International Workshop on the Science with and the Instrumentation for Small Quantum Systems at the European XFEL

October 29th-31st 2008

Presentation of final report from Working Group II on Dilute Ion Targets

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Working meeting on the Science with and the Instrumentation for
Small Quantum Systems at the European XFEL, Hamburg, January 29th 2009

The scientific cases

XFEL light source

- 250-3100 eV
- 10^{12}-10^{14} photons/pulse
- Large average intensity (high repetitiion rate)

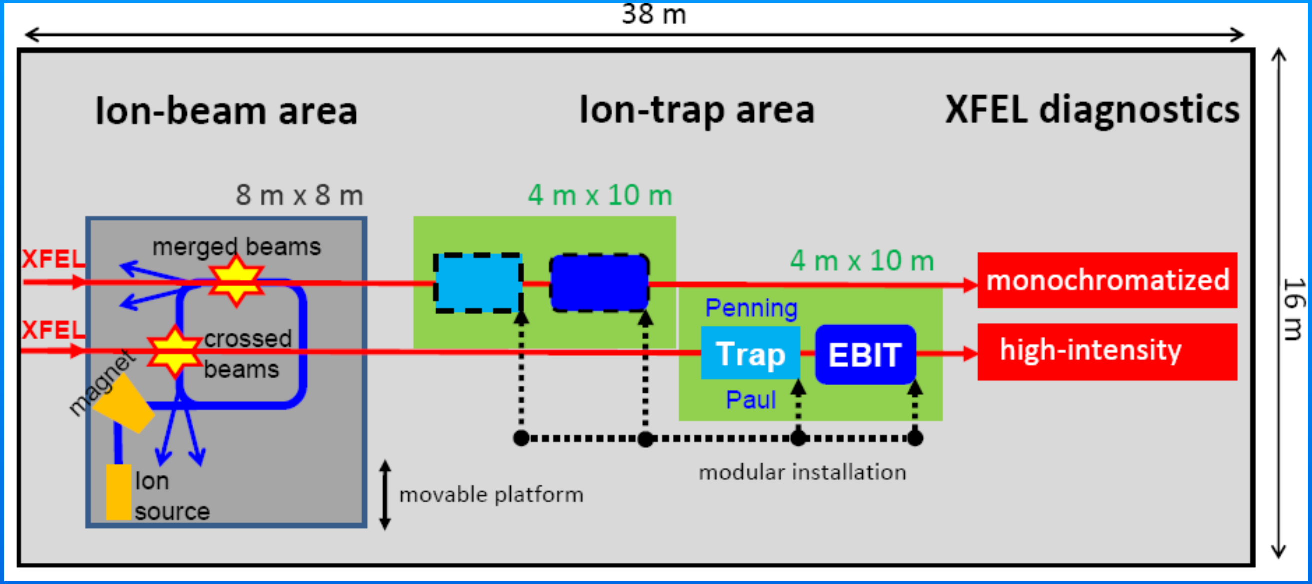
Dilute ion targets

- 10^4-10^6 ions/cm^3
- Specialized methods for preparation manipulation and detection

- *Inner shell ionization in atomic ions in both low and high charge states.*
- *Molecular dynamics following x-ray photoionization revealed by kinematically complete momentum imaging.*
- *Multiphoton studies in the x-ray spectral region.*
- *X-ray photons scattered at trapped ion crystals in Penning or Paul Traps.*
- *Photoelectron spectroscopy and photoelectron-photoion coincidences in photoionization of atomic ions*
- *Photofragmentation of large biomolecular ions*
- *Inner shell photodetachment and photofragmentation of atomic and molecular anions*
- *Photoionization and photofragmentation of (endohedral) fullerene ions, mass selected cluster ions, and complex molecular ions*
- *Investigations of Highly Charged Ions with an EBIT*
- *Photoionization of single trapped atomic and molecular ions*
- *X-ray spectroscopy of single Highly Charged Ions (HCIs)*
- *…*

•Ion targets provide a versatile tool for studies of fundamental interactions
•Ionic matter is important everywhere in nature

Starting with the end ..



