A radio-frequency ion trap and quadrupole mass spectrometer for atomic and molecular physics at ASTRID2

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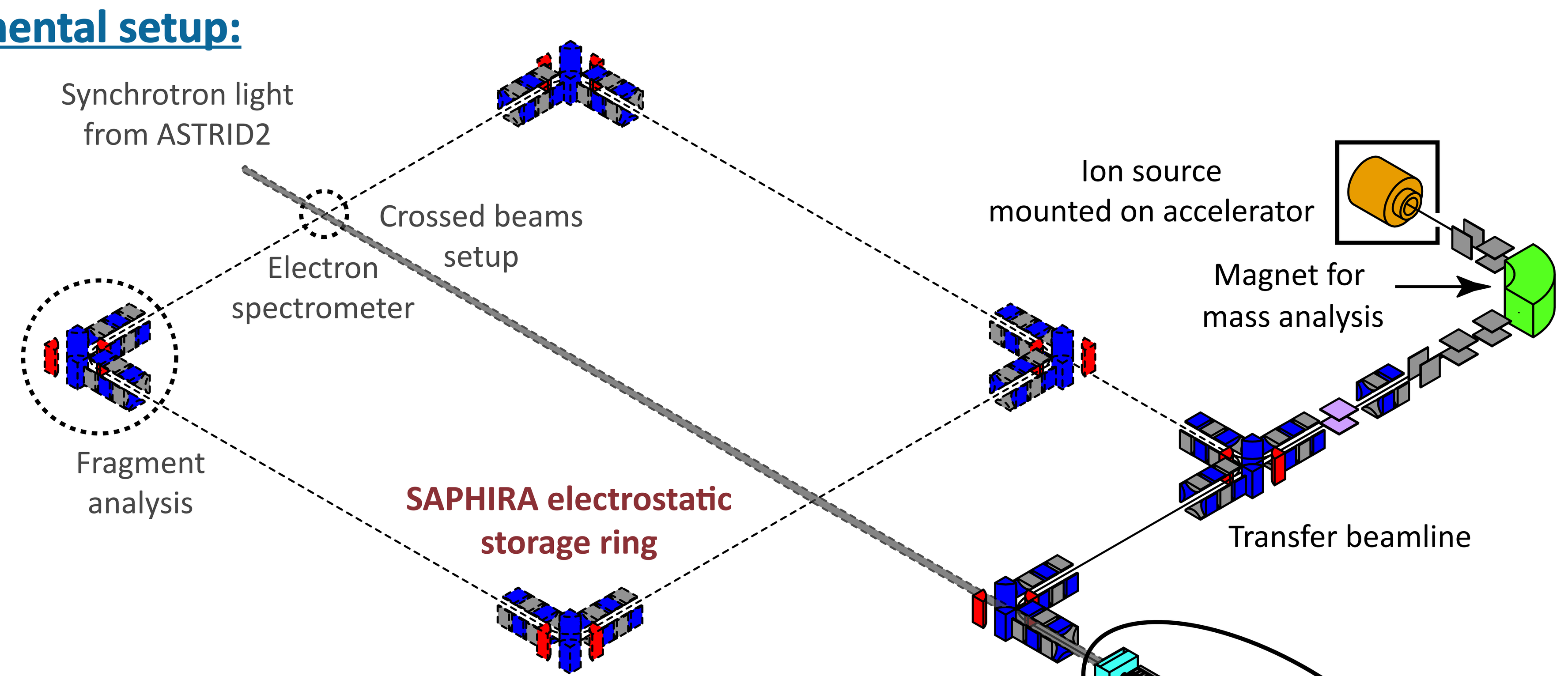
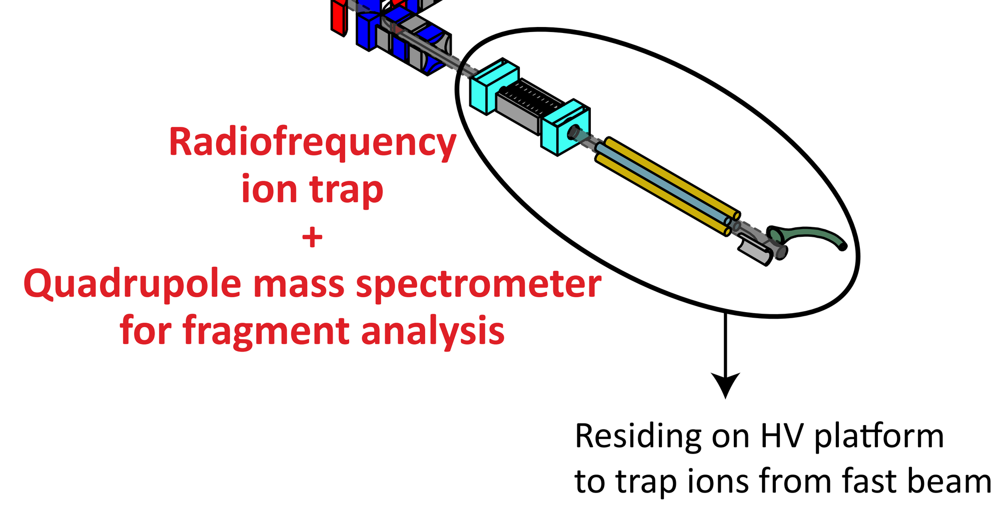
A new experimental setup for studying photophysics of atomic and molecular ions in the XUV range is currently under development at Aarhus University. The XUV light will be provided by the AMO beamline, a photon beam line at the new synchrotron ring, ASTRID2, at Aarhus University. The end station comprises an electrostatic storage ring and a radio-frequency ion trap followed by a quadrupole mass spectrometer. The two complementary setups at the end station allow to study both the details of the molecular break-up as well as the spectroscopy of molecular ions at a well-defined temperature. Here, the first test experiments with the trap and quadrupole mass spectrometer setup are presented.

