Coherence of a dynamically decoupled single neutral atom

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Long qubit coherence and efficient atom-photon coupling are essential for advanced applications in quantum communication. One technique to maintain coherence is dynamical decoupling (DD) [1,2], where a periodic sequence of refocusing pulses is employed to reduce the interaction of the system with the environment.

Early work has demonstrated a coherence time of around 100 ms for a single neutral atom in the magnetic insensitive basis [3]. With the implementation of DD on the same basis, the coherence time has been extended by a factor of 3 (to around 300 ms) [4]. On the other hand, dephasing suppression with DD for the magnetic sensitive states, remains relatively unexplored.

In this work, we experimentally study the implementation of dynamical decoupling on an optically-trapped $^{87}\text{Rb}$ atom. We use the two magnetic-sensitive $5S_{1/2}$ Zeeman levels, $|F=2, m_F=-2\rangle$ and $|F=1, m_F=-1\rangle$ as qubit states, motivated by the possibility to couple the former state to $5P_{3/2}$ the excited state $|F'=3, m_{F'}=-3\rangle$ via a closed optical transition, opening a possible path to protocols such as generation of time-bin atom-photon entanglement and the sequential generation of an entangled photonic string [5].

With fixed total free evolution time, we vary separation time between pulses to investigate the optimal pulse sequence for our system. As shown in Fig. 1, the optimal sequence matches well with the Carr-Purcell (CP) sequence where $(\frac{\tau}{2}, \frac{\tau}{2}, \frac{\tau}{2}) = (10\%, 20\%, 20\%)$. Due to the drop in signal contrast when applying CP sequence, we apply the Carr-Purcell-Meiboom-Gill (CPMG) sequence which has been shown to be able to mitigate pulse imperfections for the preservation of a quantum state. With 50 $\pi$-pulses applied using CPMG sequence, we manage to extend the coherence time from 38(3) $\mu$s to around 7 ms (Fig. 2).

References
[1] M. J. Biercuk, H. Uys, A. P. VanDevender, N. Shiga, W. M. Itano, and J. J. Bollinger, “Optimized dynamical decoupling in a model quantum memory,” Nature 458, 996 - 1000 (2009).
[2] J. R. West, D. A. Lidar, B. H. Fong, and M. F. Gyure, “High fidelity quantum gates via dynamical decoupling,” Phys. Rev. Lett. 105, 230503 (2010).
[3] J. Yang, X. He, R. Guo, P. Xu, K. Wang, C. Sheng, M. Liu, J. Wang, A. Derevianko, and M. Zhan, “Coherence preservation of a single neutral atom qubit transferred between magic-intensity optical traps,” Phys. Rev. Lett. 117, 123201 (2016).
[4] S. Yu, P. Xu, X. He, M. Liu, J. Wang, and M. Zhan, “Suppressing phase decoherence of a single atom qubit with carr-purcell-meiboom-gill sequence,” Opt. Express 21, 32130 - 32140 (2013).
[5] I. Schwartz, D. Cogan, E. R. Schmidgall, Y. Don, L. Gantz, O. Kenneth, N. H. Lindner, and D. Geroshni, “Deterministic generation of a cluster state of entangled photons,” Science 354, 434 - 437 (2016).