A Cryogenic Cylindrical Ion Trap Velocity Map Imaging Spectrometer

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Abstract

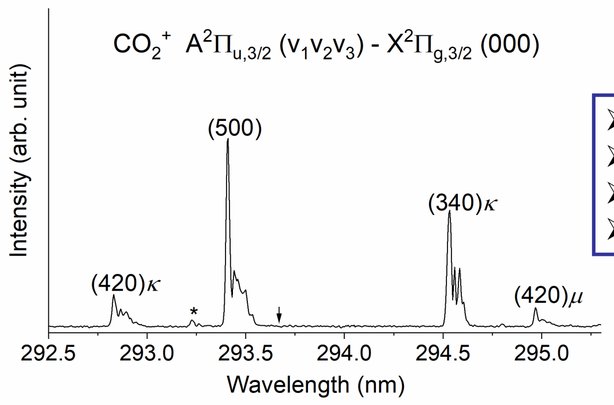
A cryogenic cylindrical ion trap velocity map imaging spectrometer (CIT-VMI) has been developed to study photodissociation spectroscopy and dynamics of gaseous molecular ions and ionic complexes. A cylindrical ion trap (CIT) made of oxygen-free copper is cryogenically cooled down to ~7 K by a closed cycle helium refrigerator and is coupled to a velocity map imaging (VMI) spectrometer. For CO_2^+ ions, a rotational temperature of ~12 K is estimated from the recorded [1+1] two-photon dissociation spectrum, and populations in spin-orbit excited $X^2\Pi_{g,1/2}$ and vibrationally excited states of CO_2^+ are found to be non-detectable, indicating an efficient internal cooling of the trapped ions. Based on the time-of-flight peak profile and the image of N_3^+, the velocity spread of the ions extracted from the trap, both radially and axially, is interpreted as approximately ±25 m/s. Experimental image of fragmented Ar^+ from 307 nm photodissociation of Ar_2^+ shows that, benefitting from the well-confined velocity spread of the cold Ar_2^+ ions, a VMI resolution of Δv/v ~ 2.2% has been obtained.

Introduction

A combination of radio frequency cylindrical ion trap and velocity map imaging make it possible to study high resolution photodissociation spectroscopy and dynamics of molecular and cluster ions by an ion beam with significantly reduced speed spread.

- Radio frequency cylindrical ion trap with cryogenic cooling
- Velocity map imaging

