FREQUENCY REDISTRIBUTION IN RESONANT RUBIDIUM VAPOR

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Objective

- We investigate the frequency redistribution of photons present in resonant, atomic vapor
- The scattered photons also follow a step-length distribution which can give many insights to the superdiffusive characteristics of Rubidium vapor

Frequency Redistribution in Atomic Vapor

- Atoms in sample of atomic vapor follow Gaussian distribution known as Maxwell-Boltzmann Distribution

$$Ae^{\frac{-mv^2}{2k_BT}}$$

- Where A is constant, m is atomic mass, k_B is Boltzmann constant, v is velocity and T is temperature
- Frequencies of scattered photons also follow this Gaussian distribution, giving rise to the frequency redistribution
- As a result of the frequency redistribution photons also have a memoryless property whereby the initial frequency is completely "forgotten" after several scattering events

Lévy Flight Paths

- Lévy flight paths refer to a type of random walk in which the movement is isotropically random
- In a system following these dynamics the probability step-length distribution has a divergent second-moment – here the **central limit theorem no longer holds**
- In resonant vapors the step-length distribution follows an asymptotic power-law $P(x) \sim x^{-\alpha}$ where $\alpha < 3$ [1] – here **the probability of extremely large steps is nonzero** and these **random, extremely large steps govern the overall system dynamics**
- Under these conditions we can **no longer use the diffusion model** because of its dependence on the CLT

Experimental Setup

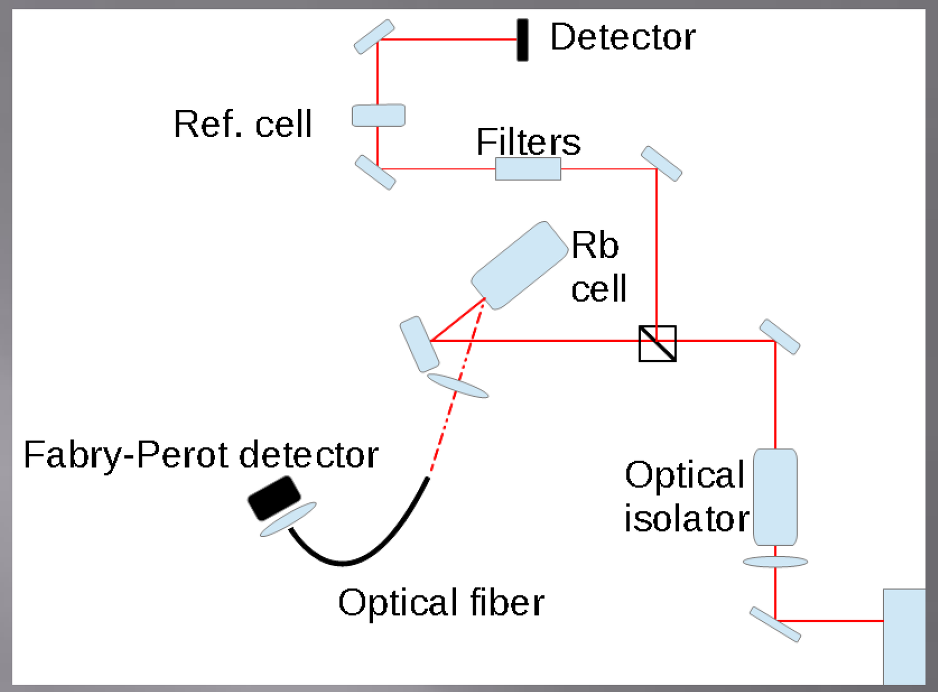


Fig. 1 The experimental setup, containing both a linear absorption reference cell and the main atomic vapor cell

- Of the 4 absorption peaks for atomic Rubidium vapor we focus on the F = 2 line for Rb 85, taking data for the on-resonance frequency and for 2 additional laser frequencies on each side of this peak
- Linear absorption reference cell allows for the conversion of Fabry-Perot frequency spectrum data into meaningful data on the frequency redistribution

Simulation Setup

- **Monte-Carlo simulation** written in C++ uses same geometry and conditions as our experiment
- Follows simple loop to send a user-defined number of photons, N, through the simulated experimental setup
- The frequency redistribution is then reconstructed by using the data From the scattered photons that collided with the detector

