Enhancement of frequency up-conversion in atomic media

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Low-intensity nonlinearity of atomic media associated with light-induced atomic coherence may result in the generation of new optical fields with substantial frequency up-conversion [1]. Our investigations of frequency up-conversion are mainly motivated by possible applications in the generation of correlated fields with a substantial frequency difference; however, an extension of this approach for sensitive atom detection seems realistic.

We have studied frequency up-conversion of near-IR resonant laser radiation in Rb vapour. After excitation into the $5D_{5/2}$ level by co-propagating laser beams at 780 nm and 776 nm, Rb atoms decay to the $6P_{3/2}$ level and then to the ground state, emitting spontaneous photons at 420 nm. At sufficiently high atomic density and laser intensity, blue light with very low divergence appears as a result of wave mixing of the laser fields with the third field at 5.2 μm produced by stimulated emission from the $5D_{5/2} - 6P_{3/2}$ transition. We find that the direction of the coherent blue light (CBL) agrees with the phase-matching relation determined by the wave vectors of all the optical fields and the refractive indices they see. The direction along which optimal matching condition is achieved forms a light-induced waveguide for CBL generation.

The spatial and spectral properties of CBL are very sensitive to various parameters, such as the frequency detuning, the polarization of the applied laser fields and their spatial overlap [2]. We have also studied the influence of optical pumping on CBL generation. Velocity selective optical pumping produced by a laser tuned to the D1 line at 795 nm can decrease the atomic density threshold of CBL generation, enhance the CBL intensity as shown in Fig. 1, and affect the blue beam transverse spatial distribution. Fig. 1c shows (i) CBL temporal dependence when a sharp-edge optical pumping pulse (ii) is applied. We note also that velocity selective depopulation produced on the D1 line may decrease the CBL intensity. Thus, optical pumping allows efficient control of the CBL generation.

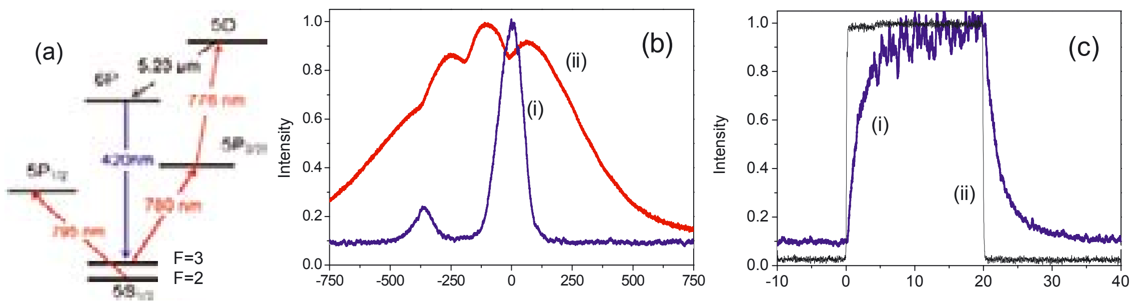

Fig. 1: (a) Energy level scheme; (b) Curve (i) shows the blue light intensity as a function of the optical pumping laser detuning from the $5S_{1/2}(F = 2) - 5P_{1/2}(F' = 3)$ transition, while curve (ii) represents the reference fluorescence profile; (c) Temporal blue light intensity evolution with pulsed optical pumping.

Possible schemes for generation of ultraviolet and THz radiation, as well as a pair of correlated optical fields from different spectral regions using this approach are under our investigation.

References

[1] A. S. Zibrov, M. D. Lukin, L. Hollberg, and M. O. Scully, Phys. Rev. A **65**, 051801 (2002).
[2] A. M. Akulshin, R. J. McLean, A. I. Sidorov, and P. Hannaford, Optics Express **17**, 22861 (2009).