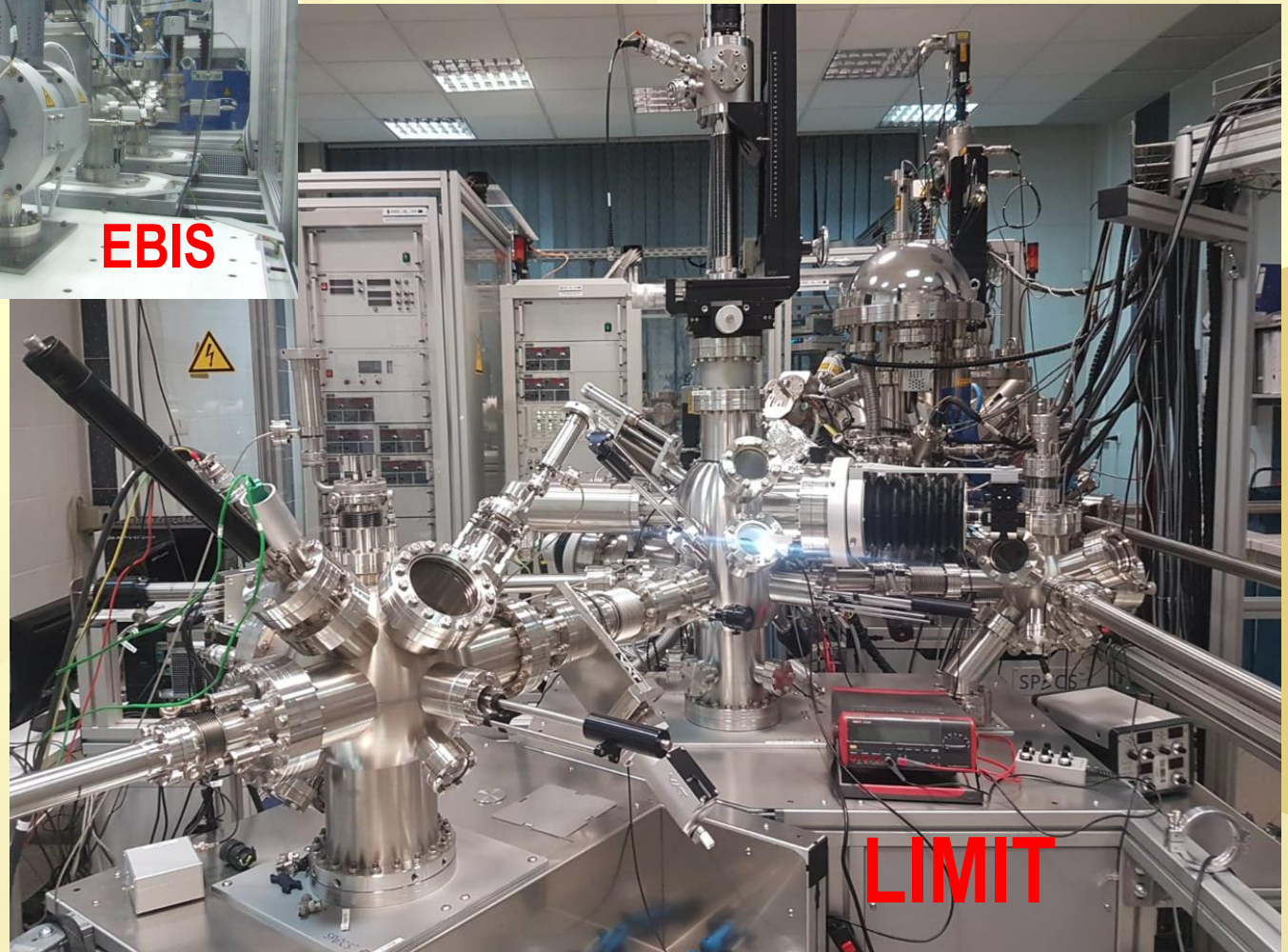


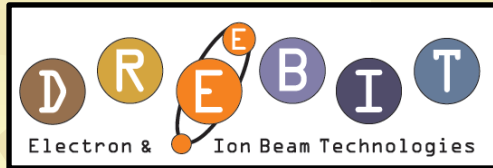
News from EBIS@LIMIT



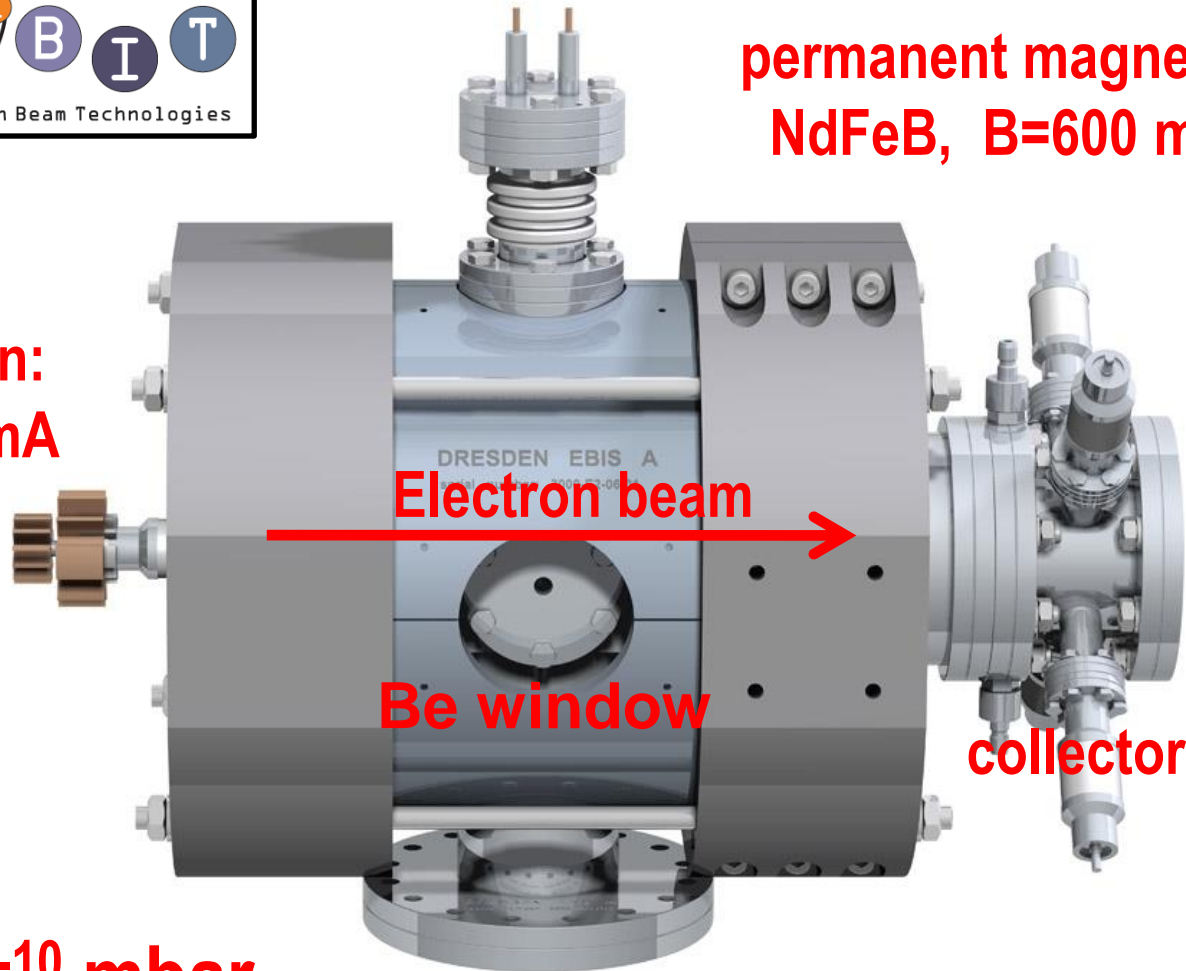
Outline

- ✿ Electron Beam Ion Trap (EBIT)
- ✿ Electron Beam Ion Source (EBIS)
- ✿ Laboratory of Ion-Matter InTeraction (LIMIT)
- ✿ Recent experiments and results
- ✿ **DIB grant for EBIS & LIMIT (2022) !**
- ✿ **EBIS upgrade (LMIS, DLS, BIS)**
