Decoherence and Collisional Frequency Shifts

Kurt Gibble*,+

*Department of Physics, The Pennsylvania State University, University Park, PA, USA
+SYRTE, Observatoire de Paris, Paris, France

Email: kgibble@psu.edu

A novel frequency shift due to collisions of fermions was recently observed in an optical lattice clock.[1] The shift was surprising since identical fermions cannot scatter at low temperature and previous arguments suggested that even distinguishable fermions could not produce a collision shift.[2] For bosons and fermions, the conventional wisdom has been that frequency shifts are proportional to the difference of chemical potentials and therefore also the partial densities of the clock states. We theoretically analyze Rabi and Ramsey spectroscopy of trapped fermions and show that the collision shift for fermions is not proportional to the difference of partial densities. Instead, when two fermions in non-identical superpositions collide, one fermion gets a positive frequency shift and the other a negative frequency shift. In Ramsey spectroscopy, when the second pulse is a π/2 pulse ($\bar{\theta}_2$=π/2 in Fig. 1), the frequency shift of both atoms is probed with the same sensitivity and there is no shift.[3] For other pulse strengths, the two shifts largely cancel. We show that the behavior for Rabi excitation is essentially identical. This problem has subsequently been treated by two other groups.[4,5] Their explanations are consistent with the conventional wisdom that collisional frequency shifts are proportional to the difference of partial densities. We will describe the shift and discuss the discrepancies of the treatments. We will also discuss the "factor of 2" controversy for bosons[6] and the confusion that arises from an over-simplified view of energy conservation.

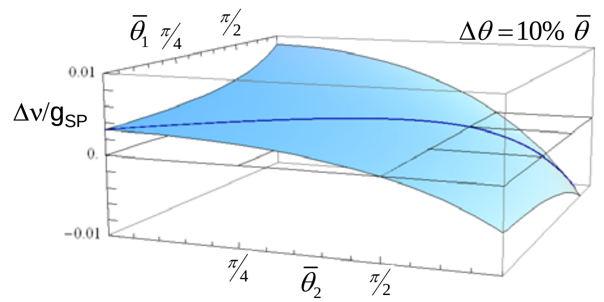

Fig. 1. Frequency shift due to fermions collisions as a function of the Ramsey pulse tipping angles, $\bar{\theta}_1$ and $\bar{\theta}_2$. The shift is not proportional to the difference of partial densities n_P–n_S, which would imply a strong dependence $\bar{\theta}_1$. The shift does vary strongly with the second Ramsey pulse area, going to 0 if the second pulse is on average a π/2 pulse. The solid line is the shift for the usual case of equal pulses.

[1] G. K. Campbell *et al.*, Science **324**, 360-363 (2009).

[2] M. W. Zwierlein, Z. Hadzibabic, S. Gupta, W. Ketterle, Phys. Rev. Lett. **91**, 250404 (2003).

[3] K. Gibble, Phys. Rev. Lett. **103**, 113202 (2009).

[4] A. M. Rey, A.V. Gorshkov, and C. Rubbo, Phys. Rev. Lett. **103**, 260402 (2009).

[5] Z. Yu and C. J. Pethick, Phys. Rev. Lett. **104**, 010801 (2010).

[6] D. M. Harber, H. J. Lewandowski, J. M. McGuirk, E. A. Cornell, Phys. Rev. A **66**, 053616 (2002).