

Direct observation of diffusion in warm atomic vapors

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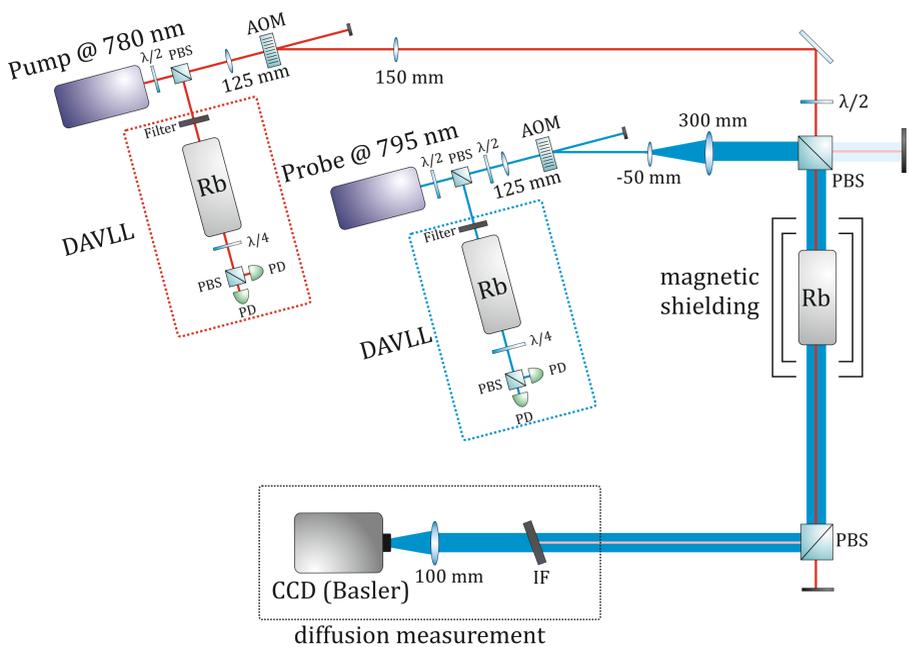


I. Introduction

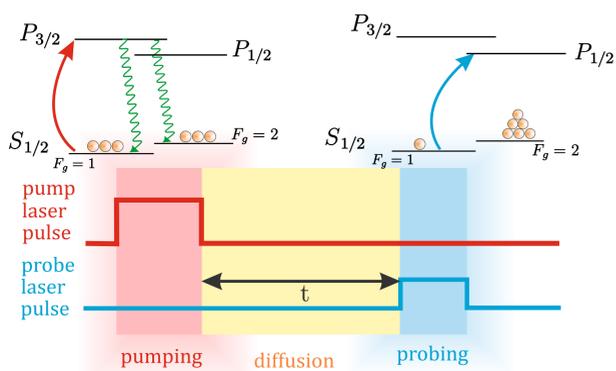
Diffusion is one of the main limitations for storage time in multimode atomic vapor memories. It can be significantly suppressed by adding neutral buffer gas, like Ne, Kr or Xe. Various results for diffusion coefficients of rubidium in buffer gases are either not precisely measured or unknown. It is a serious obstacle, when it comes to planning experiments or conducting simulations.

We present a very robust and simple method to determine diffusion coefficients of atoms in vapor cells. We also present normalized diffusion coefficients, notably the second published result for rubidium in Xe. Our result is consistent with the result published in [1], which had been acquired with more complex method.

II. Experimental methods



Schematic of the experimental setup. AOM - acousto-optical modulator, Rb - Rubidium vapor cell, PBS - polarizing beam-splitter, $\lambda/2$ - half wave plate, $\lambda/4$ - quarter wave plate, IF - interference filter. Dichroic atomic vapor laser lock setup (DAVLL) serves as a reference and ensures the required stability of frequency.



Laser pulse sequence used in the experiment with energy level structure of Rubidium 87.

For each delay time t we record a spatial intensity distribution of the probe beam with and without optical pumping. The quantity we are interested in is the difference in optical density for the probe beam induced by optical pumping.

$$\Delta_{OD}(x, y) = \ln \frac{I_{pumping}(x, y)}{I_{no\ pumping}(x, y)} = \alpha L \Delta \rho(x, y)$$