- ✿ **EUV spectrometer**
- ✿ **SIMS/SNMS quadrupole mass spectrometer**
- ✿ **Electron Cylindrical Mass Spectrometer (CMS)**

EBIT details



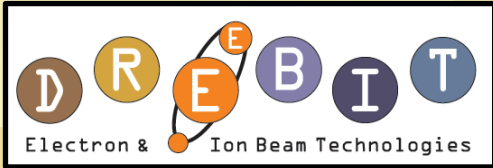
electron-gun:
20 keV, 200 mA



permanent magnets:
NdFeB, $B=600$ mT

UHV: 10^{-10} mbar

EBIT principle & design

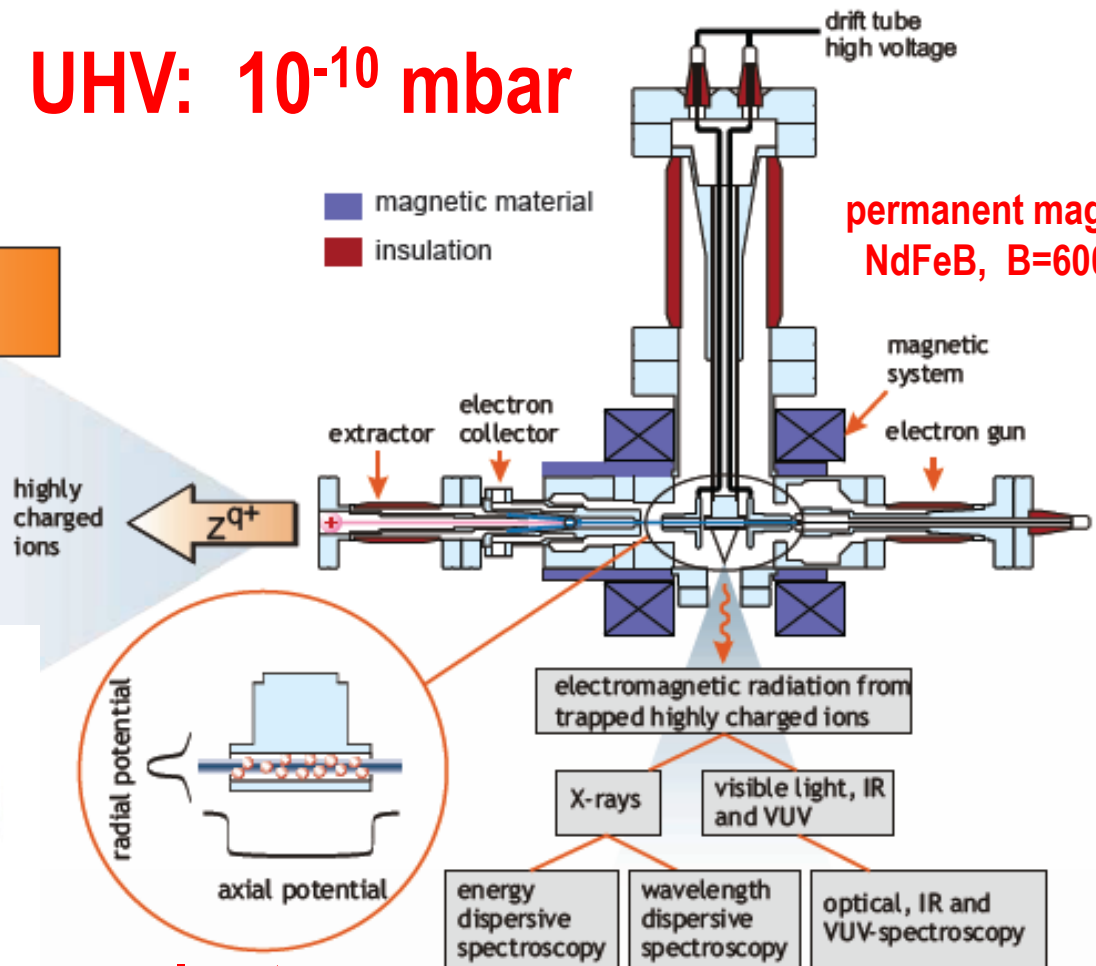


UHV: 10^{-10} mbar

Maximum ionization stage:

