***Laser Pulse Shaping and Coherent Control of Molecules***, *Brijuni, Croatia, August 26th - 31st, 2007.*

# Prospects for formation of stable ultracold molecules via photoassociation with chirped laser pulses

Eliane Luc-Koenig, Jordi Mur-Petit and Françoise Masnou-Seeuws

*Laboratoire Aimé Cotton, bât.505 Campus d'Orsay, 91405 Orsay Cedex France*

eliane.luc@lac.u-psud.fr, jordi.mur@lac.u-psud.fr, francoise.masnou@lac.u-psud.fr

Our group has been working for a few years at the theoretical description of photoassociation with chirped laser pulses [1], and formation of stable ultracold molecules in a pump-dump experiment [2]. This work shows that pulses in the picosecond range are very convenient. Recently [3], in connection with ongoing experiments of Walmsley's group in Oxford [4], we have proposed to use dynamical interferences in order to probe short pulse photoassociation of cold Rb atoms. Indeed, when a pump laser pulse couples the ground state continuum to bound vibrational levels of $Rb_2$ $0_u^+(5P_{1/2})$ and $0_u^+(5P_{3/2})$, the non-adiabatic coupling between the two channels induces time-dependent beatings in the populations. We show that these oscillations can be exploited to probe the photoassociated molecule with a delayed ionizing pulse, or to optimize the stabilization into vibrational levels of the ground state with a dump pulse.

In collaboration with Ronnie Kosloff (Jerusalem), we have investigated [5] how a photoassociation pulse is carving out a dynamical hole in the stationary scattering wavefunction describing colliding atoms in the initial state. Considering, as a case study, photoassociation into loosely bound levels of $Cs_2$ $0_g^-(6P_{3/2})$, we analyze the depletion of the ground triplet state wavepacket and its evolution after the pulse. We show that, due to a "momentum kick", a significant flux of population is moving to short distances, at the timescale of the vibrational motion in the excited state. This compression effect markedly increases the density probability at short distances, so that photoassociation with a conveniently delayed red-detuned second pulse will populate deeply bound levels of $Cs_2$ $0_g^-(6P_{3/2})$. Another signature of the hole is the formation of correlated pairs of hot atoms.

In collaboration with Pascal Naidon (NIST) [6], we study how short pulse photoassociation can probe the pair correlation function in a condensate. Calculations are performed for the case of a metastable helium condensate, where the correlated pairs of hot atoms are detected in the experiment of the Westbrook's group [7] in Orsay.

References:

[1] E. Luc-Koenig, R. Kosloff, F. Masnou-Seeuws and M. Vatasescu, Phys. Rev. A **70**, 034414 (2004), E. Luc-Koenig, M. Vatasescu and F. Masnou-Seeuws, Eur. Phys. J. D **31**, 239-262 (2004), C. P. Koch, R. Kosloff, E. Luc-Koenig, F. Masnou-Seeuws and A. Crubellier, J. Phys. B **39**, S1017 (2006)

[2] C. P. Koch, E. Luc-Koenig and F. Masnou-Seeuws, Phys. Rev. A **73**, 0033408 (2006)

[3] J. Mur-Petit, E. Luc-Koenig and F. Masnou-Seeuws, Phys. Rev. A **75**, 061404(R) (2007)

[4] B. L. Brown, A. J. Dicks, and I.A. Walmsley, Phys. Rev. Lett. **96**, 173002 (2006)

[5] E. Luc-Koenig, F. Masnou-Seeuws and R. Kosloff, submitted to Phys. Rev. A

[6] P. Naidon and F. Masnou-Seeuws, Phys. Rev. A**73**, 043611 (2006)

[7] M. Schellekens, R. Hoppeler, A. Perrin, J. Viana Gomes, D. Boiron, A. Aspect, C. Westbrook, Science **310**, 648 (2005), J. Jeltes *et al* Nature **445**, 402 (2007)