Experimental setup:

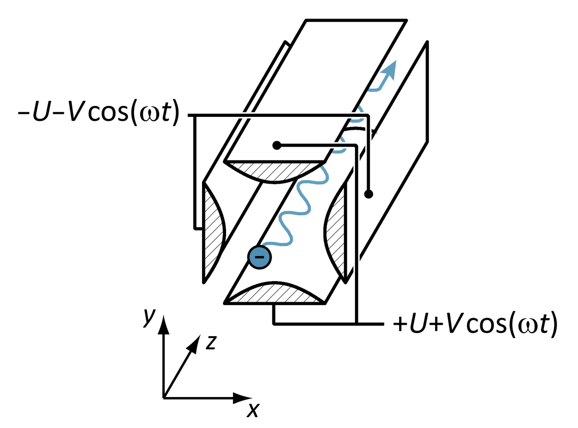




Radiofrequency ion trap:
- Photofragment spectroscopy of cold ions
- Manipulation/storage of ions before injection into ring

Electrostatic storage ring, SAPHIRA:
- Crossed and merged beams setups
- Detection of charged and neutral fragments as well as electrons

Quadrupole mass spectrometer:

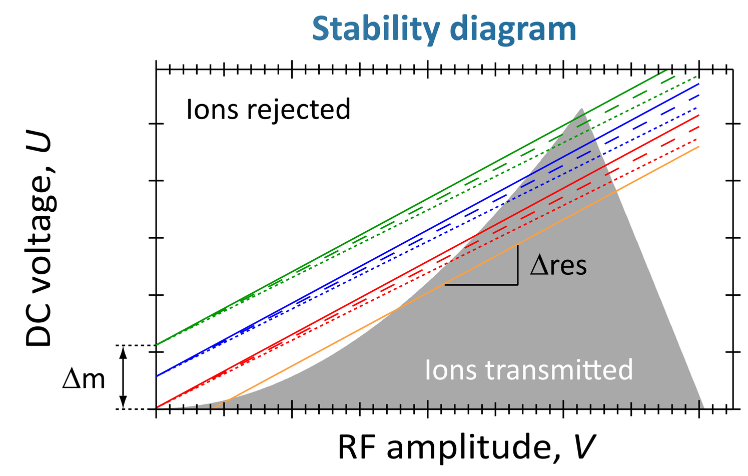


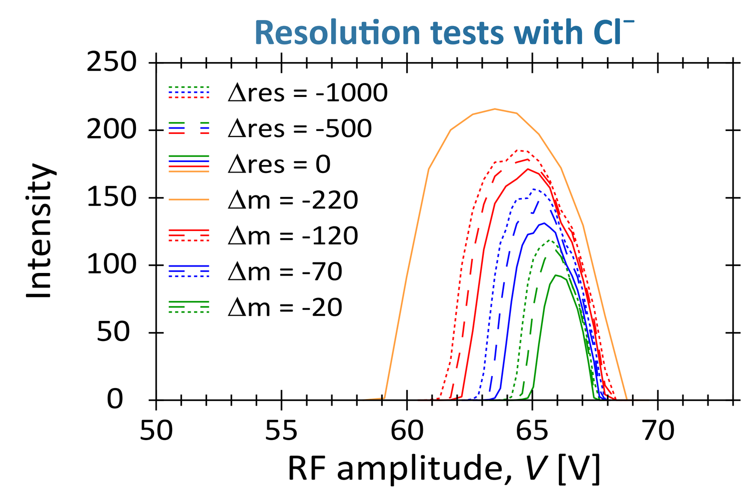
Equations of motion for ion in quadrupole:

$$0 = \ddot{x} + \frac{2Ze}{mr_0^2}(U + V\cos\omega t)x$$

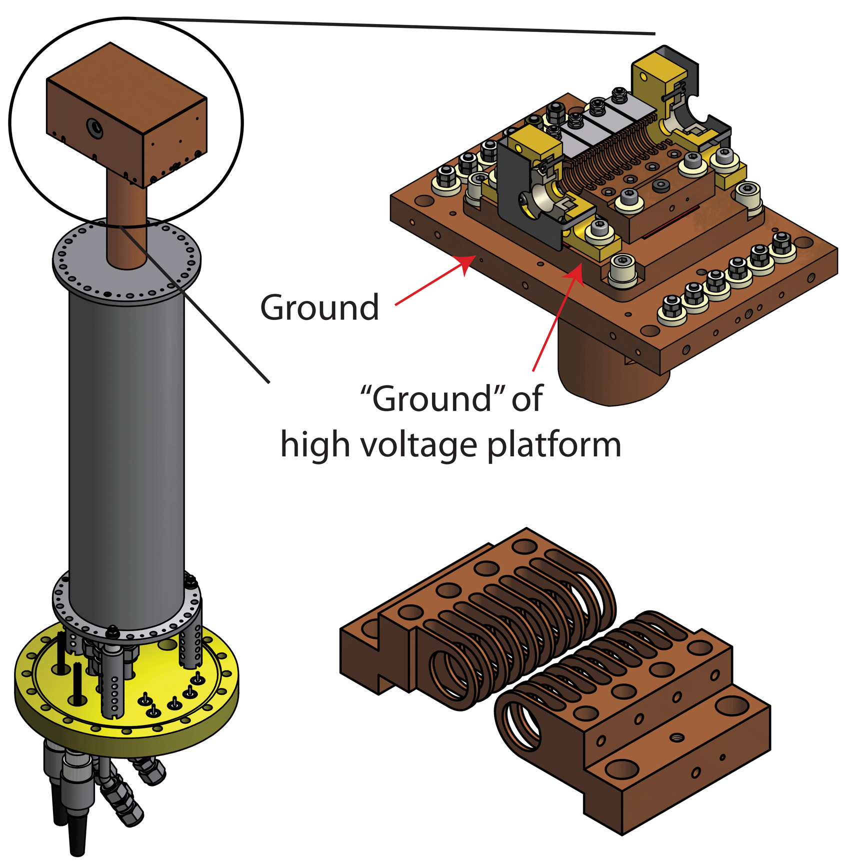
$$0 = \ddot{y} - \frac{2Ze}{mr_0^2}(U + V\cos\omega t)y$$