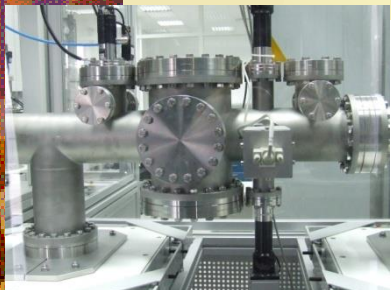
light Z:	bare nuclei
medium Z:	up to helium-like ions
high Z:	up to neon-like ions

**electron-gun:
20 keV, 200 mA**



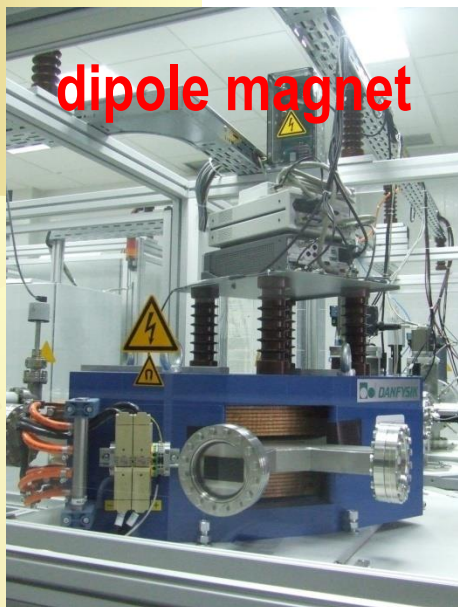
Ion trap

EBIS & ion beamlines



LMIS+QB

beamlines



dipole magnet



EBIT



HV supplies & controls

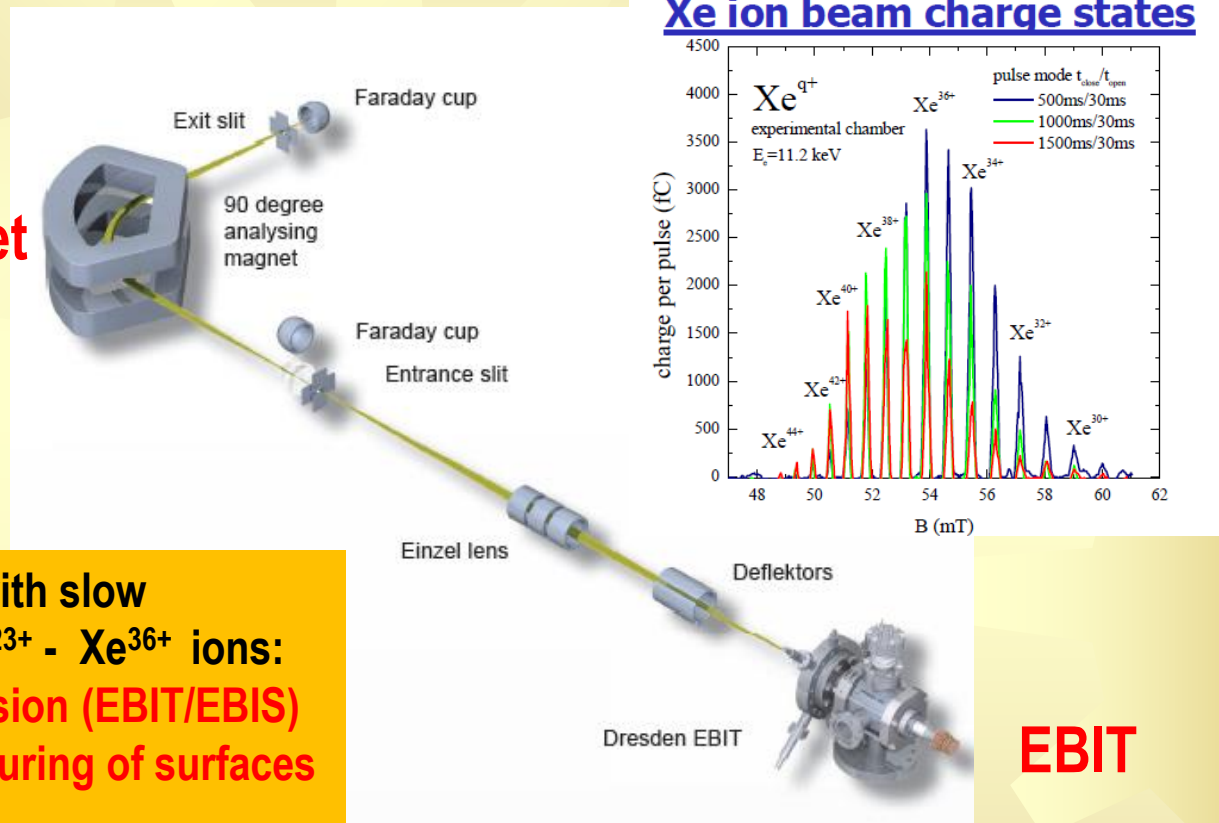


EBIS chamber

EBIS ion beams

pulsed and leaky extraction modes

