Combined separated oscillatory fields technique

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For decades, Ramsey method of separated oscillatory fields (SOFs)[1] serves as a powerful tool for quantum metrology. Several different Ramsey patterns, including bright pattern excited by zero-phase-difference SOFs, dark pattern excited by π-phase-difference SOFs, and time-varying pattern excited by frequency-offset SOFs, have been used for performing precision measurements.

Here, we propose a Rabi-background-free version of Ramsey method, which combines zero-phase-difference SOFs and π-phase-difference SOFs to produce Ramsey interference pattern. For monokinetic atoms, the transition probability describing the central Ramsey pattern is given by[2] $P(\tau) \approx \sin^2(b\tau)[1+\cos(\Delta T+\phi)]/2$ when the free evolution time T is much longer than the interaction time τ. Here, $\Omega = \sqrt{b^2+\Delta^2}$ denotes the generalized Rabi frequency of atoms in the SOFs with strength b, Δ is the detuning from resonance, and ϕ is the phase difference between the two oscillatory fields in a single SOFs. We here consider a combined Ramsey scheme where two identical atomic-beams emerging from an atomic source, interact with $\phi = 0$ SOFs and $\phi = \pi$ SOFs, respectively, and the other parameters (τ, T, and b) of these two different types of SOFs are designed to be the same except for the phase difference. Through the subtraction of the obtained bright pattern and dark pattern, the transition probability function describing the combined Ramsey pattern can be written as $P_c(\tau) = P(\tau)|_{\phi=0} - P(\tau)|_{\phi=\pi} \approx \sin^2(b\tau)\cos(\Delta T)$. In actual case where the beams have a certain velocity distribution, the probability function becomes

$$P_c = \int_0^\infty f(\tau)\sin^2(b\tau)\cos(\Delta T)\,d\tau$$

where $f(\tau)$ is the interaction time distribution. Taking hot Cs beam tube as an example where atomic state preparation and transition detection are realized with D_2: 4-4' laser and D_2: 4-5' laser, respectively, P_c is calculated and shown in Fig. 1.

It is found that the peak-to-valley height of the combined pattern is twice that of the single pattern without increasing the atomic linewidth. Another important feature of the combined pattern—in contrast to the typical one—is that the broader Rabi pedestal insensitive to the phase difference ϕ, is removed.

To summarize, the combined SOFs technique presented here has the advantages of enhancing the Ramsey signal and being insensitive to the noise, making it a promising method for obtaining beam resonance signals with high signal-to-noise ratio.

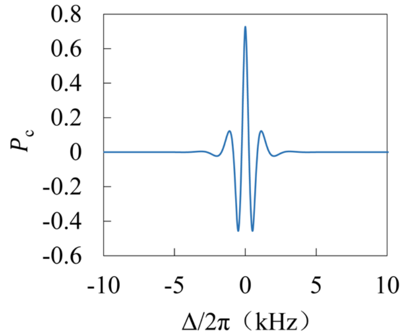

Fig. 1: Combined pattern.

[1] N. F. Ramsey, "A molecular beam resonance method with separated oscillatory fields", Phys. Rev., vol. 78, p. 695-699, 1950.

[2] J. Vanier and C. Audoin, "The quantum physics of atomic frequency standards", Adam Hilger, Bristol and Philadelphia, 1989.