An Experimental Setup to Generate Ultra-Short Ion Pulses for Use in Pump-Probe Experiments

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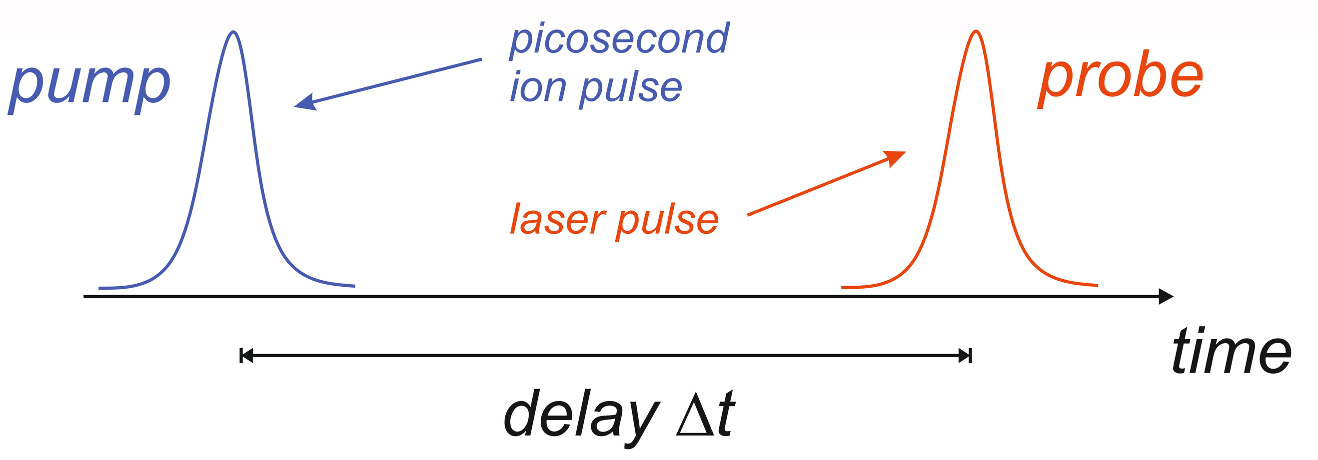
Motivation

- Can we generate ion pulses of picosecond time resolution in the keV-range for observation of ultra-short dynamics via pump-probe technique?

