High-resolution imaging of C-He and C-H_2 collisions using a Zeeman decelerator

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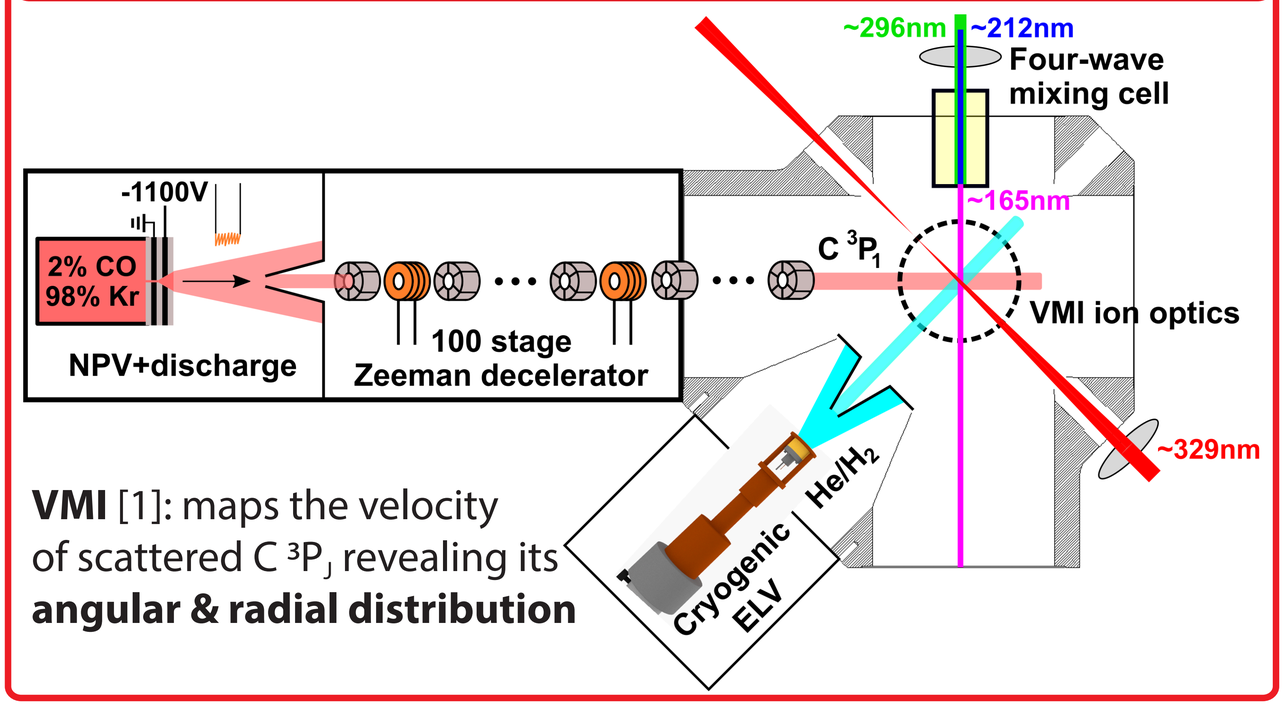
1. Goals

Testing models of molecular interactions with high-resolution crossed beam **scattering experiments**.

Extend the diversity of these scattering experiments to paramagnetic species, with the use of a **Zeeman decelerator**.

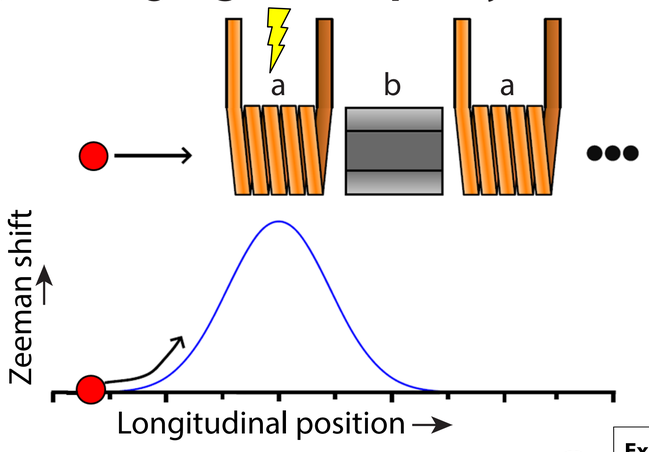
2. Crossed beam setup



VMI [1]: maps the velocity of scattered C ^3P_J revealing its **angular & radial distribution**

3. Zeeman decelerator

The Zeeman shift in paramagnetic species allows the use of strong, pulsed magnetic fields (>2.5 T) to state-selectively decelerate [2] providing **high-state-purity beams with narrow velocity spreads**.