- Modular stations
- Serial arrangements of experiments

Development of an ion beam facility

- Electrostatic storage ring at room temperature
- Separator magnet
- Ion beam optics and diagnostics
- RF-trap
- Modular interaction regions for merged and crossed beam experiments

~ 2 M€

Bizeau (Orsay)
Larsson (Stockholm)
Pedersen (Aarhus)
Müller, Schippers (Giessen)
Wolf (Heidelberg)

Development of a versatile ion trap facility

- EBIT
- Penning trap
- Paul (RF) trap
- Optical setup for laser cooling and fluorescence detection

~ 1.3 M€

Crespo (Heidelberg)
Drewsen (Aarhus)
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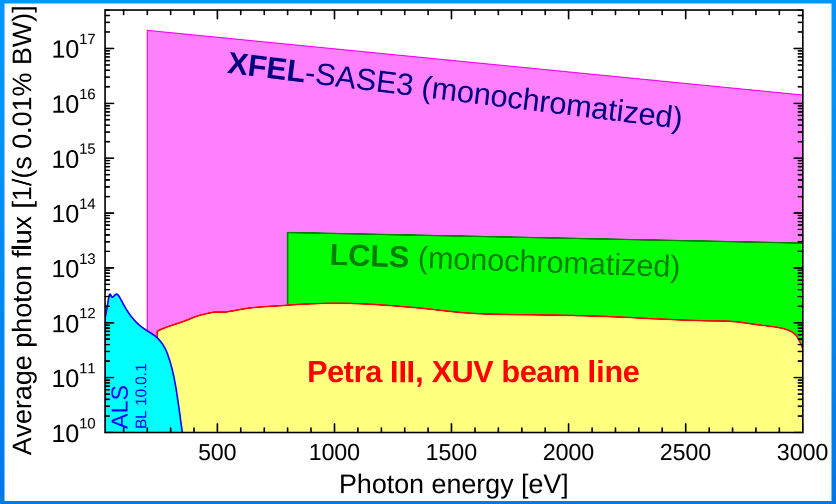
XFEL beam parameters and features



Photon energy range

- XFEL envisaged range 250 – 3100 eV

Intensity:

- **10^{12}-10^{14} photons/pulse**

Pulse repetition rate and time structure

- Increased average flux: 10 Hz x 30000 pulses
- Different time structure for different part of XFEL train adapted to serial experiments

Polarization

- Linear. Farther future experiments could demand circular polarization.

Focus

- Ion beam experiments: beam size of 1 mm
- Ion trap experiments: <100 μm (EBIT), 1μm (Penning traps, Paul trap)

Monochromaticity

- E/ΔE =100-1000 for photon hungry experiments (crossed beams)
- E/ΔE = 20 000 for spectroscopic experiments (EBIT, Penning trap, merged-beams)