$$0 = \ddot{z}$$

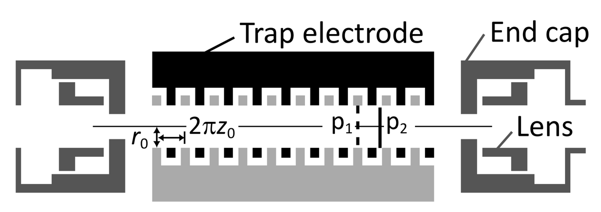


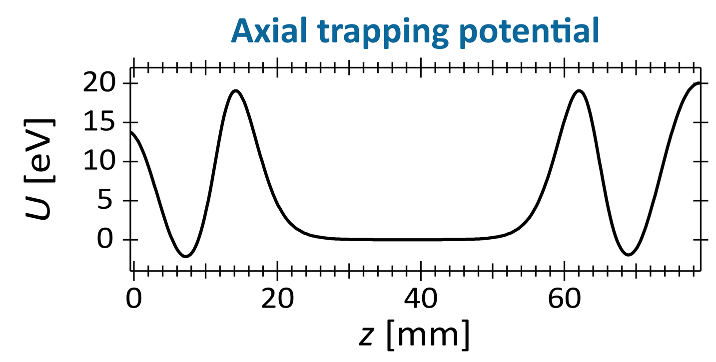


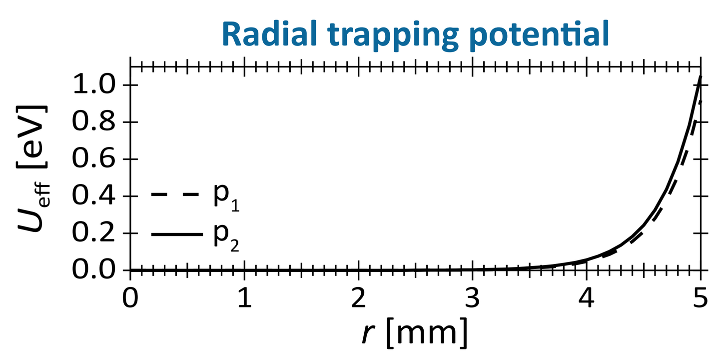
Radiofrequency ion trap:



