Femtosecond pulse train excitation of a Doppler broadened rubidium vapor

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The frequency spectrum of the pulse train consists of a series of fringes separated by the pulse repetition rate. The fringes are regular in frequency space if the pulses in the pulse train have a defined phase relation relative to each other. In the systems where the atomic coherence relaxation time is longer than the pulse repetition period the atoms interact with the spectrum of the pulse train, and not with the spectrum of a single pulse. In that account the short pulse trains can be used for the high resolution spectroscopy [1,2], where the observed linewidths are much less than the Fourier- transform limit of the individual pulse in the train.

In our recent papers [3,4] we presented the observation of the velocity selective population transfer between the Rb ground state hyperfine levels induced by fs pulse train excitation. We developed a modified direct frequency comb spectroscopy (DFCS) which uses a fixed frequency comb for the ^{85,87}Rb $5^2S_{1/2} \rightarrow 5^2P_{1/2,3/2}$ excitation (Tsunami mode-locked Ti:sapphire laser with pulse duration of 100 fs and pulse repetition of 80 MHz) and a weak cw scanning probe (TOPTICA DL100, ECDL at 780 nm) for ground levels population monitoring. The Rb($5^2P_{1/2,3/2}$) excited atomic levels have the relaxation times greater than the fs laser repetition period. In the time domain this leads to population and coherence accumulation effects. This corresponds to the interaction of the Rb atoms with the fs frequency comb in the frequency domain. As a result, velocity selective excited state hyperfine level populations are obtained, i.e. the mapping of the frequency comb to the atomic velocity comb. Simultaneously, velocity selective optical pumping of the ground hyperfine levels is achieved. We measured the ^{85,87}Rb ($5^2P_{1/2,3/2}$) hyperfine levels population by monitoring the $5^2S_{1/2} \rightarrow 5^2P_{3/2}$ probe laser absorption. Modulations in the $5^2S_{1/2} \rightarrow 5^2P_{3/2}$ hyperfine absorption line profiles are observed as a direct consequence of the velocity selective optical pumping induced by the frequency comb excitation. The ^{85,87}Rb $5^2S_{1/2} \rightarrow 5^2P_{1/2,3/2}$ fs pulse train excitation of a Doppler broadened rubidium vapor was investigated theoretically in the context of the density-matrix formalism. Simulated $5^2S_{1/2} \rightarrow 5^2P_{3/2}$ absorption profiles were compared with the experiment and the agreement was excellent. The dependence of the observed modulations upon the wavelength and power of the fs laser and external magnetic field was investigated experimentally.

References

[1] A. Marian, M. C. Stowe, J. R. Lawall, D. Felinto and J. Ye, Science 306, 2063 (2004).
[2] A. Marian, M. C. Stowe, D. Felinto and J. Ye, Phys. Rev. Lett. 95, 023001 (2005).
[3] D. Aumiler, T. Ban, H. Skenderovic and G. Pichler, Phys. Rev. Lett. 95, 233001 (2005).
[4] T. Ban, D. Aumiler, H. Skenderovic and G. Pichler, to be published in Phys. Rev. A (2006).