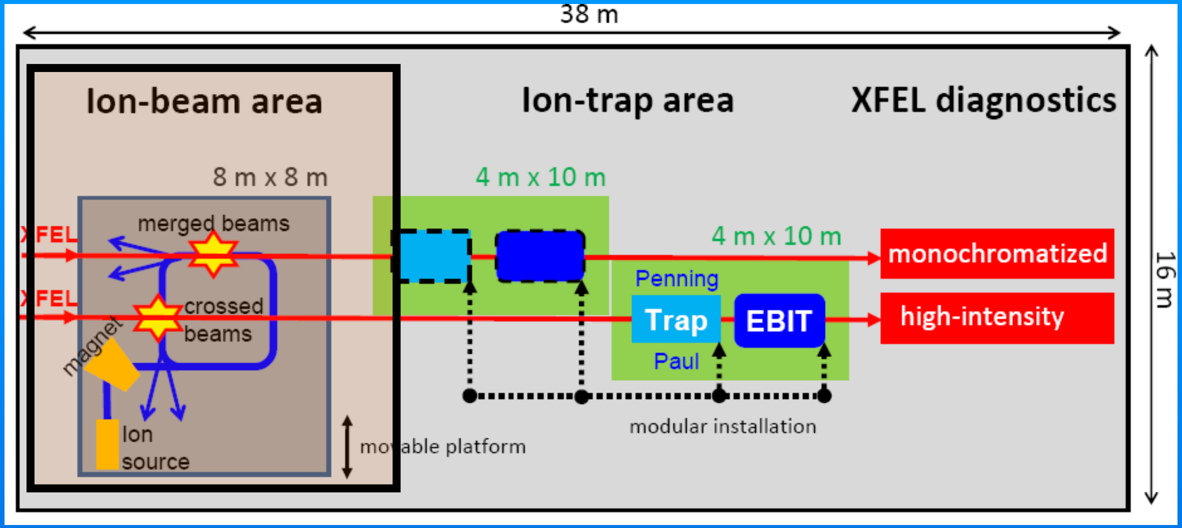
Tunability

- For spectroscopic experiments (EBIT, Penning trap, merged-beams) as large as possible tunability desired

Diagnostics

Pulse-to-pulse XFEL diagnostic: 1) absolute intensity, 2) polarization, 3) energy spectrum, 4) spatial intensity distribution, 5) temporal intensity distribution

Ion beam facility



General aspects for ion beam targets

Accelerated ions

- methods for state preparation (E,m,q,quantum state, conformer)
- Fragment detection benefit from moving beam (universal separation)

Cooling of the internal state

- Cryogenic storage ring
- RF trap with buffer gas cooling

Increase of the target density

- Ion storage + electron cooling
- RF trap for accumulation, combined with storage ring for temporal matching to XFEL

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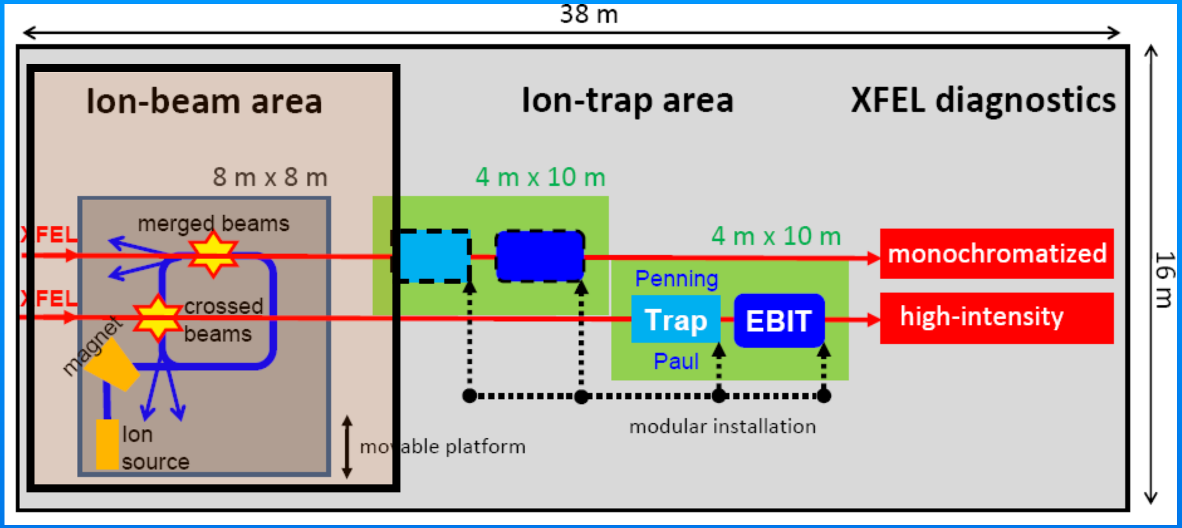
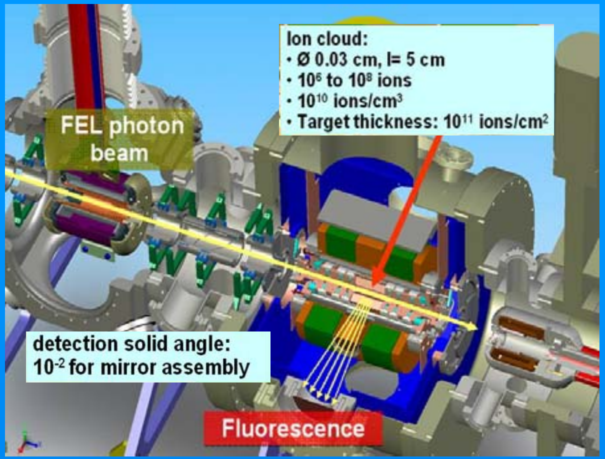
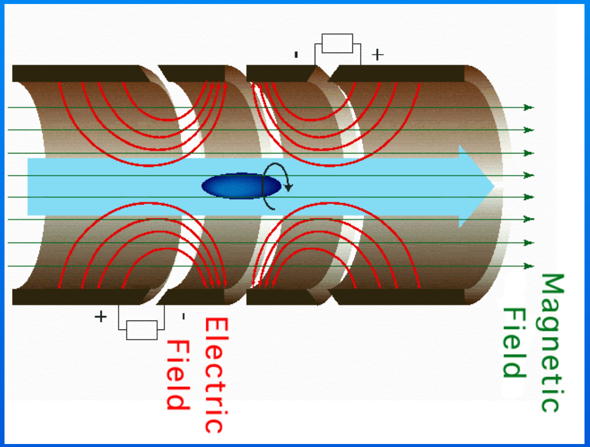
Ion trap facility