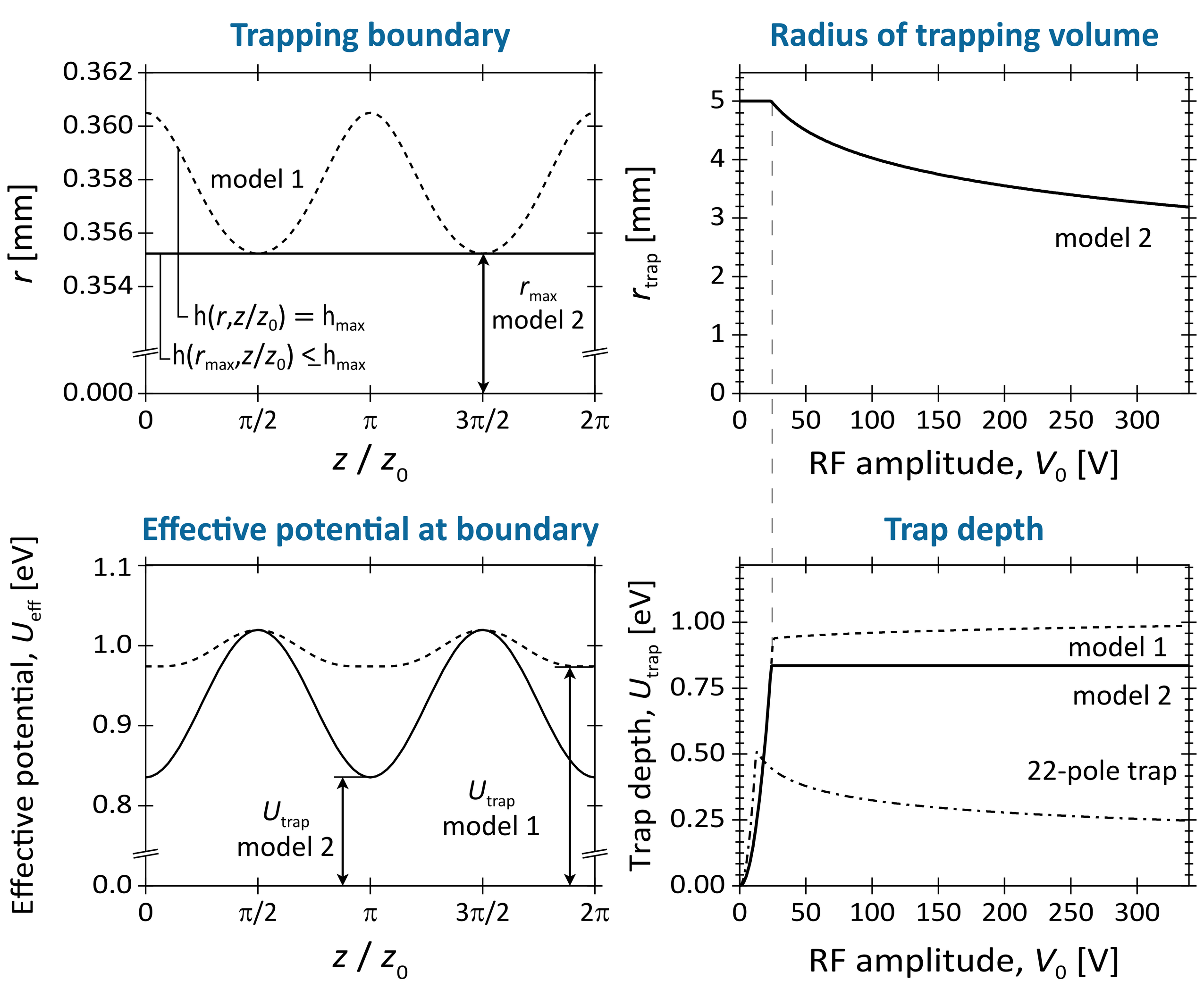
Trapping potentials



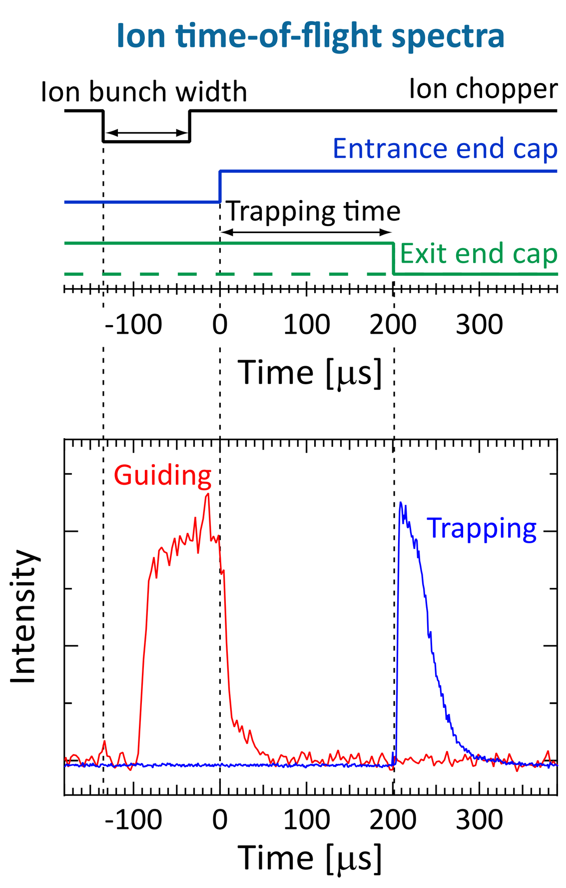


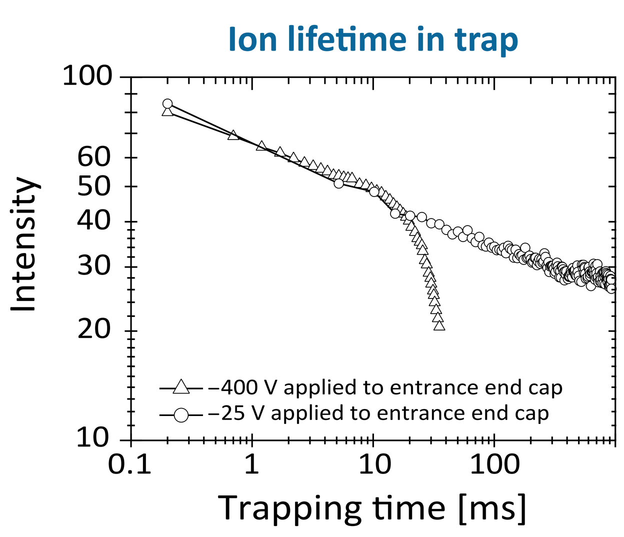


Trap depth model



Demonstration of trapping





Adiabatic ion motion:

Equation of motion:

$$m\ddot{\vec{r}} = \vec{E}_0(\vec{r})\cos(\omega t)$$

Approximative solution (*adiabatic approximation*):