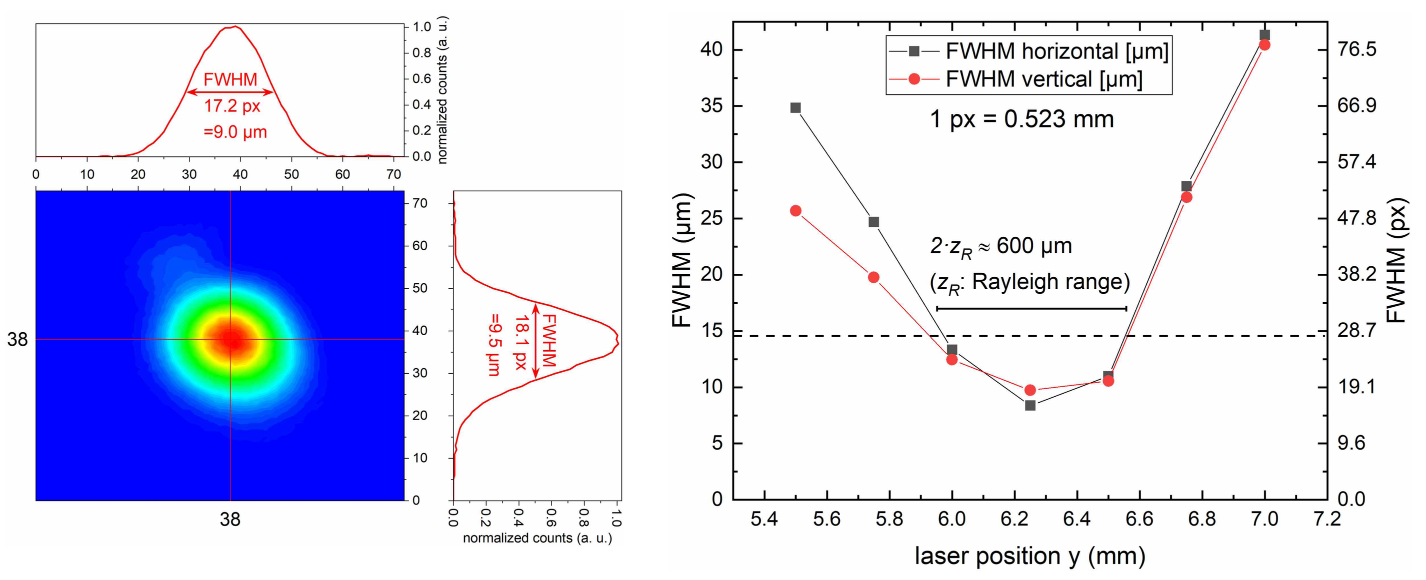


- generation of ultra-short ion pulses: difficult task due to space-charge broadening and velocity distribution of ions at a given temperature

⇨ supersonic gas expansion - control over number density and temperature distribution

- characterization of such a supersonic gas expansion of Argon via Excimer laser

Characterization of fs photoionization laser



beam properties:

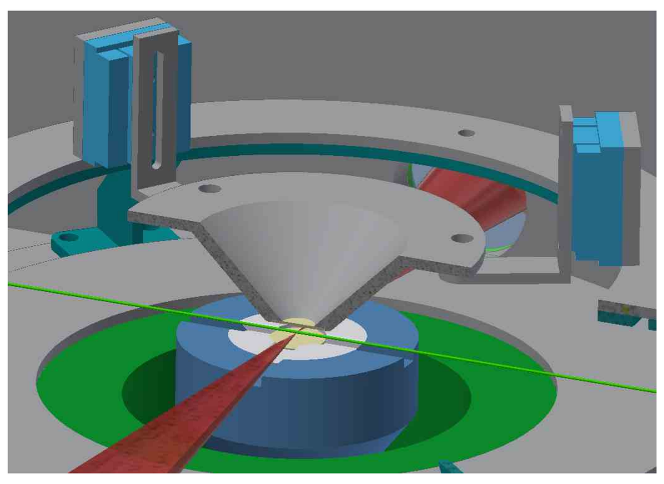
800 nm
50 fs
1.5 mJ / pulse
1 kHz

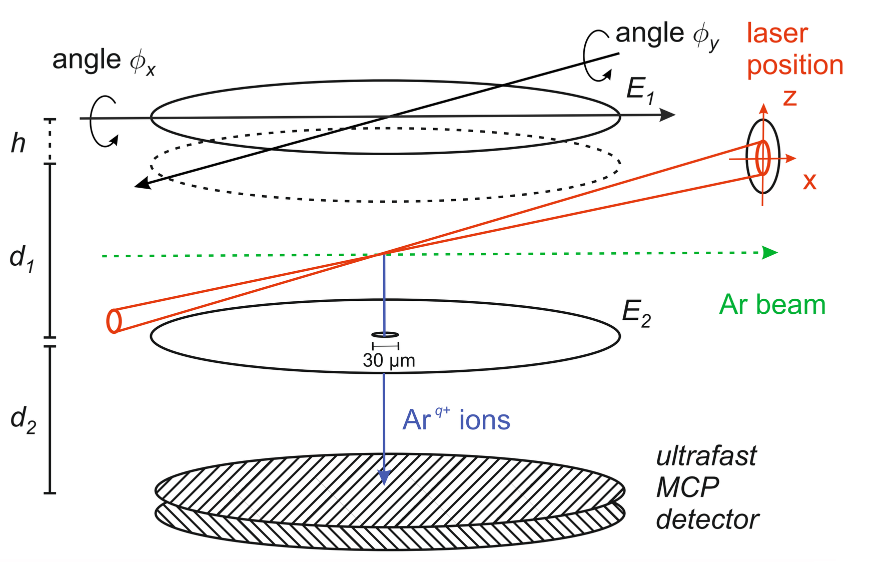
- nearly symmetrical laser spot profile with diameter < 10 µm and Rayleigh range of $z_R \approx 300$ µm
- measured spot profile leads to a maximum peak intensity $I_0 \approx 3.5\times10^{16}$ W/cm^2