Aspects for ion trap targets

EBIT

- Very high charge states
- Increased target density (10^9-10^{11} cm^{-3})

Penning trap

- Ion crystals in cold environment
- Harmonic fields

Linear Paul trap

- Single ion trapping and observation

Development of a versatile ion trap facility

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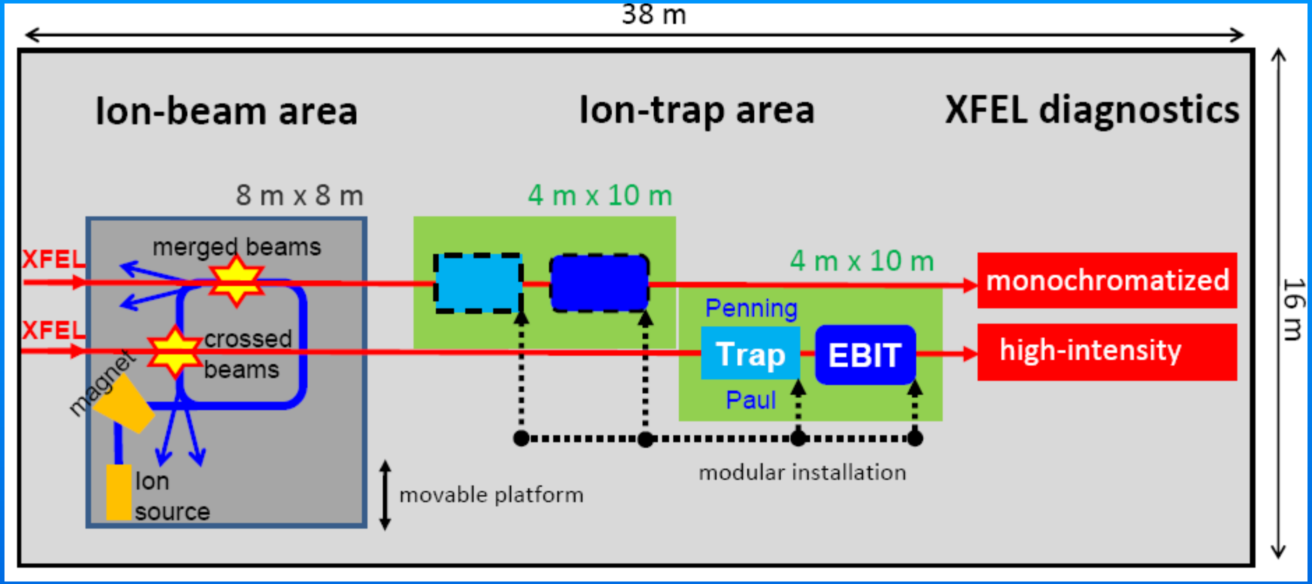
- Penning trap
- Paul (RF) trap
- Optical setup for laser cooling and flourecence detection

Envisaged layout



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