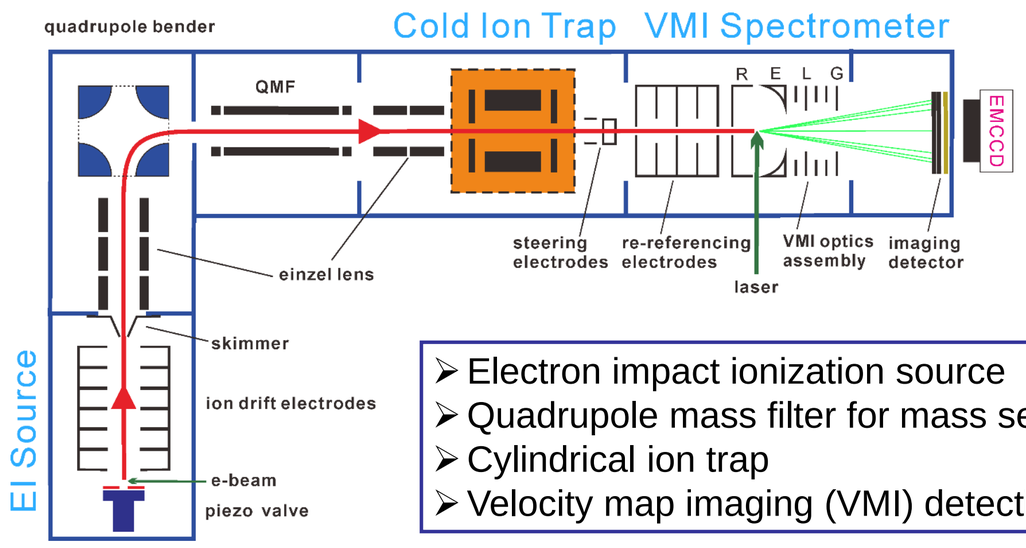
Photodissociation spectroscopy



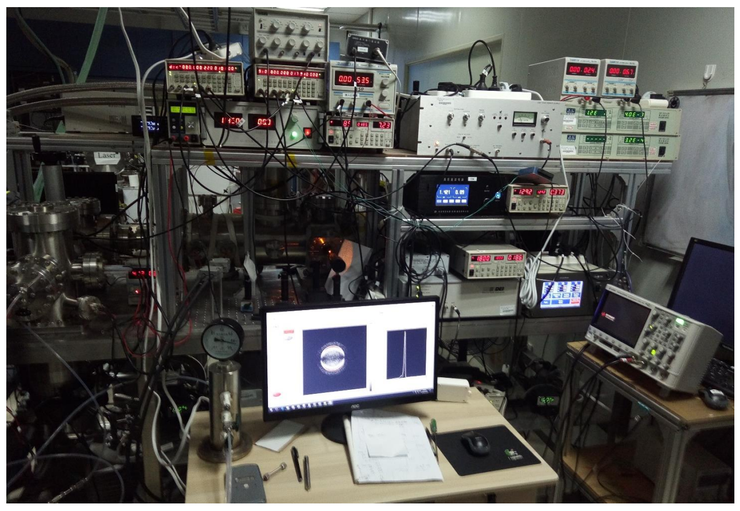
- Rotational temperature: 12 ± 2 K
- No detection of electronic excited CO_2^+
- No detection of vibrational excited CO_2^+
- No detection of CO_2^+ $X^2\Pi_{g,1/2}$ (000)

[1+1] two-photon dissociation spectrum of CO_2^+.

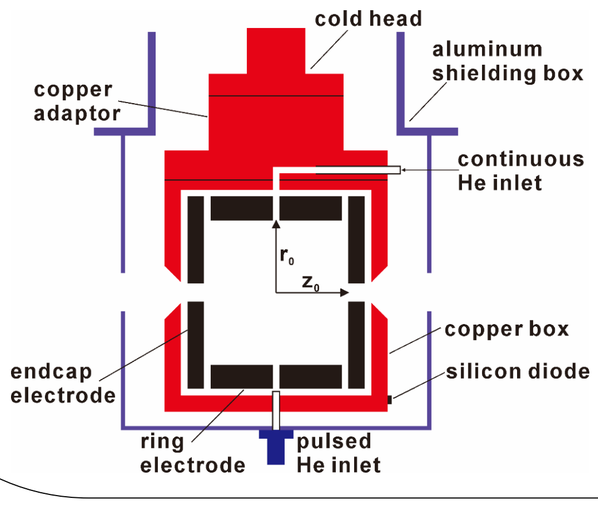
Experimental setup



- Electron impact ionization source
- Quadrupole mass filter for mass selection
- Cylindrical ion trap
- Velocity map imaging (VMI) detection



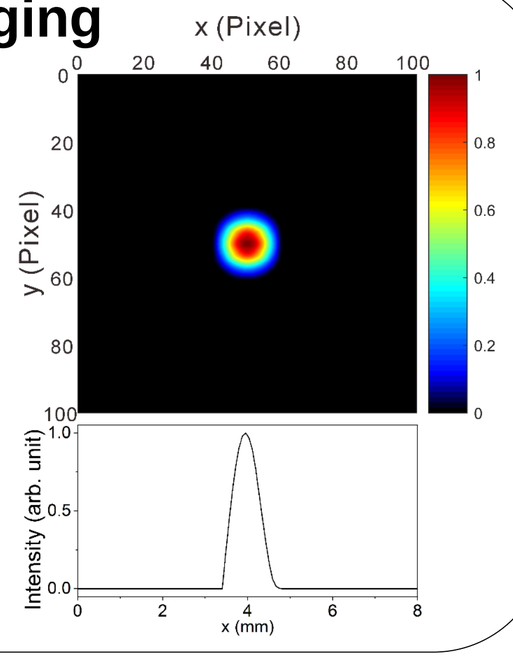
Cylindrical ion trap (CIT)