analysing
dipole magnet



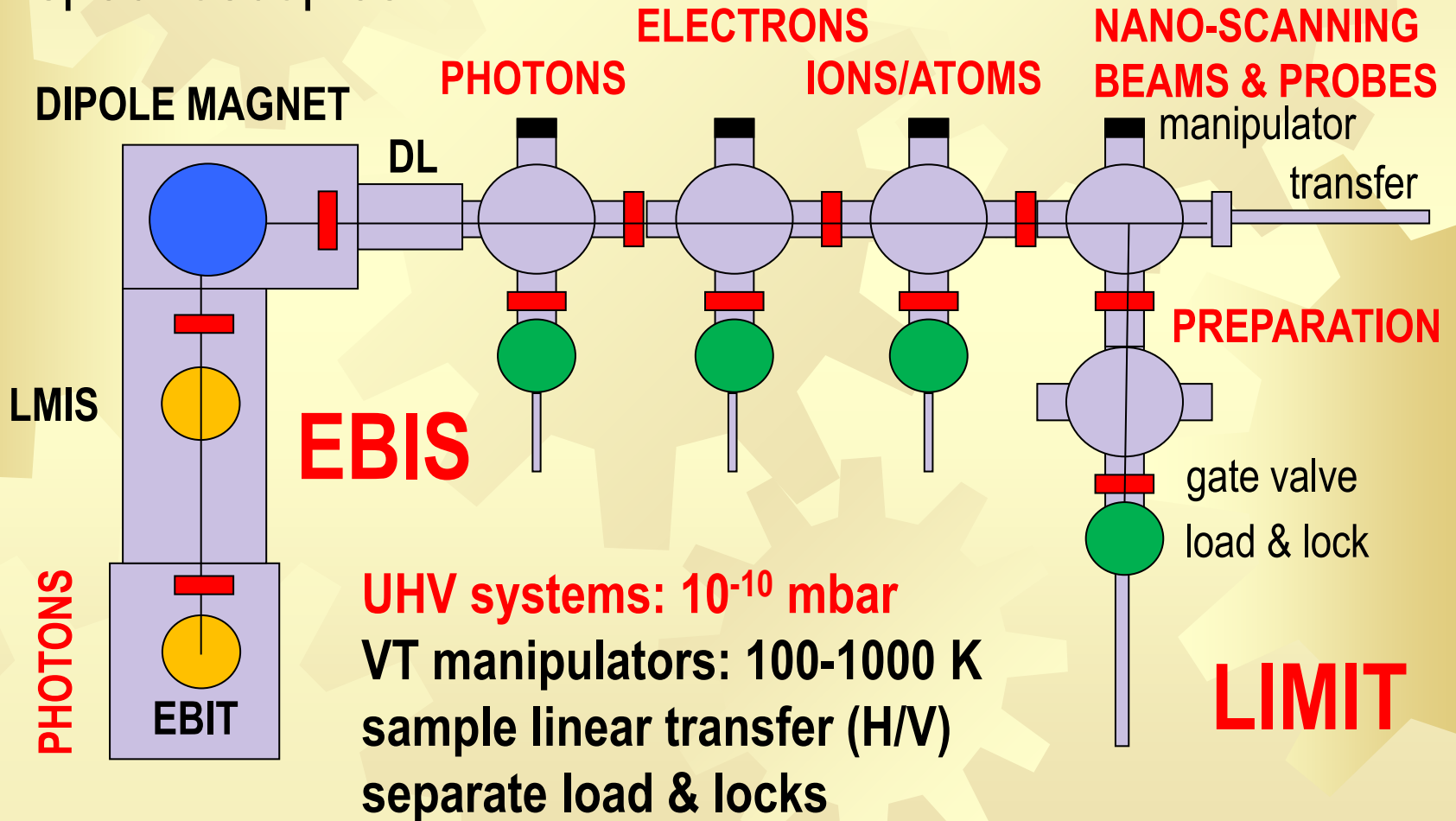
- Experiments with slow
 \sim keV/amu $Xe^{23+} - Xe^{36+}$ ions:
- x-ray emission (EBIT/EBIS)
 - nanostructuring of surfaces (EBIS)

EBIT

HCI intensity: $\sim 10^5 - 10^7$ ions/pulse

LIMIT project (2012)

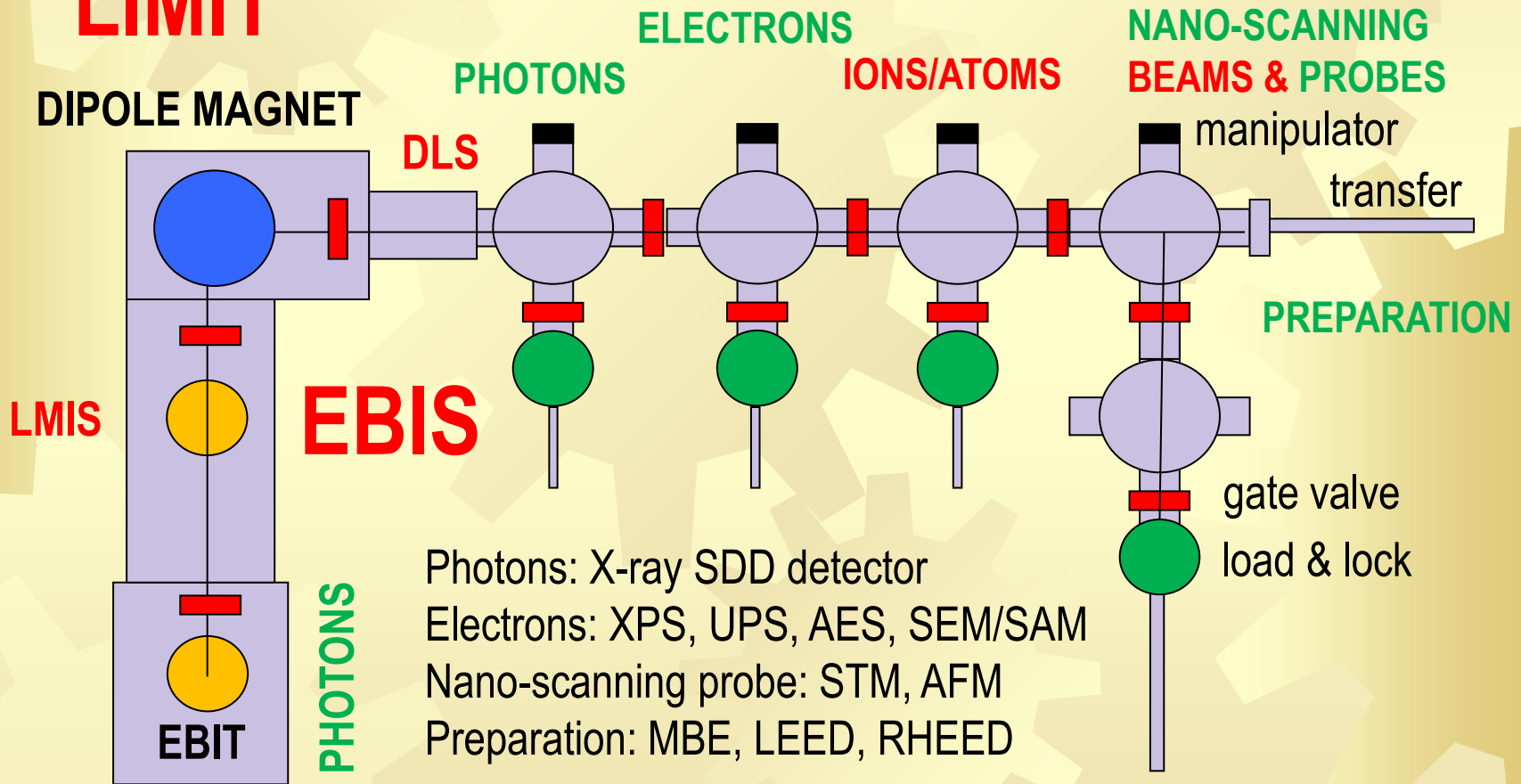
EBIS/EBIT facility and photon, electron, ion/atom mass spectroscopies