⇨ intensity allows in principle to create Ar^{q+} with charge state q = 1,..., 6

Characterization of buncher geometry with Argon

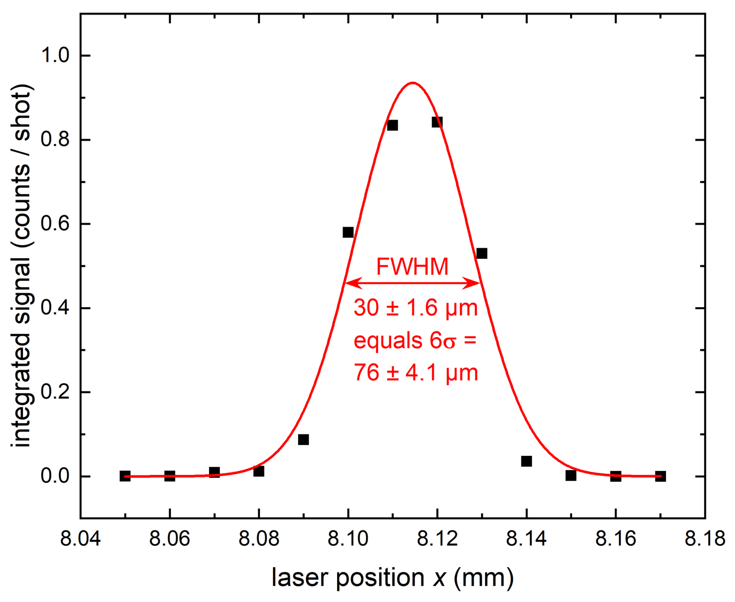
Experimental setup



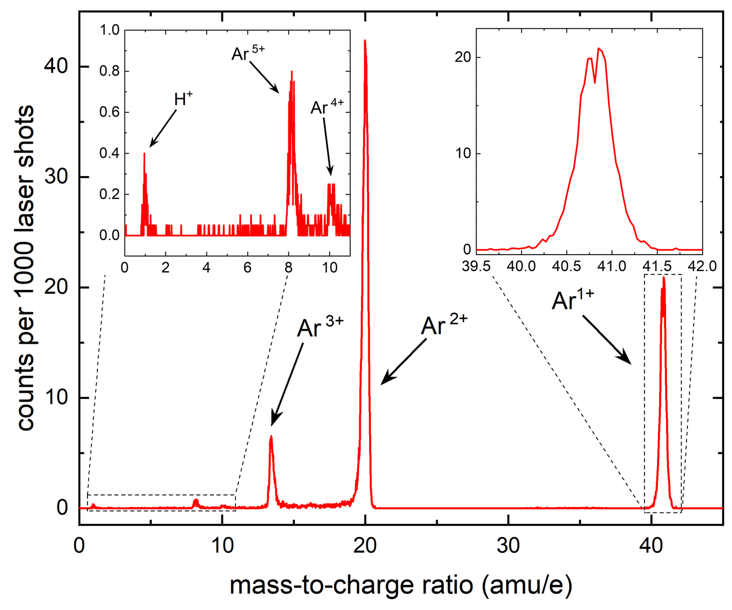


- 3 **piezo motors** allow *in-situ* alignment of upper electrode for height h and angular tilt $\phi_{x,y}$
- vacuum chamber backfilled with Argon gas at $p_0 = 9.0\times10^{-7}$ mbar

