

# Triplet or Singlet Molecular vibrational cooling by Optical Pumping with shaped pulses

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## Why cold molecules?

- Fundamental tests (e- dipole, chirality, variation of fundamental constants)
- Photochemistry (photoassociation)
- Quantum properties (dipole), molecular collective quantum systems BEC, BCS
- Quantum Reactions and control
- Frequency standards and ultracold chemistry
- Quantum information, ... [3]

Need ultra-cold molecules in  $v_x=J=0$

## Gold molecules made of cold atoms [4]

-Magnetoassociation (Feshbach Resonance) 2002-2003  
(R. Grimm, C. Salomon, W. Ketterle, D. Jin, G. Rempe, ...)



-Collision with another partner, 3-body recombination  
(E. Cornell, C. Gabbanini, R. Grimm, 1998-2003, ...)



-Photoassociation, (Pillet 1997, ...)



All form cold molecules but with high vibration

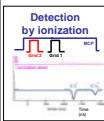
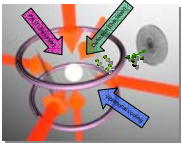
## Motivation

- Ultra-cold [1]
  - Laser cooling of atoms : reduction of velocity through accumulation of light momentum.
- Laser manipulation of molecules [2]
  - laser sources and spectral-shaping techniques as main tool to cool down and control all degrees of freedom

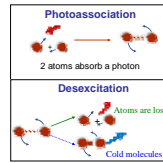
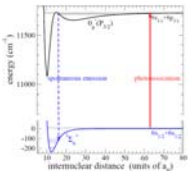
->Toward the ro-vibrational cooling of ultra-cold molecules

## Experiment

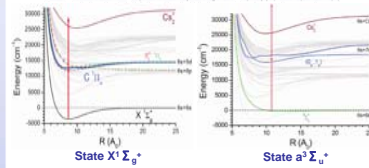
- Cs MOT:
- T=100μK
  - diameter ~400μm
  - density ~5·10<sup>10</sup>cm<sup>-3</sup>



## Photoassociation of cold atoms [5]



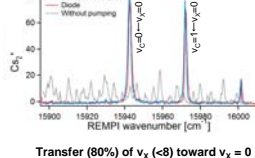
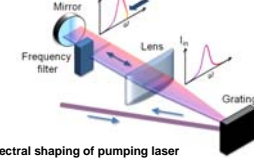
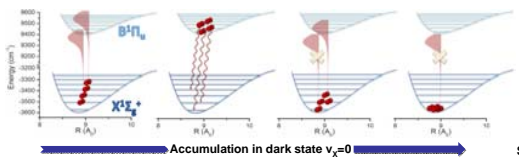
## REMPI\* detection schemes



Both detection schemes are performed in the same frequency range

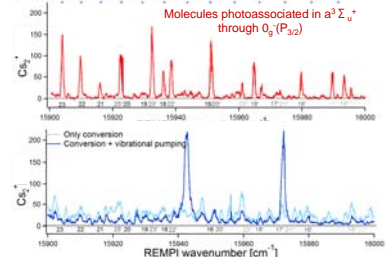
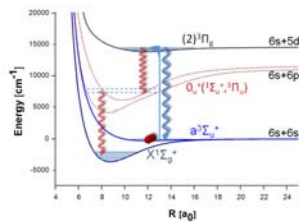
\*REMPI: Resonantly Enhanced Multi-Photon Ionization

## Optical pumping and vibrational cooling [6,7]

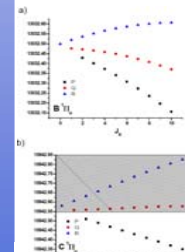


## Triplet-singlet conversion by a broadband laser

Scheme for state conversion



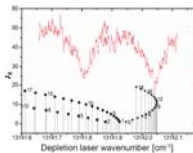
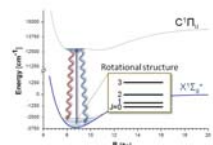
## Next step: Rotational cooling



Initial idea:  
Remove the Q and R branches from the excitation spectrum  
→ Difficult for the B<sup>1</sup>Π<sub>u</sub> state  
→ Feasible for the C<sup>1</sup>Π<sub>u</sub> state  
  
Required Resolution:  
~ 500 MHz

## Measuring the rotational population

Scheme for depletion measurement



Depletion spectroscopy of  $v_x=1$  level. Diode laser is scanned on  $v_x=1$  to  $v_x=4$  transition. Calculated lines for P, Q and R branches are shown (with  $J_x$ ).

## Outlook

- Studies of rotations and rotational cooling.
- Molecular trapping.