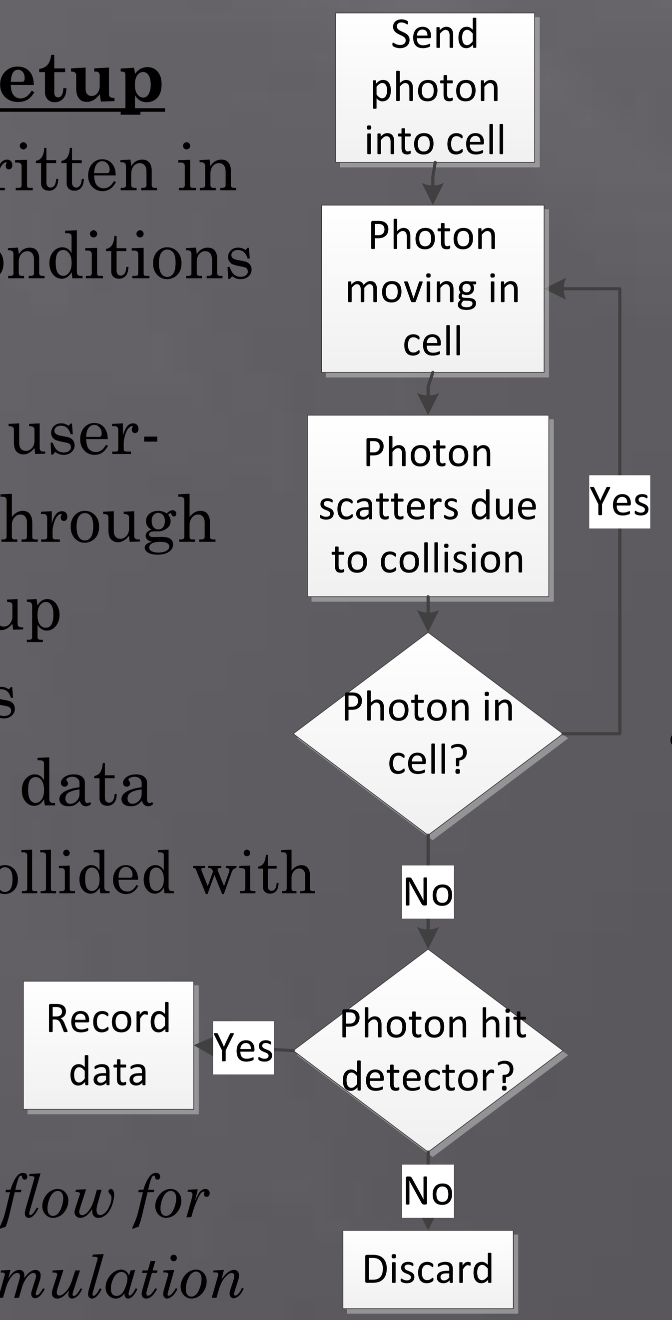
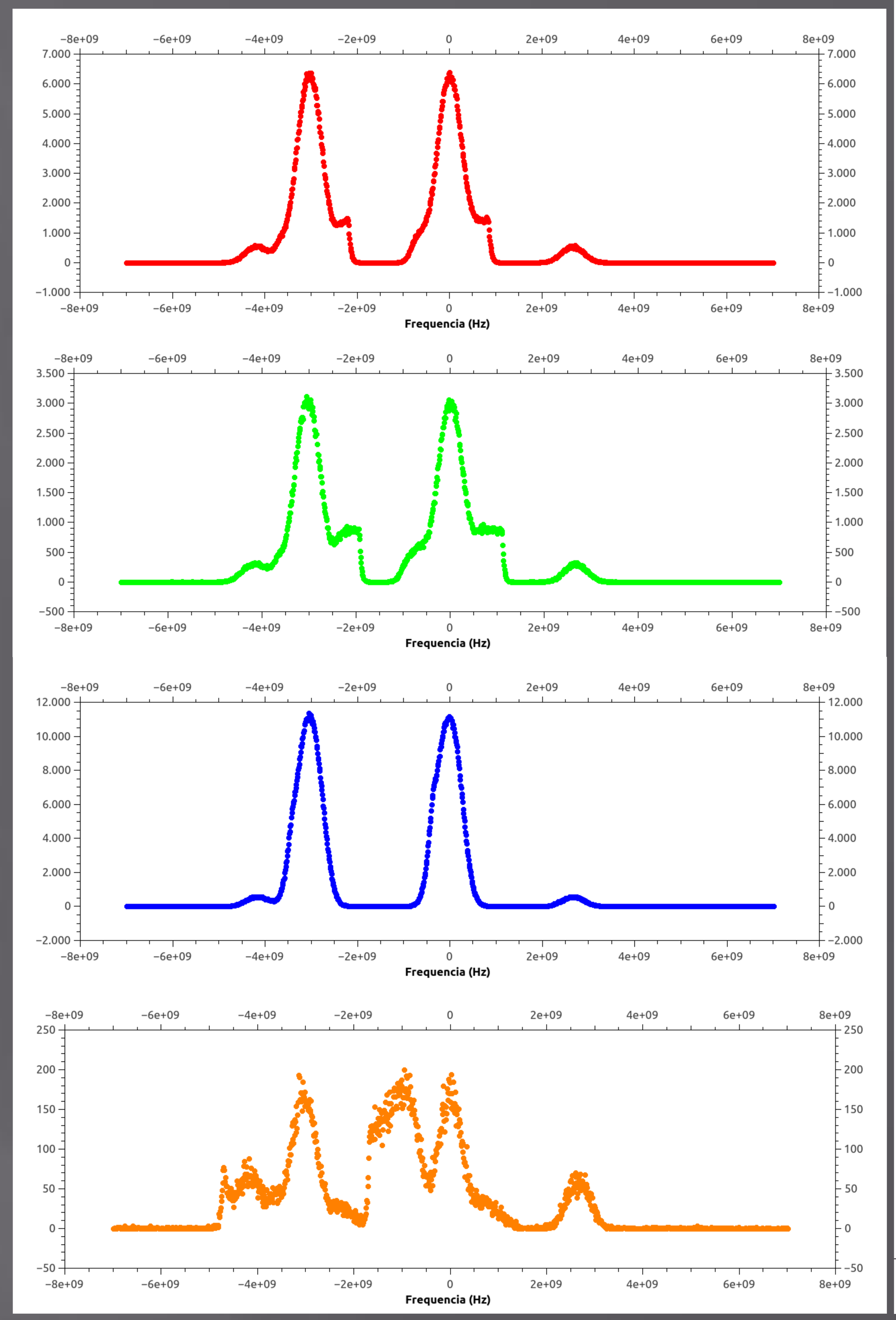


