Realization of radio-frequency assisted Förster resonances in an ensemble of a few cold Rb Rydberg atoms

C. Andreeva[1], A. Cinins[2], A. Ekers[3], A. Markovski[4], D. Tretyakov[5], V. Entin[5], I. Beterov[5,6], E. Yakshina[5,6], and I. Ryabtsev[5,6]

[1] *Institute of Electronics, Bulgarian Academy of Sciences, Sofia*
[2] *Institute of Atomic Physics and Spectroscopy, Latvian University, Riga*
[3] *King Abdullah University of Science and Technology, Saudi Arabia*
[4] *Faculty of Automatics, Technical University of Sofia, Bulgaria*
[5] *Institute of Semiconductor Physics, Russian Academy of Sciences, Novosibirsk*
[6] *Novosibirsk State University, Russia*

Presenting Author: christina_andreeva@yahoo.com

We present the realization of radio-frequency-assisted Förster resonances in cold Rb Rydberg atoms in a magneto-optical trap [1]. Förster resonances occur due to dipole-dipole interaction between Rydberg atoms when the atoms are laser-excited to a level that lies midway between two other levels of opposite parity. In the standard experiments, the resonant condition is realized by tuning the levels by means of weak electric field.

In our experiments we excite cold Rb atoms to the initial 37P state. At dc electric field of 1.79 V/cm there is a single Förster resonance 37P+37P $\rightarrow$ 37S+38S and Rydberg atoms in the final state 37S are detected by means of selective field ionization technique. If we admix a radio-frequency electric field to the dc field, it can induce additional Förster resonances. The rf photons compensate for the energy defect of the Förster resonance and induce additional resonances, which correspond to the induced absorption or emission of rf photons. If the rf amplitude is large enough, it can even induce multiphoton transitions of high orders.

Not all levels can be used to realize Förster resonances by tuning dc electric field. An example of such „inaccessible" Förster resonance is the 39P+39P $\rightarrow$ 39S+40S, for which the dc field alone increases the energy detuning. However, our experience with the Förster resonance for the 37P state suggests that the rf-field can induce transitions between collective states, so the Förster resonance occurs irrespective of the possibility to tune it by the dc field alone. The dc field, however, should be applied to increase its efficiency. We have obtained a Förster resonance at 39P+39P $\rightarrow$ 39S+40S with rf-field at multiple frequencies. The position of the rf-assisted Förster resonance depends on the rf-frequency, while its width and height depend on the number of atoms N.

These resonances correspond to single- and multiphoton rf-transitions between many-body collective states of a Rydberg quasi-molecule or to intersections of the Floquet sidebands of Rydberg levels appearing in the rf-field. We have shown that they can be induced both for the "accessible" Förster resonances, which are tuned by the dc field, and for those which cannot be tuned and are "inaccessible". The van der Waals interaction of almost arbitrary high Rydberg states can thus be efficiently transformed to resonant dipole-dipole interaction using the rf-field with frequencies below 1 GHz. This strongly enhances the interaction strength and distance and can give rise to much stronger dipole blockade effect, which is used in numerous applications of Rydberg atoms.

This work was supported by RFBR (Grant Nos. 13-02-00283 and 14-02-00680), the Russian Academy of Sciences, and the Russian Quantum Center.

References

[1] D.B. Tretyakov *et al.* Phys. Rev. A **90** 041403(R) (2014)