$$\vec{r}(t) = \vec{R}(t) + \vec{\zeta}(t)$$

Smooth drift motion — Rapid oscillatory motion *micromotion*

Equation of motion for R:

$$m\ddot{\vec{R}} = -\vec{\nabla}U_{\text{eff}}(\vec{R})$$

Effective potential:

$$\vec{\nabla}U_{\text{eff}}(\vec{R}) = \frac{(Ze)^2}{4m\omega^2}\vec{\nabla}E_0^2$$

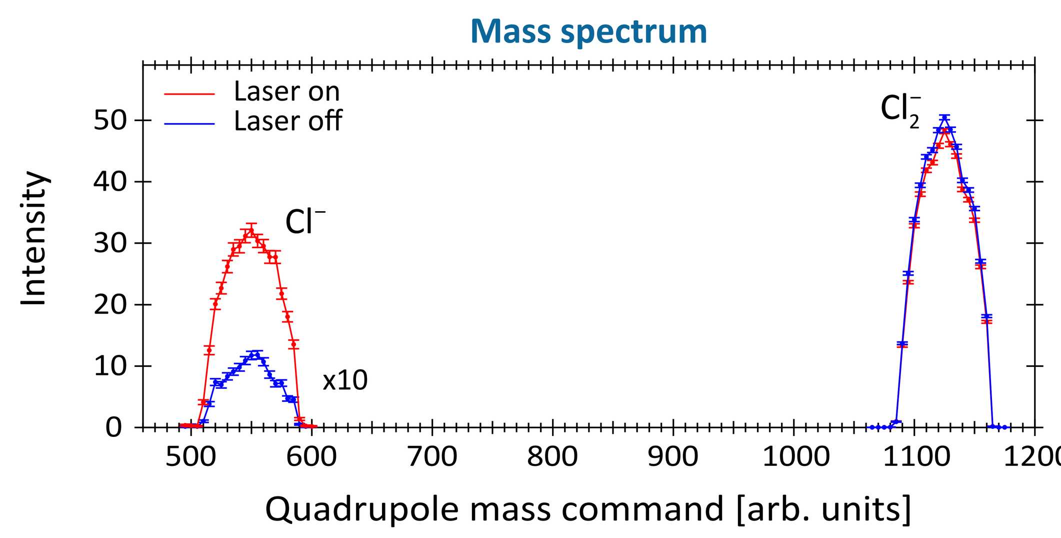
Adiabaticity parameter:

