Coherent interaction of atoms with a femtosecond laser

Sandra S. Vianna

Departamento de Física,Universidade Federal de Pernambuco,50670-901 Recife, Brazil

vianna@ufpe.br

In recent years, femtosecond lasers have became a standard tool for the development of several branches of science. In particular, the use of these lasers has been responsible for major breakthroughs in the field of coherent control, with prospects for applications in physics, biology and chemistry. The coherent control techniques are usually designed for the excitation of the system by single pulses from the laser. This fact has been explored using both temporal coherent control, in which case pairs of pulses of equal shape are employed to both excite and probe the sample, and optimal control techniques, where the control has been achieved by manipulating the coherent properties of the optical field.

Here we report on coherent accumulation processes in three-level atoms excited by a train of femtosecond optical pulses in a situation where the atomic relaxation times are greater than the laser repetition time, T_R. In this case the resonances of the laser field with the atomic system are determined by the laser frequency comb rather than by the spectrum of a single pulse. In particular, we review theoretical predictions concerning accumulation effects on both the population and coherence of an atomic system for a sequential two-photon transition and for two different pulses envelops: hyperbolic secant and 0π pulses [1], and it is shown that the populations excited by two-photon absorption are dramatically different, within the Doppler profile. The predicted results are compared with data from temporal-coherent-control experiments in rubidium vapor. Results for accumulative effects recently observed in time-resolved four-wave mixing and probe-pump experiments are also presented.

Experimental results not affected by accumulation processes are also discussed. In particular, we analyze four-wave mixing with incoherent pulses from broadband dye lasers with very long repetition times [2]. In these lasers there is no phase relation between the longitudinal modes. This contrasts with the previous experiments, where the role of the laser frequency comb is fundamental. However, we show that some of the interferences between different quantum paths are preserved because the atomic system filters out the relevant frequency components of the incident light. These interferences have also been observed with time-delayed femtosecond pulses [3] and despite the fact that in the later case accumulation could be present, a single pulse pair description accounts for all the main features of the experimental results.

References:

[1] D. Felinto, L. H. Acioli and S. S. Vianna, Phys. Rev. A **70**, 043403 (2004).

[2] J. Ferraz, D. Felinto, L. H. Acioli and S. S. Vianna, Opt. Lett. **14**, 1876 (2005).

[3] H. G. Barros, J. Ferraz, W. Lozano B., L. H. Acioli, and S. S. Vianna, Phys. Rev. A **74**, 055402 (2006).