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Combining red- and blue-detuned optical potentials to form a Lamb-Dicke trap for a single neutral atom

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We propose and demonstrate a scheme for strongly radially confining a single neutral atom in a bichromatic far-off resonance optical dipole trap (BFORT) . BFORT is composed of a blue-detuned Laguerre-Gaussian $LG^1_ 0$ beam and a red-detuned Gaussian beam. The trapping radial dimension of a single atom trapped in the Gaussian FORT can be greatly compressed by imposing a blue-detuned Laguerre-Gaussian $LG^1_ 0$ beam with moderate potential depth. By modulating the potential depth of the Gaussian FORT we observed that the resonant and parametric excitation of the oscillatory motion of a single atom in this BFORT and obtained the oscillation frequency that well fits prediction from the theoretical model. The frequency measurement shows that effective trapping dimension can be greatly sharper than that diffraction limited of microscopic objective we used. Then we show that the excess scattering rate due to imposing blue detuned light can be eliminated when single atoms is close to ground-state theoretically. So BFORT suits the purpose of acting as a Lamb-Dicke trap for further cooling a single neutral atom to motion ground-state and finding application in quantum information progressing.

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