LIMIT project (2022)

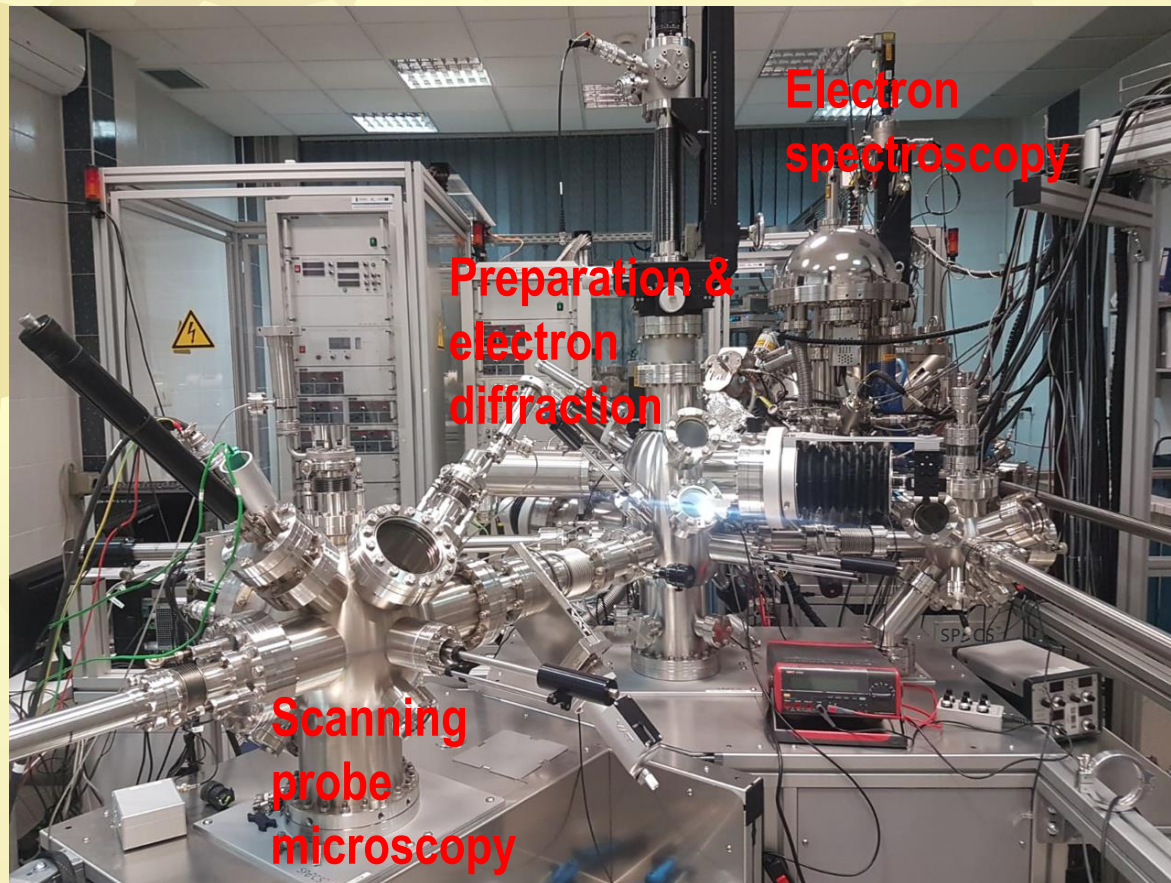
EBIS/EBIT: photon, electron, ion mass spectroscopies