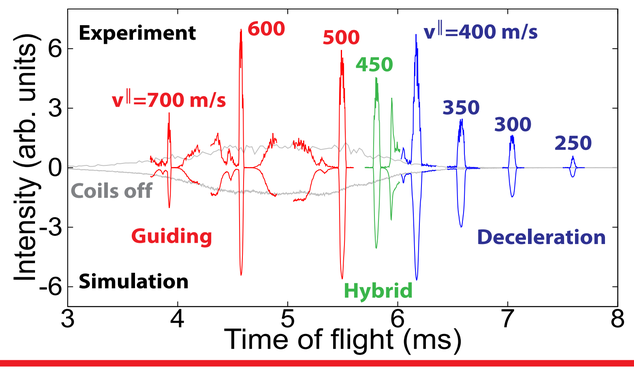


Alternating array of:

Pulsed solenoids[a]
- Used to guide/decelerate
- Longitudinal (∥) focussing

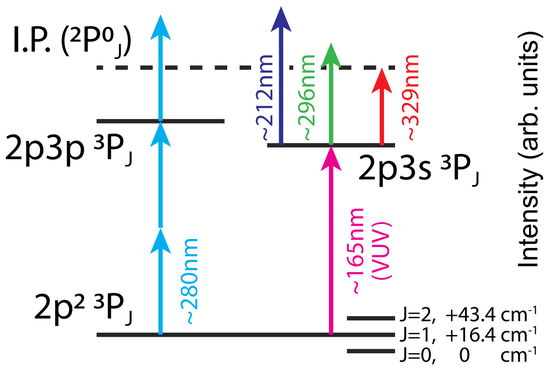
Permanent hexapoles[b]
- Transverse (⊥) focussing independent of solenoids

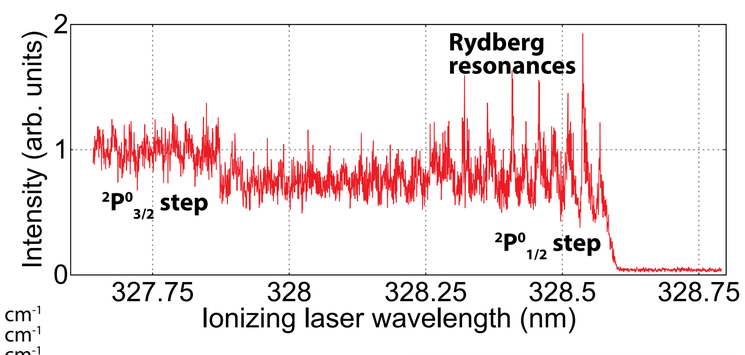
Computer controlled C-atom $^3P_1$ state longitudinal velocity ($v^{\parallel}$)



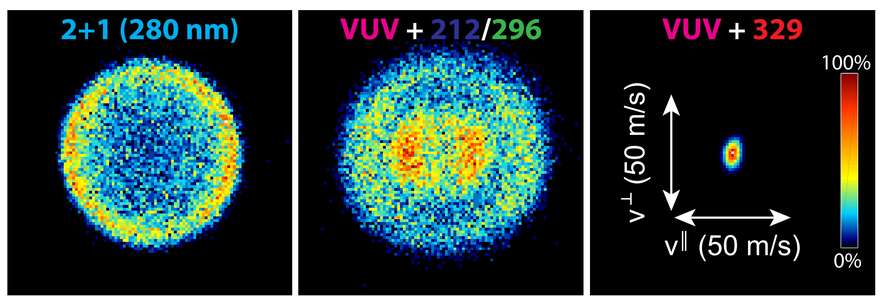
4. Recoil-free C-atom REMPI

Four-wave mixing [3] of 212 nm and 296 nm in a Kr gas cell generates 165 nm VUV. Subsequent threshold ionization by ~329 nm enables **efficient high-resolution detection**.



