Investigation of the high-contrast sub-Doppler absorption spikes observed in a cesium vapor cell under the dual-frequency regime

Denis Brazhnikov[1,2], Moustafa Abdel Hafiz[3], Grégoire Coget[3], Alexei Taichenachev[1,2], Valeriy Yudin[1,2,4], Emeric de Clercq[5], Rodolphe Boudot[3]

[1]Institute of Laser Physics SB RAS, Novosibirsk 630090, Russia

[2]Novosibirsk State University, Novosibirsk 630090, Russia

[3]FEMTO-ST, CNRS, UBFC, 26 rue de l'épitaphe 25000 Besançon, France

[4]Novosibirsk State Technical University, Novosibirsk 630073, Russia

[5]LNE-SYRTE, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universités, UPMC Univ. Paris 06, 61 avenue de l'Observatoire, 75014 Paris, France

Recently, the new bright feature of Doppler-free resonance in a cesium vapor cell under the two-frequency counterpropagating light waves has been observed [1] (see Fig.1). It consists in observation of a natural-linewidth nonlinear resonance with very high contrast. In spite of this effect is becoming very useful tool for laser frequency stabilization in CPT atom clocks [2, 3], it has not been understood and studied well enough. Here we focus on the detailed experimental as well as theoretical study of the new effect. Three physical reasons have been revealed that can result in observation of enhanced absorption at the center of the resonance. Moreover, simultaneous and constructive action of these reasons can greatly increase amplitude of the nonlinear resonance, which can be two times bigger than a wide Doppler background. Theory is based on a well-known Λ-scheme of atomic energy levels. The scheme has provided us with very clear physical interpretation of the effect. The real structure of atomic energy levels with taking into account all magnetic sublevels has been also considered.

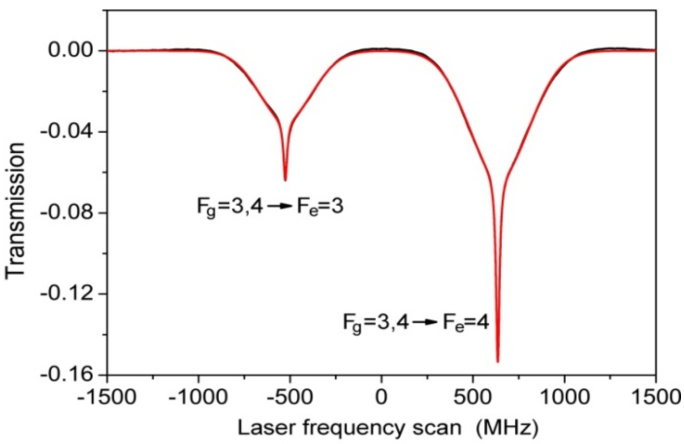

Figure 1. The high-contrast Doppler-free resonances in a cesium vapor cell.

Russian part of the team thanks RFBR (grant nos. 15-02-08377, 17-42-543193), LabeX FIRST-TF and RSF (project nos. 16-12-00054, 16-12-10147). French authors thank LabeX FIRST-TF, Région de Franche-Comté, EURAMET (EMRP programm, MClocks project) and DGA. The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union.

[1] M. Abdel Hafiz, G. Coget, E. De Clercq, R. Boudot, Opt. Lett. **41**, 2982 (2016).
[2] M. Abdel Hafiz *et al.*, J. Appl. Phys. **121**, 104903 (2017).
[3] P. Yun *et al.*, Phys. Rev. Appl. **7**, 014018 (2017).