Active optical clock based on ^{87}Rb atoms cooled by 780 nm diffuse laser

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Atomic clocks, as the instrument with the highest measurement accuracy, are of great value in the fields of basic physics research and precision measurement. Currently, the best-performing optical clocks are passive optical clocks[1]. However, their frequency stability is limited by the cavity-length thermal noise of the oscillator laser. This limitation can be overcome by the principle of active optical clock (AOC)[2], which utilizes the weak feedback of low-finesse optical cavity to realize multi-atom stimulated emission of radiation[3]. Nevertheless, a continuously operable cold-atom AOC has not yet been realized. Here, we propose an innovative AOC based on ^{87}Rb atoms cooled by 780 nm diffuse laser. The cold atoms serve as a quantum frequency reference and provide atomic gain. The stimulated radiation signal at 1367 nm is directly output as a clock laser, thereby realizing a cold-atom AOC signal capable of continuous output.

The experimental scheme is depicted in Fig. 1. The 780 nm cooling laser is tuned to the transition from $5S_{1/2}$ ($F = 2$) to $6P_{3/2}$ ($F' = 3$) with red detuning, while the 780 nm repumping laser is locked to the transition from $5S_{1/2}$ ($F = 1$) to $6P_{3/2}$ ($F' = 2$). Isotropic diffuse laser fields are prepared so that the atoms of a certain velocity interact with a specifically red-detuned laser, compensating for the Doppler shift. Experimentally, the optical depth of the 100 cm-long cold atom cloud reaches 4, providing large atomic number for the subsequent realization of the 1367 nm AOC. With a 420 nm pumping laser, the 1367 nm spontaneous emission of radiation signal (from $6S_{1/2}$ to $5P_{3/2}$) has been initially observed without cavity feedback, with a power up to 0.3 μW. In the future, a low-finesse optical cavity will be constructed to realize a truly continuous-wave cold-atom AOC, facilitated by the weak coupling between the cavity and the cold atoms.

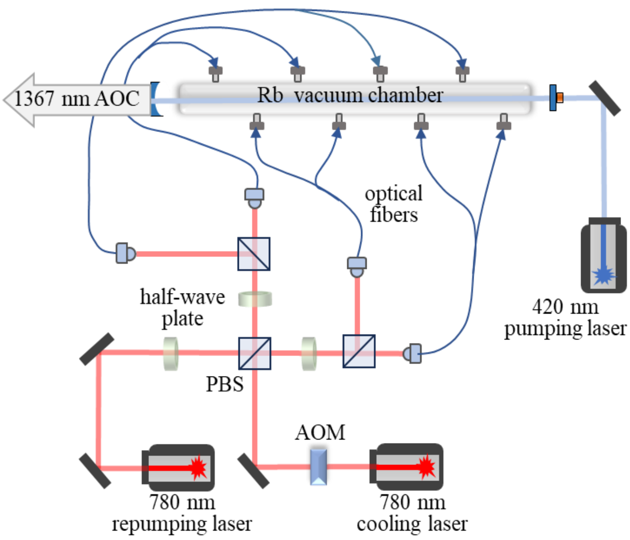

Fig. 1: Experimental system.

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