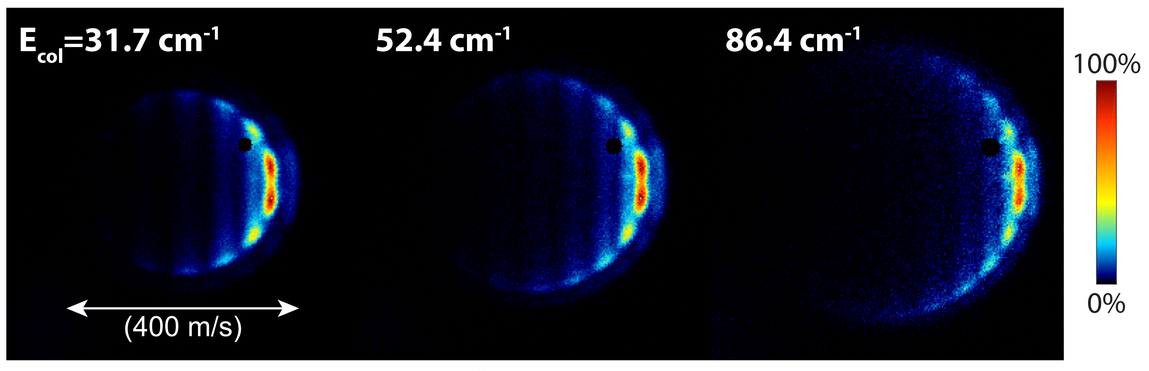


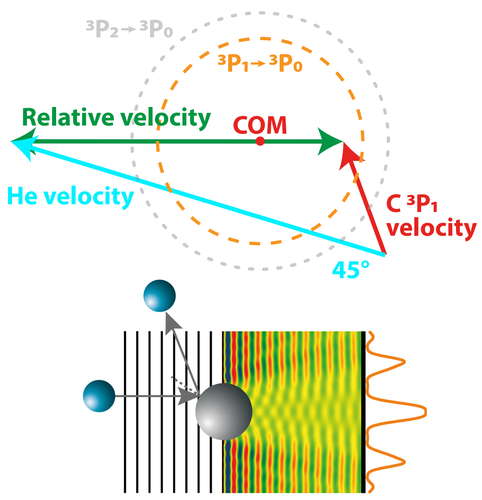
Imaged decelerated C$^3P_1$ beam **$v^{\parallel}$=300 m/s**



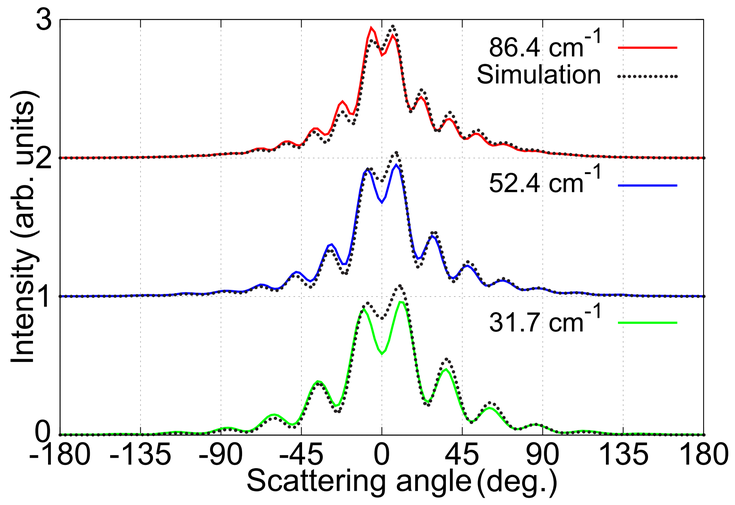
$v^{\parallel}$ (m/s)	FWHM $v^{\parallel}$ (m/s)		FWHM $v^{\perp}$ (m/s)	
	Exp.	Sim.	Exp.	Sim.
700	15.6	13.8	10.0	7.3
600	13.5	13.1	9.7	7.4
500	12.2	11.9	11.5	10.4
450	9.2	8.8	10.9	11.7
400	11.7	11.8	7.7	8.6
350	6.7	6.6	8.9	7.3
300	**4.8**	**3.9**	**7.8**	**9.9**
250	4.1	2.1	8.0	7.2

