transfer Matrix. To examine the superfluidity under different relative velocities, an acoustic-optic modulator will be used to move the beam against the BEC. At this point, the optical system is mostly finished. Our next step is to perform the critical velocity measurement of a BEC with and without SOC.

KEYWORD

Spin-orbit coupling, cold-atom, Bose-Einstein Condensate, condensed matter, superfluid, critical velocity, ray transfer matrix analysis, chemical potential