Fig 2. – Basic program flow for Monte-Carlo Simulation

Results

- For on-resonance (black) and with an shift induced in the laser frequency we **observe a change in the frequency redistribution** but experimentally it is hard to distinguish if the same result is obtained due to measurement noise



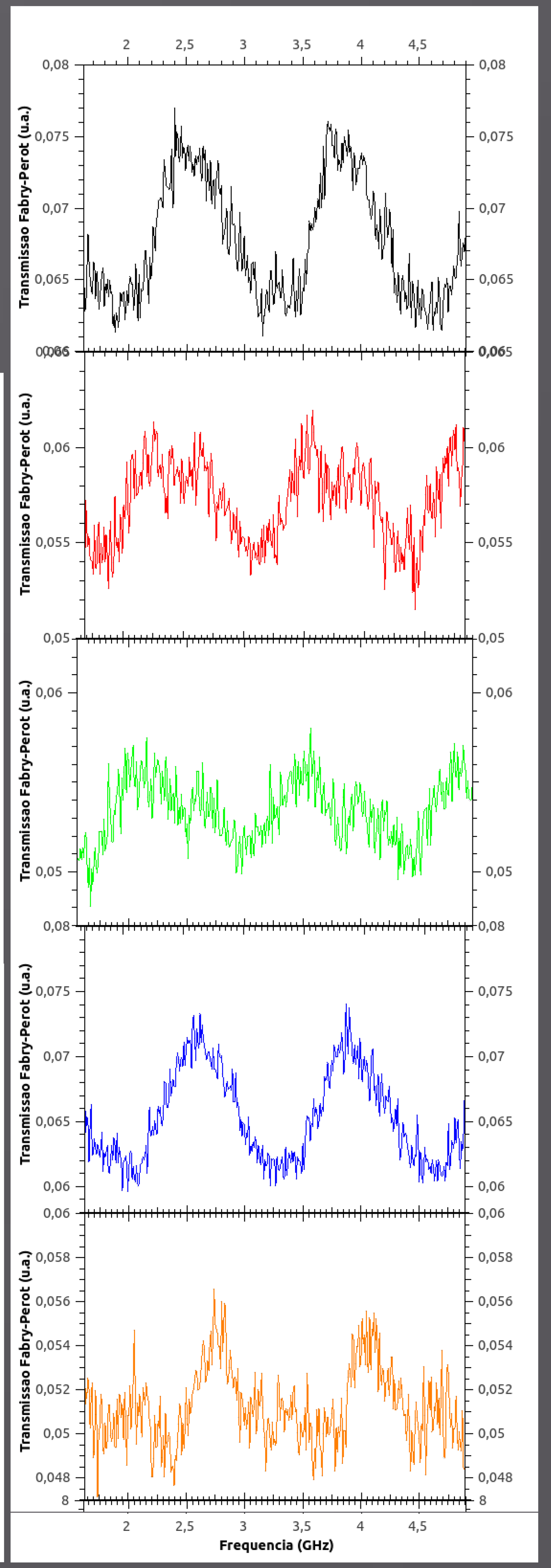


Fig. 3 – ~2 periods of the frequency redistribution are shown (at right, experimental) for the case of laser frequency tuned to resonance and for 2 slightly-shifted frequencies in each direction. Simulation results (left) show the expected result on the curve centered at f = 0 GHz for each case

Conclusions

- Numerical simulation results show that the frequency redistribution in a resonant vapor is a function of the illuminating light but more experimental work must be done to verify this hypothesis

References
[1] N. Mercadier, W. Guerin, M. Chevrollier, and R. Kaiser, Nat. Phys. 5, 602 (2009).

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