5. C-He collisions ($^3P_1 \rightarrow {}^3P_0$)



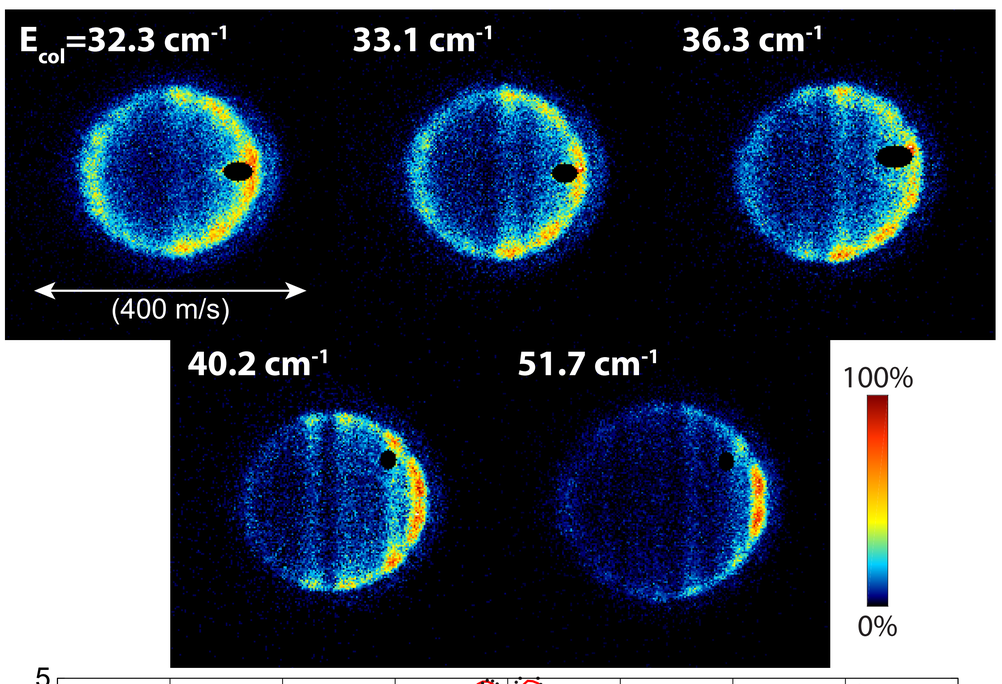


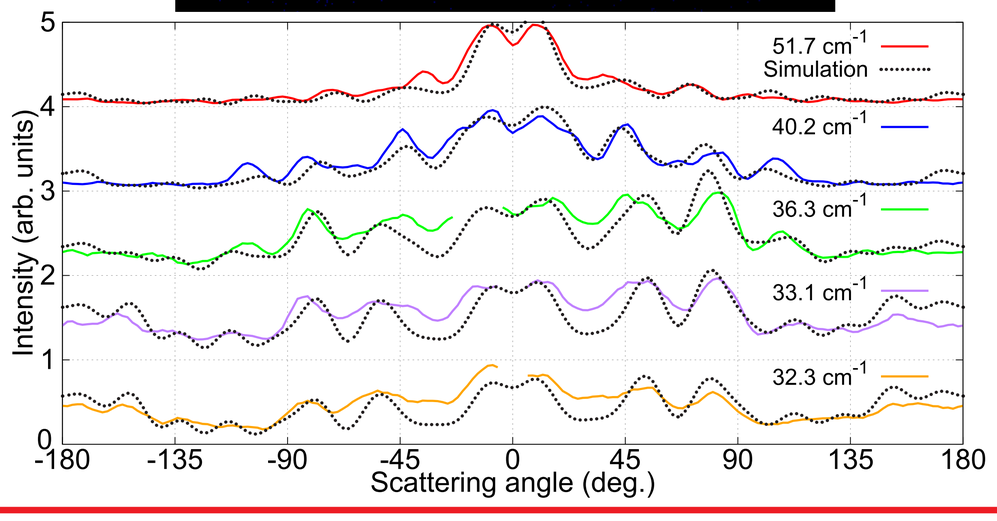
Diffraction oscillations [4]



Simulations based on ab initio calculations of the cross sections

6. C-H_2 collisions ($^3P_1 \rightarrow {}^3P_0$) - Preliminary





7. Conclusion & Outlook

We developed an **efficient recoil-free detection** scheme for C ^3P_J atoms. Combined with **Zeeman deceleration & VMI** this allows for **high-resolution imaging of C-He and C-H_2 collisions**, where we directly **observe diffraction oscillations and rapid changes** in the angular scattering distribution with changing energy. **Excellent agreement** is found with simulations based on **ab initio calculations** of the cross sections.

We aim to **extend this experiment** to investigate scattering **resonances in low-energy C-He and C-H_2** collisions and image **reactive collisions of C with O_2**.

Acknowledgements & References

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[1] Mol. Phys. 119, e1814437 (2020)

[2] Phys. Rev. A 98, 033406 (2018)

[3] Instrum. Sci. Technol. 28, 85 (2000)

[4] Nat. Chem. 6, 216 (2014)

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