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Shaping potentials at 'will':
Making cold molecules with coherent control

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While ultracold matter brought quantum effects onto the macroscopic scale, ultrafast lasers made quantum dynamical phenomena observable in real-time. Bringing the two together seems natural and holds the promise of employing quantum interferences in an unprecedented way. Photoassociation provides an optimal framework for the merger since in principle it relies only on the presence of optical transitions. Combining it with coherent control where the potential energy surfaces governing the dynamics can be 'shaped', a general route toward stable ultracold molecules is obtained.

Theoretical predictions for coherent formation of ultracold calcium dimer molecules in a two-color pump-dump scheme [1] will be presented. The pump or photoassociation pulse transfers part of the atomic density into an electronically excited molecular state, giving rise to a non-stationary wavepacket. Subsequently, the dump or stabilization pulse catches this wavepacket, sending it back to the electronic ground state before spontaneous decay sets in. This pump-dump scheme leads to ultracold ground state molecules as well as pairs of hot atoms. The efficiency of molecule formation is determined by the shape of the excited state potentials [2].

While in the heavy alkali systems potentials favorable for both the pump and dump steps exist, they are missing in alkaline earths such as calcium. It is shown that an additional external field can be employed to change the excited state dynamics qualitatively. The additional external field can be realized by a narrow-bandwidth nanosecond pulse of moderate intensity in the near infrared. Thus the proposed scheme takes the coherent control concept of 'shaping' the potentials which govern the dynamics literally without resorting to full optimal control. This yields an intuitive, robust mechanism facilitating dynamics toward the vibronic ground state.

References:

[1] C.P. Koch, E. Luc-Koenig, and F. Masnou-Seeuws, *Phys. Rev. A* **73**, 033408 (2006)

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