Ultracold doubly-polar molecules: on the way to create them via a Laser-Assisted Self-Induced Feshbach Resonance

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Controlling the scattering properties between ultracold alkali-metal atoms and alkaline-earth or ytterbium atoms (with a closed-shell (^{1}S) ground state) offers fascinating perspectives like the realization of topological phases of matter [1], novel Efimov states with systems of large mass imbalance, or the formation of ultracold polar paramagnetic molecules which are promising for instance for quantum simulation of lattice-spin systems [2]. It has long been thought that if one of the atoms has no magnetic moment, magnetic Feshbach resonances (MFR) could not be observed. A subtle coupling mechanism has been recently invoked to predict MFRs between paramagnetic Rb(^{2}S) and non-magnetic Sr(^{1}S) atoms [3, 4]. The observation of the resulting very narrow MFR remains however challenging [4].

We propose a new type of Feshbach resonance (FR): the Light-Assisted Self-Induced Feshbach Resonance (LASIFR), where the closed and open coupled channels characterizing the FR are both associated with the electronic ground state of a heteronuclear diatomic molecule, which possesses an intrinsic permanent electric dipole moment (PEDM) varying with the internuclear distance. A sub-THz photon couples the pair of ultracold atoms, occupying for instance the lowest motional state of an optical lattice site, to a bound rovibrational state close to the dissociation limit. The resonant pattern becomes obvious in the field-dressed-state picture, which formally maps the scheme of a MFR.

The interspecies scattering length can then be controlled by both the intensity and the detuning of the photon frequency with respect to the transition one. A frequency chirp across the resonance can be engineered to fulfill the adiabaticity criterion for the complete population transfer toward the molecular bound level. Like with a "regular" MFR, a STIRAP can be followed for transferring the population to the absolute ground state. We exemplify this proposal with the case of RbSr, based on our investigations on the structure of this molecule [5, 6].

The similarities of the proposed approach with previous works (see for instance [7, 8]) will also be discussed.

References

1. F. Schafer, N. Mizukami, P. Yu, S. Koibuchi, A. Bouscal, and Y. Takahashi, Phys. Rev. A **98**, 051602 (2018).
2. A. Micheli, G. K. Brennen, and P. Zoller, Nature Physics **2**, 341 (2006).
3. P. S. Zuchowski, J. Aldegunde, and J. M. Hutson, Phys. Rev. Lett. **105**, 153201 (2010).
4. V. Barbé, A. Ciamei, B. Pasquiou, L. Reichsöllner, F. Schreck, P. S. Zuchowski, and J. M. Hutson, Nat. Phys. **14**, 881 (2018).
5. A. Devolder, E. Luc-Koenig, O. Atabek, M. Desouter-Lecomte, and O. Dulieu, Phys. Rev. A **98**, 053411 (2018)
6. P. S. ˙ Zuchowski, R. Guérout, and O. Dulieu, Phys. Rev. A **90**, 012507 (2014).
7. S. Kotochigova, Phys. Rev. Lett. **99**, 073003 (2007).
8. M. Tomza, R. Gonzalez-Ferez, and C. P. K. N. R. Moszynski, Phys. Rev. Lett. **112**, 113201 (2014)