LIMIT



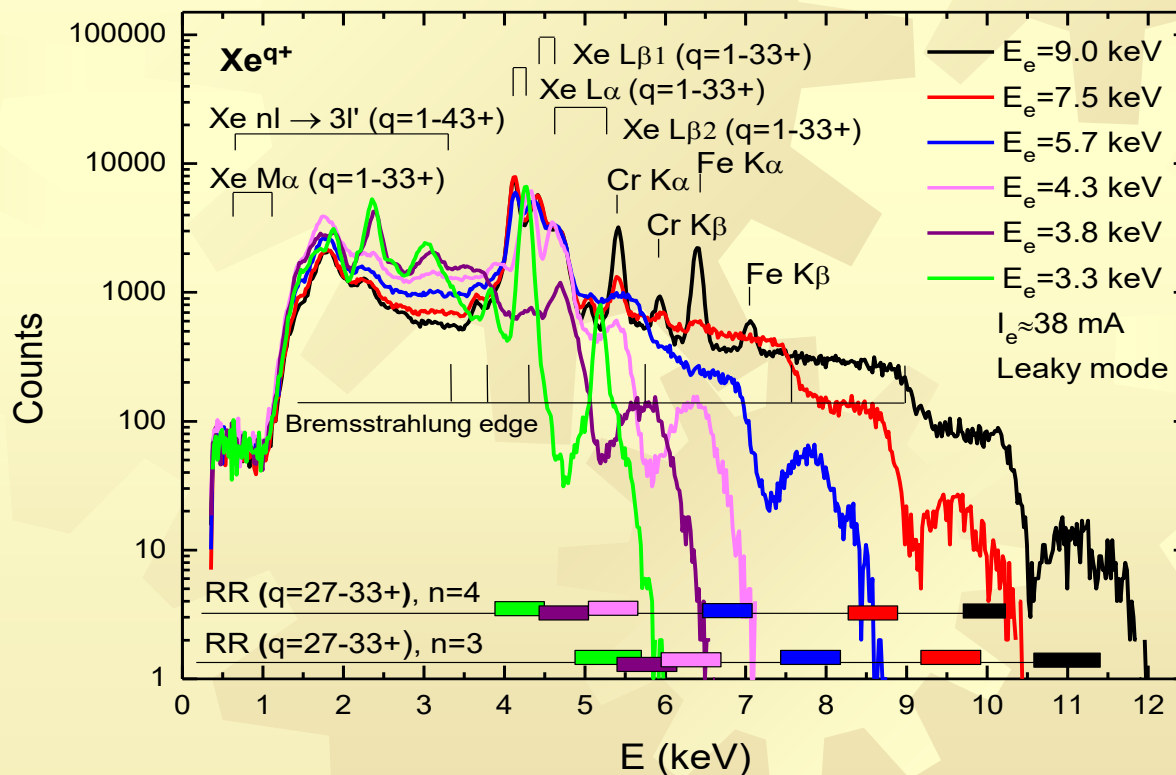
LIMIT: status of 2022

- photon (X-ray) and electron spectroscopy, electron diffraction, sample deposition (MBE) and ion beam cleaning, scanning electron (SEM/SAM) and probe (AFM/STM) microscopy



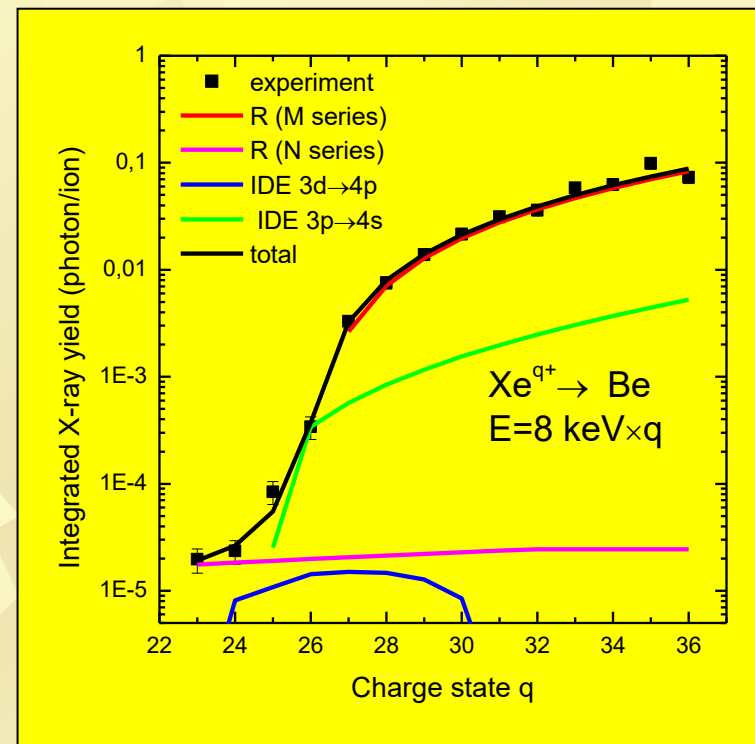
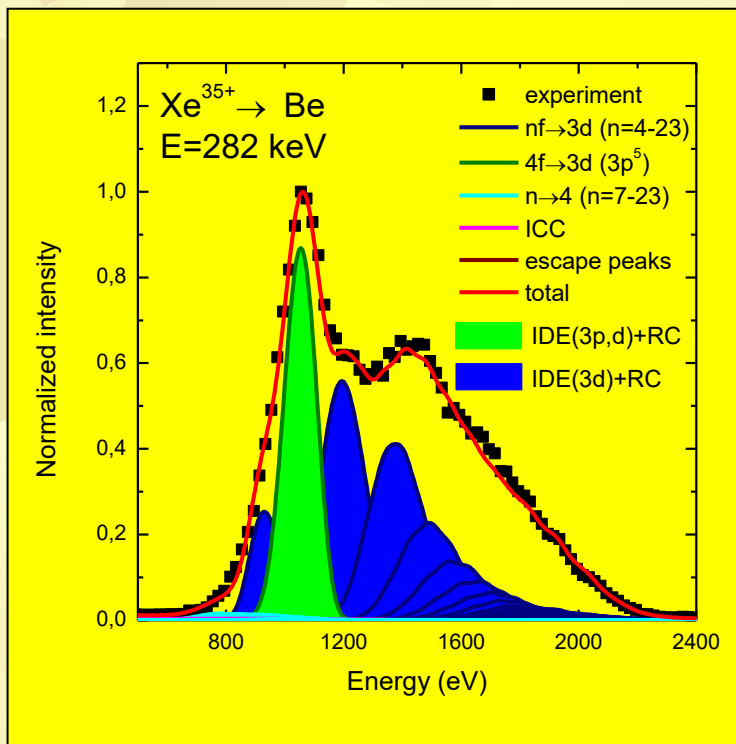
X-rays from EBIT

