Inhomogeneous-excitation frequency shifts of ytterbium optical lattice clocks

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The performance of the optical clocks has better than that of the best cesium clocks in accuracy and stability[1-3], which makes the optical clocks have the potential to replace microwave clocks to be the next generation frequency standards. In order to improve the atomic optical clocks, the eliminating of various frequency shifts should be paid great attention. The ac Stark shift, the Doppler shift and the recoil shift can be eliminated when the atoms are confined in the optical lattice with the "magic" wavelength. Therefore, the collisional shift has become one of the major limitations to the optical lattice clocks. By Pauli Exclusion Principle, the fermionic atoms can immune from the collisional shift. However, the theoretical and experimental results reported recently show that the collisional shift does still exist in fermionic optical lattice clocks, which is resulted from the inhomogeneous excitation. This inhomogeneous-excitation collisional frequency shift mainly depends on the atomic temperature and the misaligning angle between the lattice laser and the clock laser. However, the ytterbium atoms are usually hotter than the strontium atoms after the second-stage cooling. For instance, the typical temperature of cold fermionic strontium atoms is about several μK, and the temperature of the fermionic ytterbium atoms is a few tens μK. It means that the inhomogeneous-excitation collisional frequency shift in the ytterbium optical clocks will be more important than that in the strontium optical clocks. Recently, this shift in the strontium optical clocks has been reduced experimentally at 10^{-19} level. Unfortunately, this shift in the ytterbium optical clocks has not been reported yet. Therefore, we theoretically investigate the frequency shifts caused by inhomogeneous excitation in a ^{171}Yb optical lattice clock. The dependences of the frequency shift on the inhomogeneity, including of the temperature of the cold ytterbium atoms and the misaligning angle between the lattice laser and the clock laser, and the ground state fraction have been studied in detail. We have found that the fractional frequency uncertainty of the ytterbium clocks contributed by the inhomogeneous excitation can be reduced at the 10^{-19} level or even lower with the optimum condition.

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