geometric boundaries

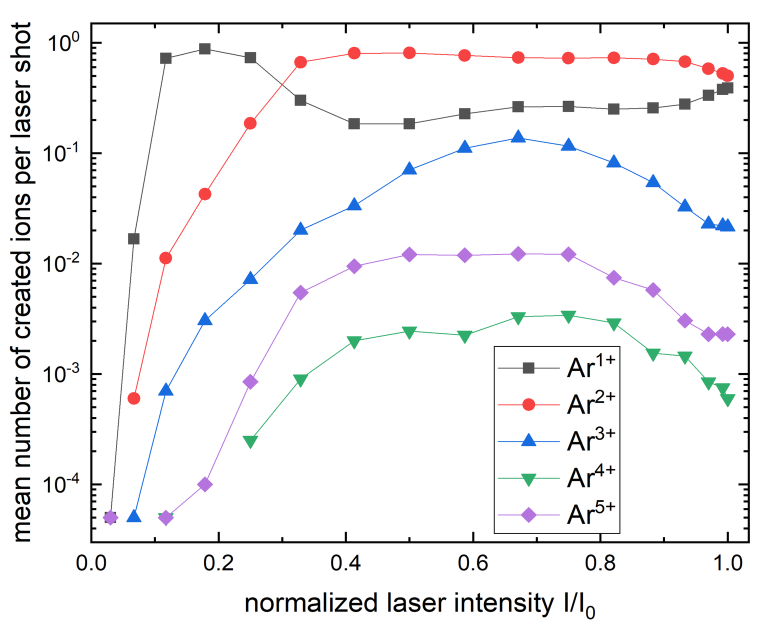


ion charge states

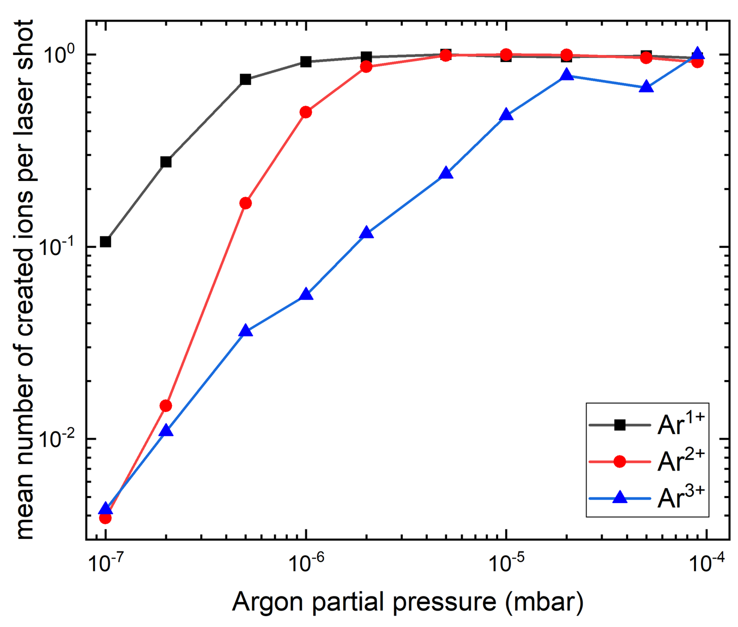


- no photoelectrons created within buncher geometry → ions only from photoionization
- creation of Argon ions Ar^{q+} with charge state q = 1,..., 5 accessible

created ions vs. intensity



created ions vs. pressure

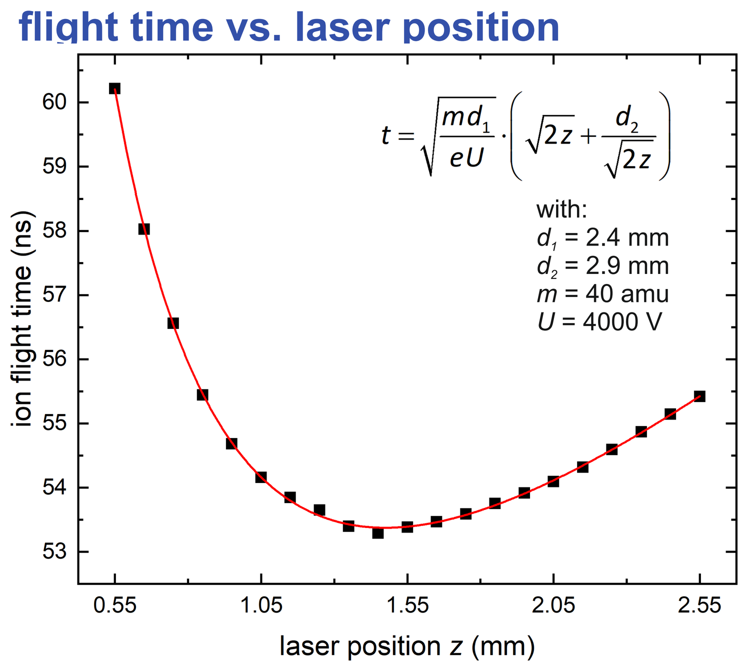


- charge state depends on the laser intensity, number of ions depends on number density