X-ray emission from EBIT plasma measured by XFLASH SDD detector → collision processes involved: radiative (RR) dielectronic (DR) recombination, electron-impact excitation (EIE) and ionization (EII) → astrophysical implications



X-rays from HCl-surface collisions

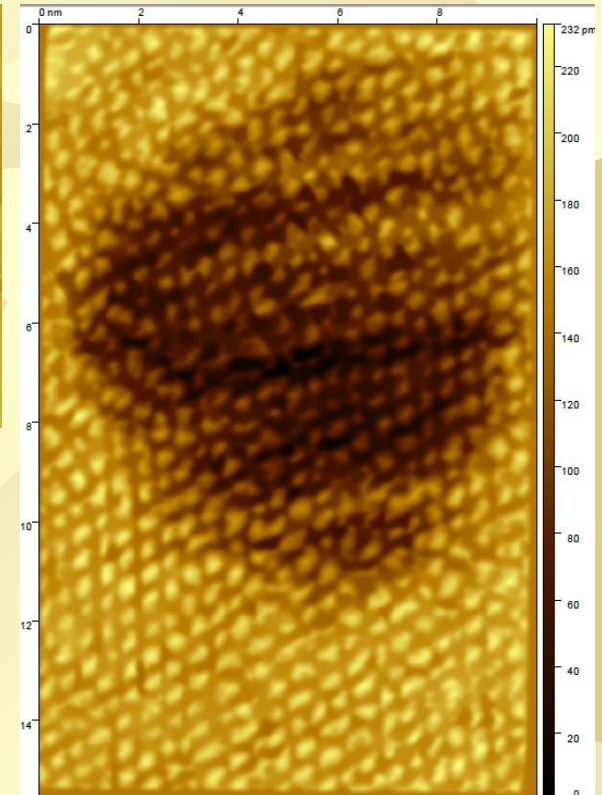
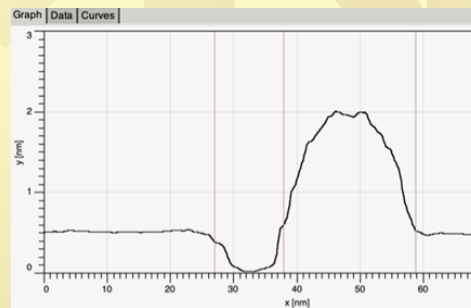
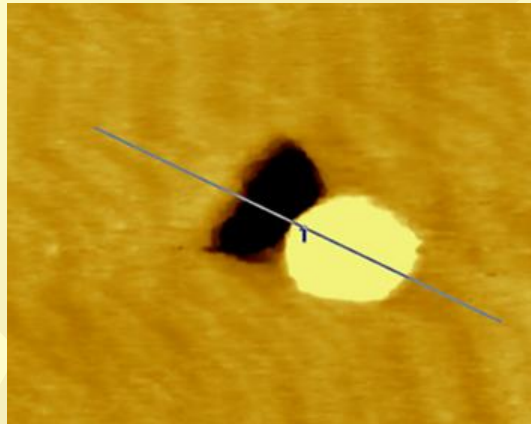
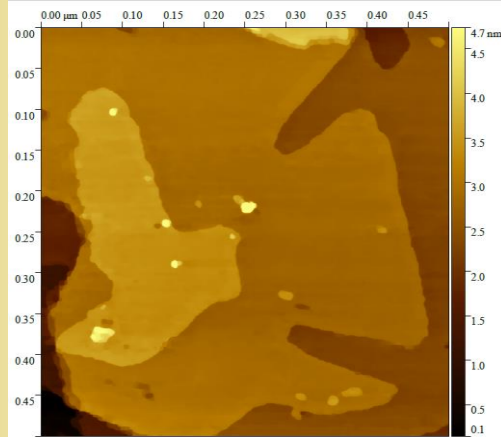
X-ray emission from Rydberg hollow atoms



Exotic Internal dielectronic excitation (IDE), Interatomic Coulombic Decay (ICD) and two-electron one-photon (TEOP) processes were observed and interpreted

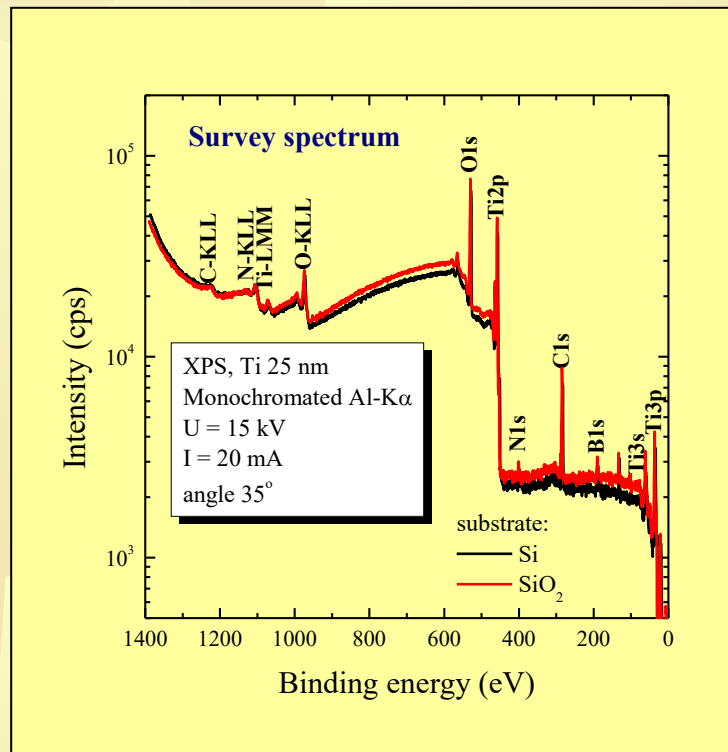
Nanostructuring of surfaces by HCl

Formation of nanostructures on surfaces by an impact of slow highly charged ions from EBIS → studied by scanning tunneling microscopy (STM)



**Xe^{q+} ions on
Au(111) crystal**

Photoelectron and Auger spectroscopy



Photoelectron (XPS) and Auger (AES) spectroscopies were applied to probe the surfaces and nanolayers using the hemispherical energy analyser.