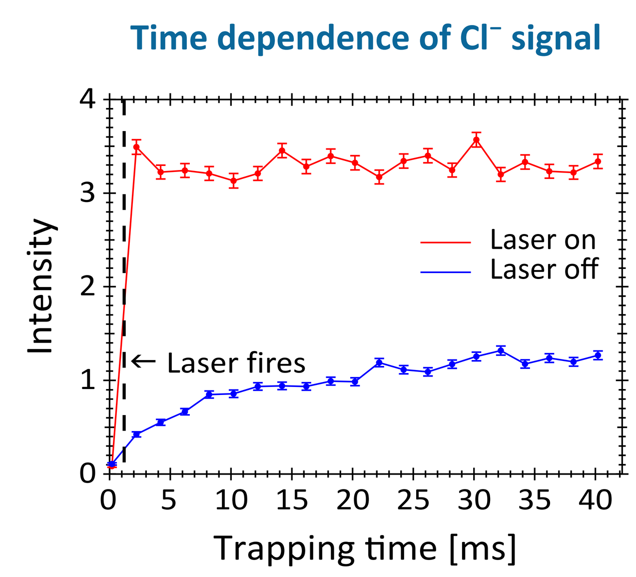
$$\eta = \frac{2Z\left|\vec{\nabla}\left|\vec{E}_0\right|\right|}{m\omega^2} \leq 0.3$$

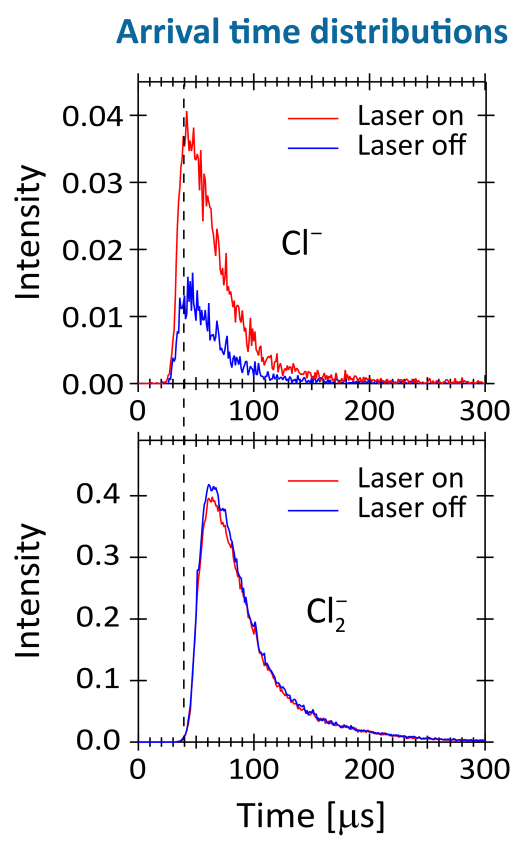
Adiabatic approximation valid and ion motion stable if η≤0.3 ⇒ **Trap depth = maximum U_{eff} in volume with η≤0.3**

First photodissociation experiments:

$Cl_2^- + h\nu$ (532 nm) → $Cl^- + Cl$







Status and future plans:

Trapping of ions in radiofrequency ion trap demonstrated
Mass selection in quadrupole mass spectrometer achieved
First photodissociation experiments performed

Next:
Explore further the trap characteristics
Implement cryocooler for the ion trap
Construction of the electrostatic storage ring

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