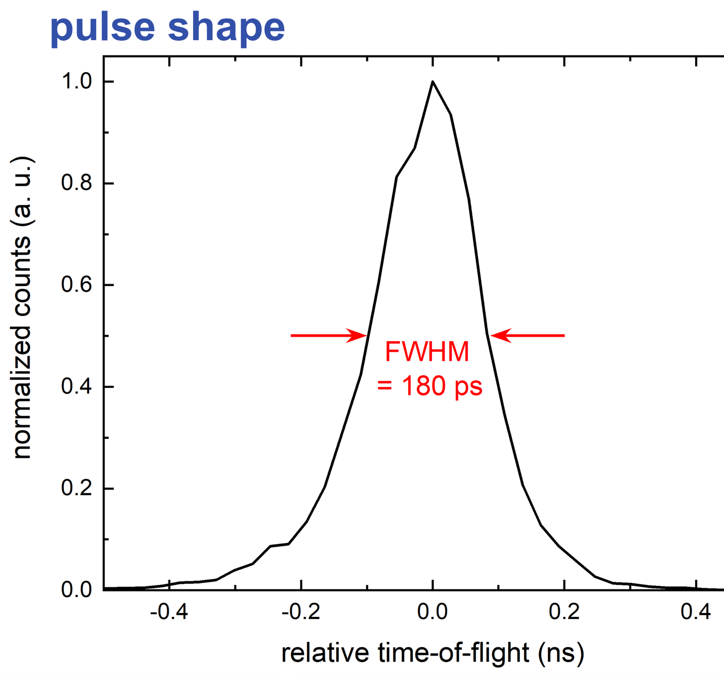
⇨ control over charge state and ion number via gas beam pressure and laser intensity

Flight time focus and 180 ps ion pulses

flight time vs. laser position



pulse shape

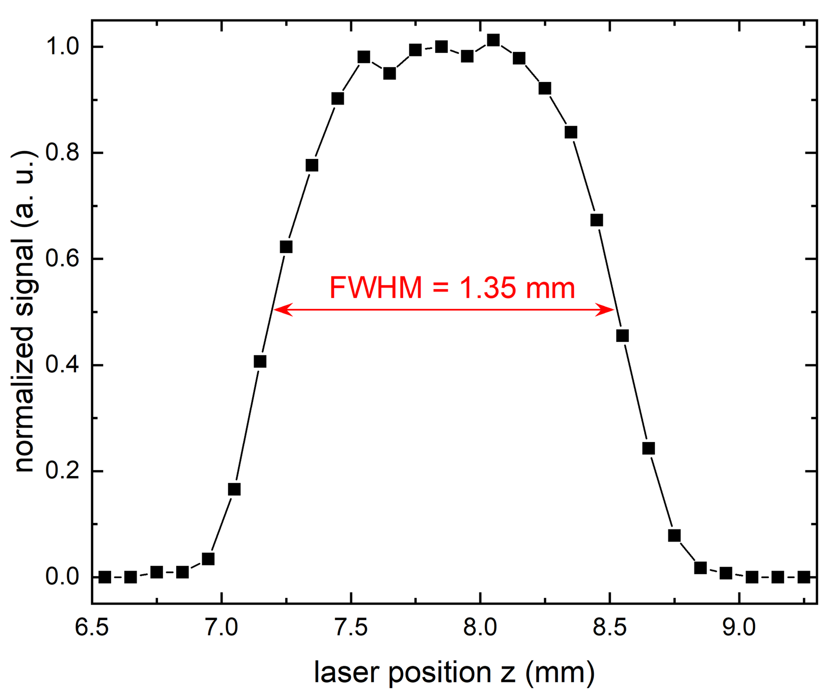


- shortest pulse duration yields a FWHM of **180 ps** for the Ar^+ pulse of the backfilled gas
- flight time as a function of laser position matches the theoretically expected behaviour

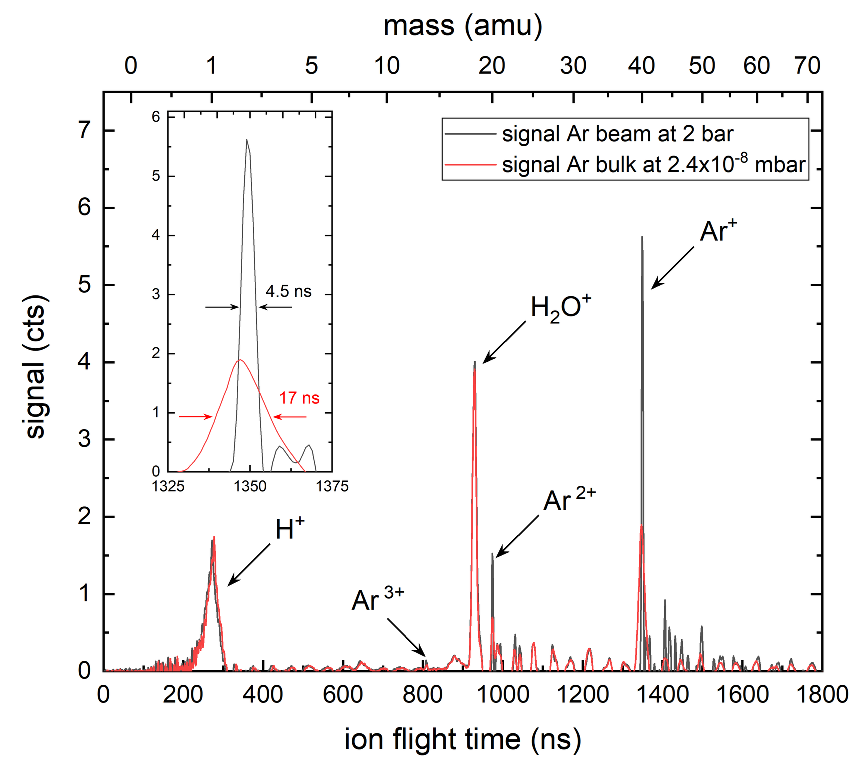
⇨ allows to extract distances d_1, d_2 and z_0 in geometric arrangement

