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Painted optical potentials for rapid evaporative cooling of neutral atoms

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A coherent source of ultra-cold neutral atoms is a crucial prerequisite for state-of-the-art quantum sensors based on matter-wave interferometry, such as quantum gravimeters. Evaporative cooling is typically a slow process, often requiring tens of seconds, hence rapid cooling schemes are desirable to increase measurement rates. We present a numerical model for the evaporative cooling of rubidium-87 atoms in a far-detuned optical dipole trap. The model builds upon previous work for rapid cooling in dynamically shaped optical traps by utilizing time-averaged or "painted"potentials. To achieve greater flexibility in the trapping potential, we consider two independent laser beams whose power and position is modulated in time using a 2D acousto-optic deflector. The simulation solves the coupled differential equations governing the evolution of temperature and atom number during the cooling process while accounting for the rate of elastic collisions, three-body loss effects, and rapid modulation of trap depths and frequency. Our results demonstrate the impact of painted potentials on the cooling rate and atom retention and provide key insights for use in a high-accuracy quantum gravimeter.

Keyword-1

Evaporative cooling

Keyword-2

Quantum sensing

Keyword-3

Painted potentials

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