Bichromatic spectroscopy and coherent population trapping in Samarium vapour

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High Q-factor of "dark" resonances in an atomic system makes them rather attractive for metrological applications. In a Λ - system the width of a "dark" resonance is limited by the relaxation time of the atomic coherence between the two lower levels and under appropriate experimental conditions can reach tens of Hertz [1]. It allows to consider this atomic system as a secondary frequency standard in which the difference of two optical frequencies is precisely stabilized [2].

So far most of experimental studies in this field have been performed with alkali atoms, where the lower levels of the Λ - system were the two hyperfine components of the ground state with the typical splitting of several GHz. In rare-earth elements the Λ - system can be built using the fine-structure components of the $4f^n 6s^2$ ground state multiplet with a typical separation of 10 - 100 THz. So one can expect an increase of the Q-factor of the "dark" Λ - resonances by 2 - 3 orders of magnitude.

In this contribution we describe the first experimental observation of such Λ - resonances in samarium vapour. In samarium atom the first metastable level $4f^6 6s^2(7F_1)$ of the $4f^6 6s^2$configuration is separated from the ground state $4f^6 6s^2(7F_0)$ by 293 cm^{-1}. We chose this two levels as the lower levels of Λ - system while the upper level is $4f^6(7F)6s6p(^3P^0)$ $^9F^0{}_1$ (Fig. 1).

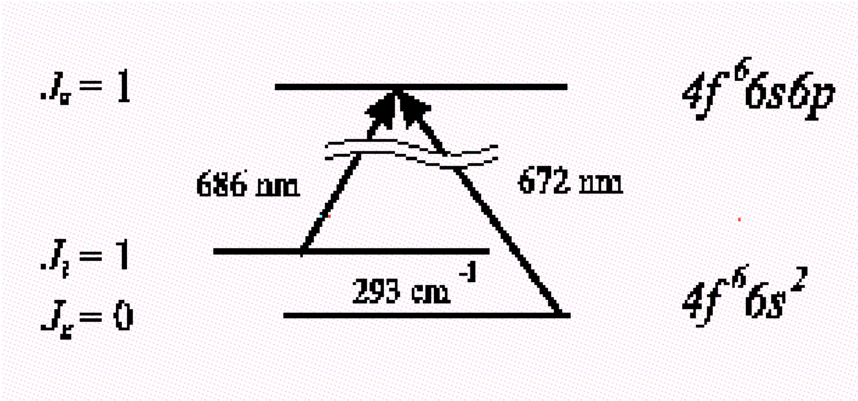

Figure 1: The energy levels forming a Λ - system in Sm atom

Two stabilized diode lasers (672 nm, 686 nm) were tuned to the transitions shown in Fig. 1. Sm has seven stable isotopes and we used the saturation absorption technique for the analysis of isotopic shifts and hyperfine structure of our transitions. By scanning the laser frequencies we recorded the saturation absorption spectra for both transitions with 1 - 2 MHz resolution. The spectra were interpreted, the relative isotopic shifts and hyperfine splitting were determined. The absolute frequencies of 672 nm transitions were measured using an iodine reference cell.

We used the levels of a well-abundant (23%) ^{154}Sm isotope with a zero nuclear spin for two-wave spectroscopy. It possesses a simple level structure ($I = 0$; $F_{g,l,u} = 0, 1, 1$) and the transitions are well separated from all others. Sm atomic vapour was illuminated by co-propagating laser beams. The 672 nm laser was locked to the $4f^6 6s^2(7\mathrm{F}_0) \rightarrow 4f^6(7\mathrm{F})6s6p(^3\mathrm{P}^0)$ $^9\mathrm{F}^0{}_1$ transition while the 686 nm laser was scanned through the $4f^6 6s^2(7\mathrm{F}_1) \rightarrow 4f^6(7\mathrm{F})6s6p(^3\mathrm{P}^0)$ $^9\mathrm{F}^0{}_1$ transition. We measured the changes in the absorption of one of the laser beams induced by the other beam. Fig. 2 shows a typical CPT spectra in ^{154}Sm recorded with orthogonal linear polarisations of the laser beams. We shall present the results of experimental study of CPT resonances under different experimental conditions (different magnetic fields, buffer gas pressures, and different polarisations of the laser beams) along with a theoretical analysis of these results.

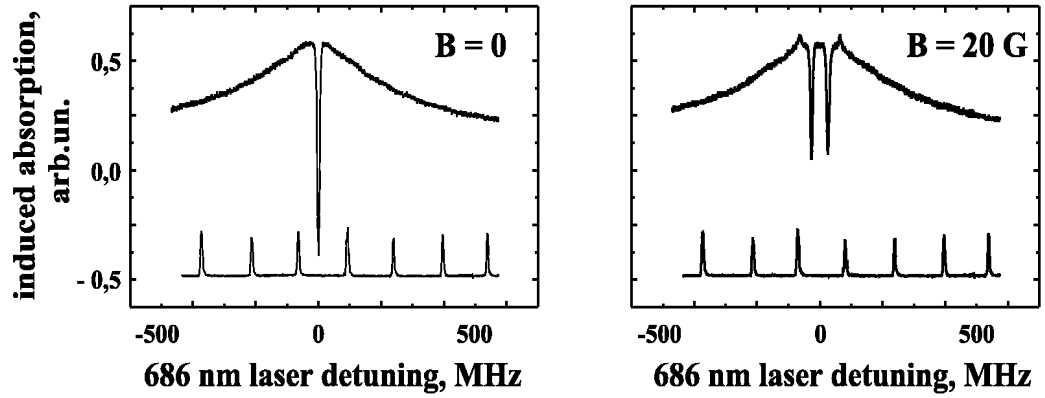

Figure 2: The resonances of CPT in ^{154}Sm recorded in the absence (left) and in the presence (right) of a magnetic field $\mathbf{B}$ directed along the polarization of 672 nm laser. The lower graph represents the frequency marks of 0,5-m confocal cavity.

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