Argon gas beam and sample measurements

Beam profile



Comparison beam & bulk spectra

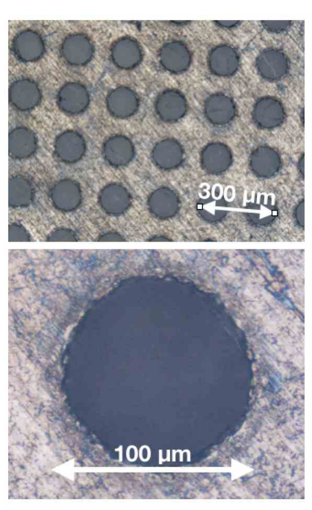


- symmetric profile of Argon beam at ionization point defined by aperture (skimmer) of Ø 1 mm
- Argon ions Ar^{q+} with charge state q = 1, 2, 3 accessible at modest beam pressure of 2 bar
- clear difference of pulse widths between beam signal and bulk signal

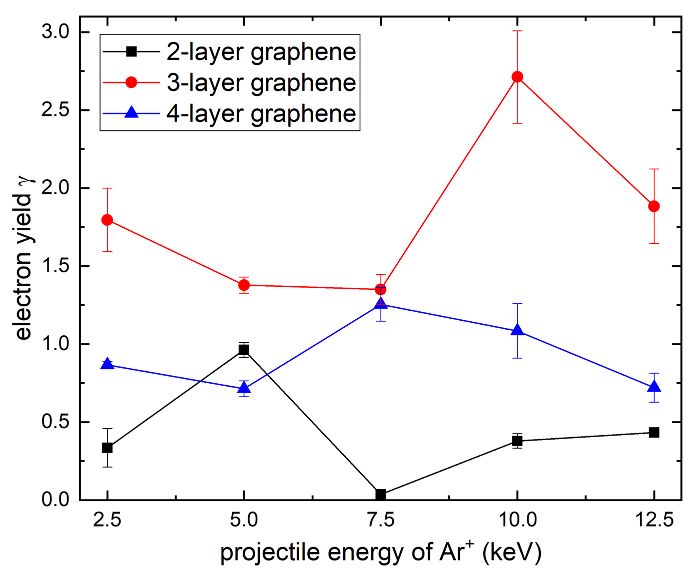
⇨ thermal velocity distribution can be reduced drastically by cold molecular beam (below 1 K)

