Coherence accumulation effects in rubidium atoms

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We investigate resonant femtosecond pulse-train excitation of rubidium atoms in conditions when the characteristic atomic relaxation times are longer then the laser repetition period. In these conditions atoms can not completely relax between two consecutive pulses, which leads to the accumulation of population and coherence. As a result, atoms interact with the spectrum of the frequency comb, rather than the spectrum of the individual pulses. Experimental technique of the modified direct frequency comb spectroscopy is used, in which the femtosecond pulse train is used for resonant Rb D_1 5 $^2S_{1/2} \rightarrow 5\ ^2P_{1/2}$ (795 nm) and D_2 5 $^2S_{1/2} \rightarrow 5\ ^2P_{3/2}$ (780 nm) excitation. Continuous wave (cw) probe laser is used to monitor the Rb 5 $^2S_{1/2}$ ground state hyperfine level populations through Rb D_2 5 $^2S_{1/2} \rightarrow 5\ ^2P_{3/2}$ absorption.

Experimental evidence of the velocity-selective optical pumping of Rb 5 $^2S_{1/2}$ ground state hyperfine levels will be presented [1]. A theoretical model is developed which considers resonant femtosecond pulse-train excitation of 4 and 6 level Rb atoms, depending on the femtosecond laser wavelength. Theoretical results show that fractional hyperfine level populations exhibit a unique oscillatory structure with a period given by the laser repetition frequency. The intensity and shape of the observed population modulations are related to relative transition dipole moments of hyperfine transitions and hyperfine energy splittings. Based on calculated Rb 5 $^2S_{1/2}$ hyperfine level populations, theoretical simulation of Rb D_2 5 $^2S_{1/2} \rightarrow 5\ ^2P_{3/2}$ absorption spectra can be constructed. The agreement of these theoretical spectra with experimental ones measured with the use of the probe laser is very good.

It will be shown how a combined theoretical and experimental approach can be used for a direct visualization of the frequency comb by physical mapping of the optical frequency comb to the atom-velocity comb [2]. Additionally, prospects for using this technique for absolute frequency comb calibration will be discussed.

References:
[1] D. Aumiler, T. Ban, H. Skenderović and G. Pichler, Phys. Rev. Lett. **95**, 233001 (2005).
[2] T. Ban, D. Aumiler, H. Skenderović and G. Pichler, Phys Rev A **73**, 043407 (2006).