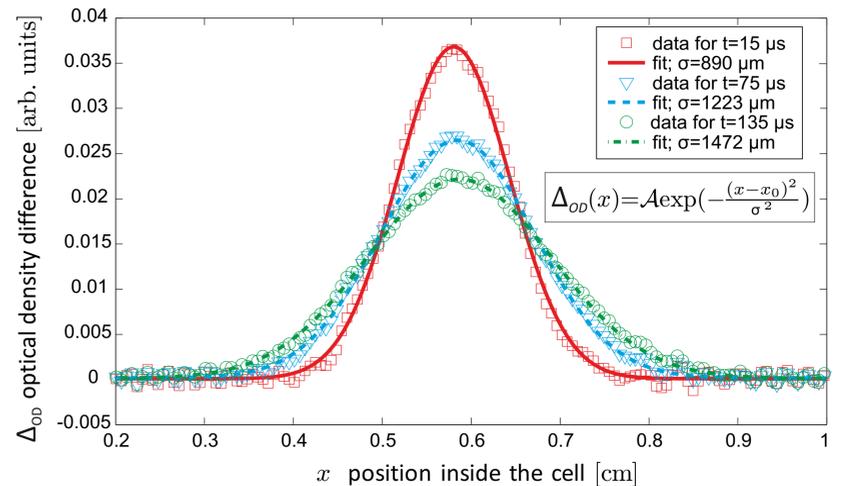
It is directly proportional to the change of density of atoms $\Delta \rho(x, y)$ in $F_g=1$ state.

References:

- [1] Chrapkiewicz, R., Wasilewski, W., & Radzewicz, C. (2013). How to measure diffusional decoherence in multimode Rubidium vapor memories? preprint: <http://arxiv.org/abs/1304.5396>
 [2] Ghatee, M. H., & Niroomand-Hosseini, F. (2007). Hard-wall potential function for transport properties of alkali metal vapors. The Journal of chemical physics, 126(1), 014302. doi:10.1063/1.2403879

III. Spatial domain analysis

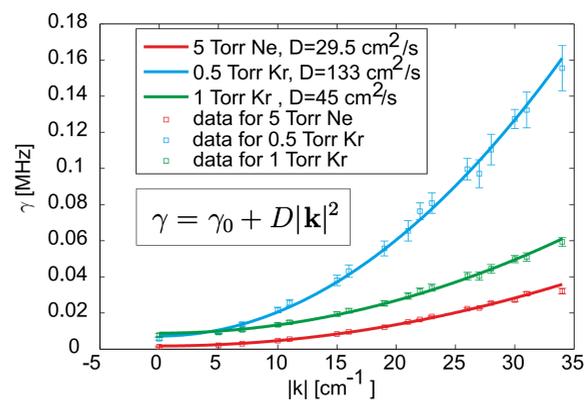
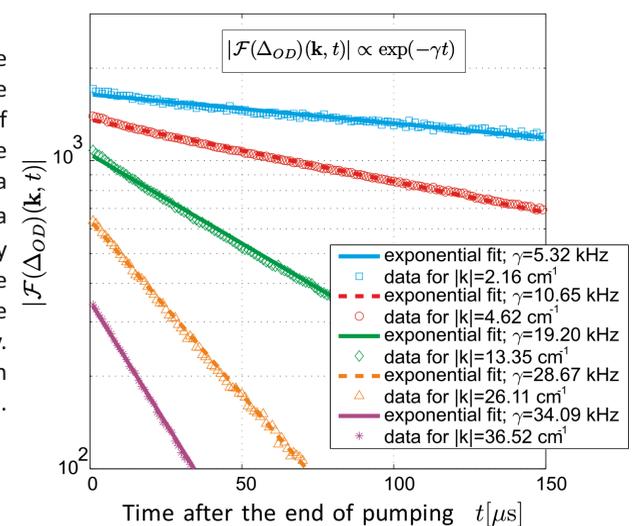
One way to analyze the data is to fit a gaussian to the spatial distribution of optical density difference. It spreads according to the following formula: $\sigma(t) = \sqrt{\sigma_0^2 + 4Dt}$.



Sections of the difference between optical densities induced by optical pumping as directly seen by the CCD camera

IV. Fourier domain analysis

Another way is to take the Fourier transform in the spatial coordinates of a set of collected images. The absolute value of a component of Δ_{OD} with a certain spatial periodicity decays exponentially in time at a rate γ dependent on the length of \mathbf{k} quadratically. Example decays are shown on the figure.



Having collected decay rates for various elements of the Fourier transform we perform angular averaging in the \mathbf{k} space. To extract the diffusion coefficient D it is now enough to fit quadratic dependence to $\gamma(|\mathbf{k}|)$. One needs to add a constant γ_0 that describes relaxation.

Buffer gas	D_0 [cm ² /s] Our Results	D_0 [cm ² /s] Chapman-Enskog theory
Neon	0.18(0.03)	0.145
Krypton	0.07(0.01)	0.064
Xenon	0.052(0.006)	0.055

Normalized (273 K, 1 atm) results for diffusion coefficients for Rubidium in various buffer gases compared with prediction based on Chapman-Enskog formula with atomic parameters taken from [2].