Slowing light pulses due to four-wave mixing in Potassium vapor
– theory and experiment

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Slow light can be obtained using different protocols and different physical systems. Here we investigate slowing of light pulses due to four wave mixing (FWM) in hot Potassium. Slow light is valuable for all signal processing, but in order to be really useful, the system has to produce fractional delays large than one, with the small broadening and absorption. Absorption and distortion are alleviated in the system with the gain, like in FWM, which opens possibilities for stacking many delay lines.

In this work we use off- resonant double Lambda scheme for FWM in K vapor to theoretically and experimentally investigate propagation of 80 ns probe pulse, and generation and propagation of conjugate pulse, which typically separates from the probe pulse at the and of the cell. This atomic scheme was used before to investigate slow light in Rb [1], Na [2]. In the model we first solve optical Bloch equations for all density matrix elements developed in the four level atomic system of K, coupled by three electric fields, pump, probe and conjugate. Calculated optical coherences are then used to calculate amplitudes of these fields as a function of time and distance using Maxwell propagation equation. In the experiment, we tune probe laser to Raman resonance with the pump laser by a pair of AOMs, and generate probe Gasussian 80 ns pulse, by EOM before it is combined with the pump laser and send to the hot K vacuum vapor cell. Group velocities were measured by recording the arrival times of the probe and the conjugate relative to the reference pulse.

Potassium is different from other alkali atoms, with small hyperfine structure, smaller then Doppler width. It wasn't so far used for slowing light pulses. Comparison between theory and experiment provides more insights into the dynamics of pulses propagation through this FWM medium. Agreement between theory and experiment, both qualitative in terms of similar pulse waveforms after the cell, and quantitative in terms of fractional delays and broadening, revels proper values of parameters in calculations, like dephasing and decoherence rates. Moreover, by placing, at the peak of input probe pulse, a small wavelets (amplitude much smaller in comparison with the probe pulse amplitude), and much shorter than the probe pulse, we can follow behavior of the probe pulse in the cell. We show that depending on the FWM parameters, pulses behave quite differently, in some cases showing complete disappearance, and revival of the pulse later in time. Results are given as a function of one photon pump detuning, two Raman pump-probe detuning, gas density, laser power and Rabi frequency.

[1] V. Boyer, C. F. McCormick, E. Arimondo, and P. D. Lett, Phys. Rev. Lett. **99**, 143601 (2007).
[2] J. Okuma, N. Hayashi, A. Fujisawa, and M. Mitsunaga, Opt. Lett. 34, 1654–1656 (2009).