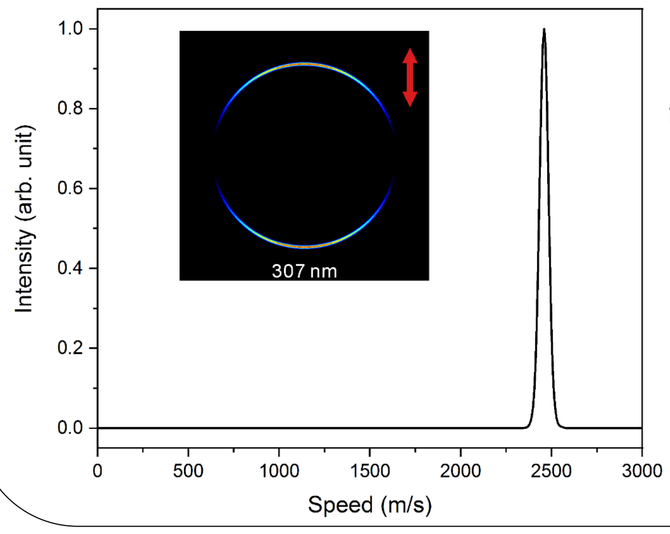
Ion imaging

- Initial radial size: ~0.2 mm
- Radial speed spread: ± 25 m/s

Upper panel: the image of N_3^+ ions after extraction from the trap; lower panel: the distribution of N_3^+ ions along the x axis.



Photodissociation of Ar_2^+

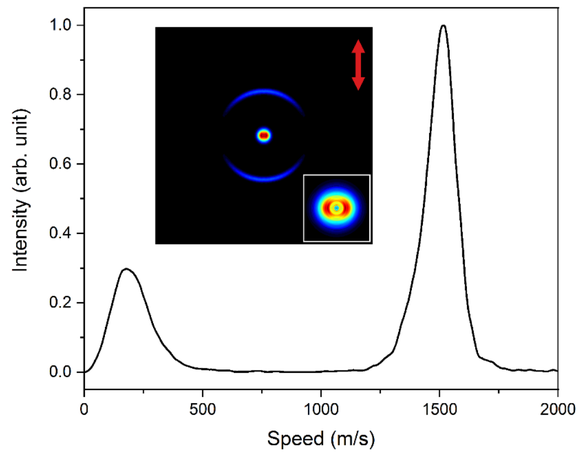


Raw image and speed distribution of fragmented Ar^+ from photodissociation of Ar_2^+ at 307 nm.

- VMI resolution: Δv/v ~2.2%
- β=1.9 , parallel transition

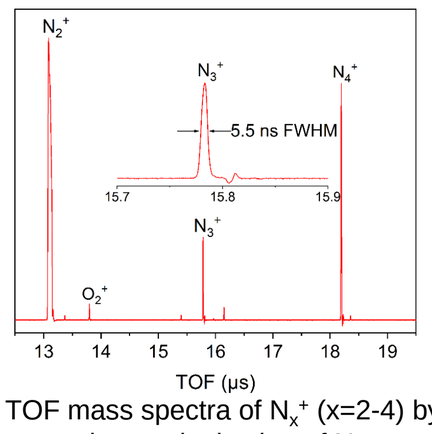
Work in progress....

$$Ar_3^+ + hv \rightarrow 2Ar + Ar^+$$



Raw image and speed distribution of fragmented Ar^+ from photodissociation of Ar_3^+ at 529 nm.

Time-of-flight mass spectra



TOF mass spectra of N_x^+ (x=2-4) by electron ionization of N_2.

The observed mass peaks in the TOF spectra.

m/z	Time (μs)	FWHM (ns)	Resolution (m/Δm)
28	13.10	48.7	134
32	13.80	5.9	1169
42	15.78	5.5	1435
44	16.15	6.2	1302
56	18.20	9.9	919

- Initial axial size: ~0.3 mm
- Axial speed spread: ± 25 m/s

References

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