Measurements on graphene as a thin target for electron emission

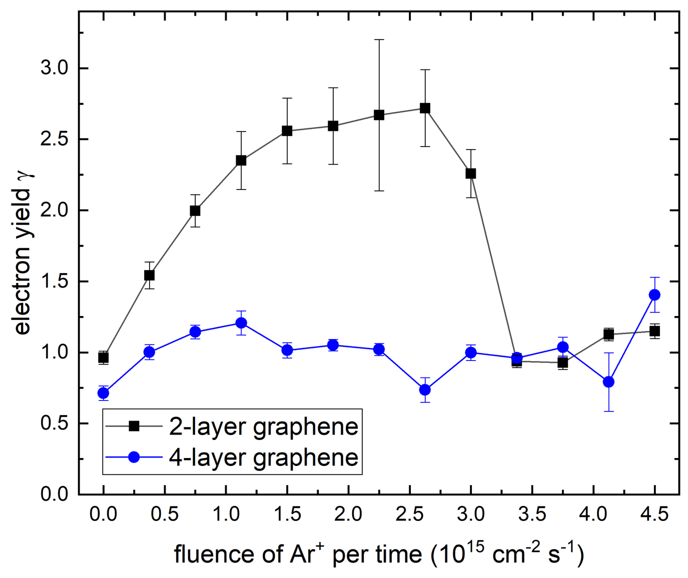
sample



electron yield in transmission



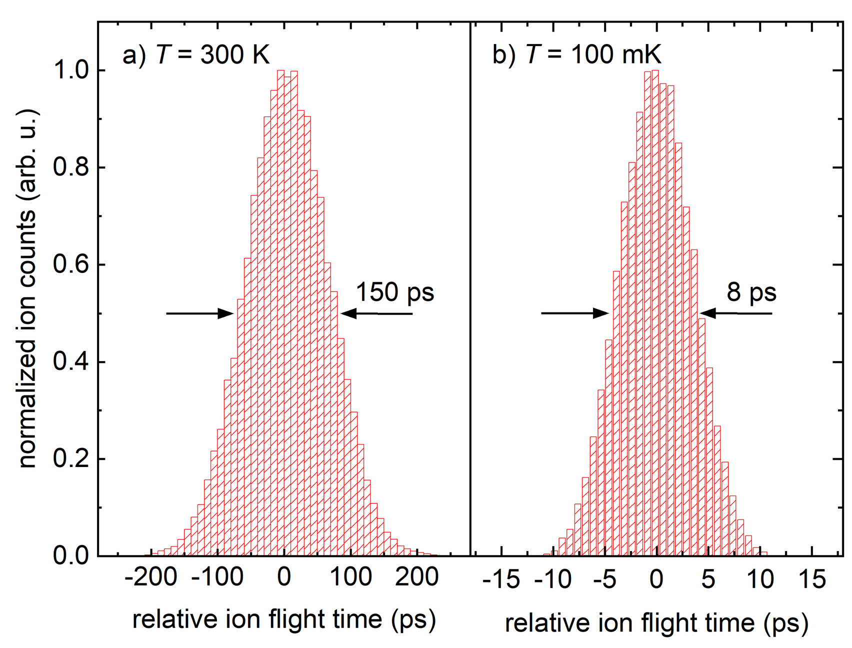
longevity of graphene target

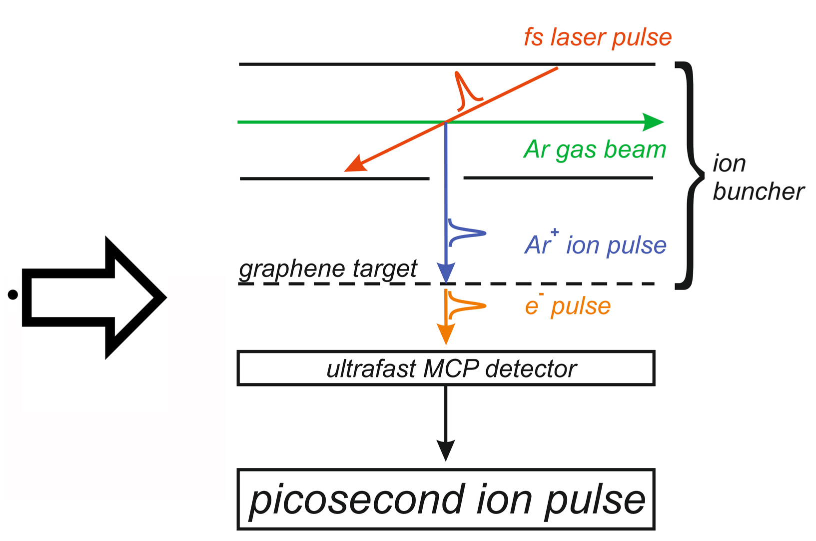


- graphene samples are suitable to emit more than one electron on average for 2.5 - 12.5 keV Ar^+
- samples withstand a total fluence of up to 10^{15} ions/cm^2 → huge longevity for our application
- varying new substrates with different grid sizes to improve graphene stability & durability
- new technique to get rid of PMMA in the processing

Goal: ion source with picosecond time resolution

simulated pulse width for sub-Kelvin starting velocity distribution





- reduction of thermal velocity distribution allows to further compress ion pulses within buncher
- detection of ultrashort ion pulses possible via thin graphene target as electron emitter

⇨ combination of ion buncher with ultracold molecular beam leads to picosecond ion source!