Financing

- ✿ EBIS facility (2010)
- ✿ X-ray spectroscopy XFLASH SDD (2013)
- ✿ Electron spectroscopy:
XPS, AES, SEM/SAM, ISS 3 MPLN (2013)
- ✿ Preparation & electron diffraction:
MBE, LEED, RHEED (2017)
- ✿ Scanning probe nanoscopy:
STM, AFM (2017) Total: ~12 MPLN
- ✿ **DIB grant 3.3 MPLN for EBIS/LIMIT
upgrade (2022) → (2023-2024)**

EBIS & LIMIT upgrade

What is missing?

Liquid metal ion source (LMIS) → higher q up to $\sim 70+$

Decelerating lens system (DLS) → lower ion energies to 100 eV

Beam imaging system (BIS) → beam profile with 25 μm resolution

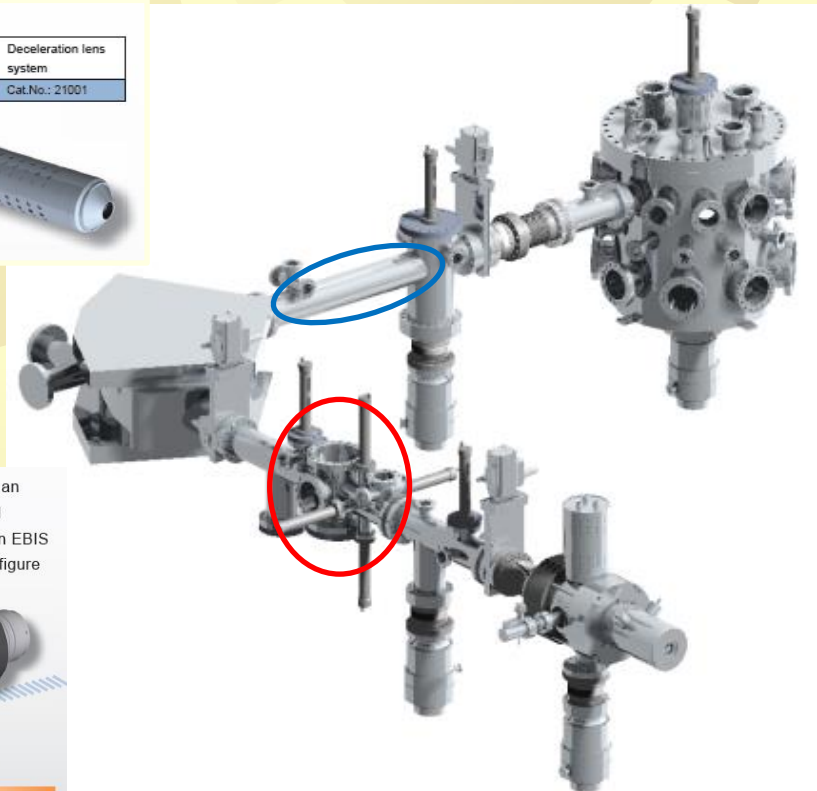
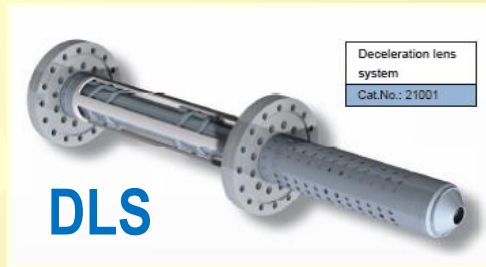
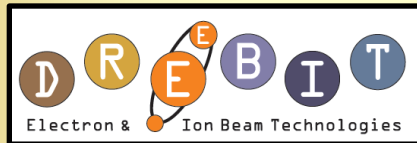
EUV spectrometer → low-energy photons (10-1000 eV)
from relaxation of Rydberg states

Mass spectrometer (SIMS/SNMS) → increased yields for potential
sputtering by HCl

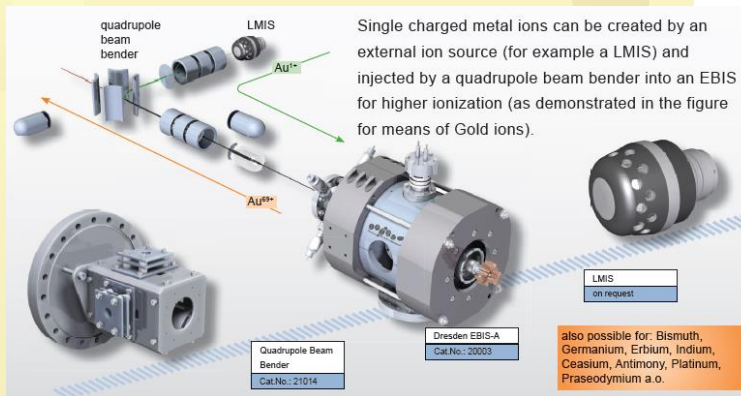
Electron cylindrical mirror analyser (CMA) → electron emission
in relaxation of Rydberg states (ICD)

EBIS upgrade: LMIS and DLS

- ★ Liquid metal ion source (LMIS) + quadrupole bender (QB)
- ★ Deceleration lenses (DLS)



LMIS + QB

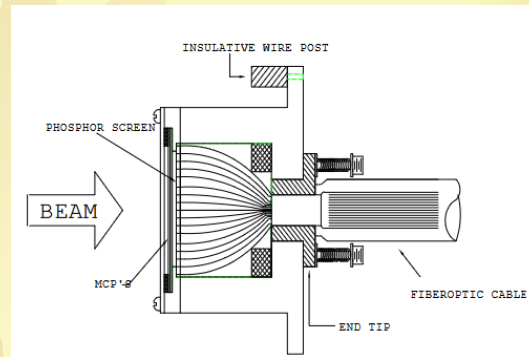


EBIS upgrade: BIS

- ✱ Instalation of Beam Imaging System (BIS)
- ✱ BIS = phosphor screen + flexible fiber optics + microchannel plate

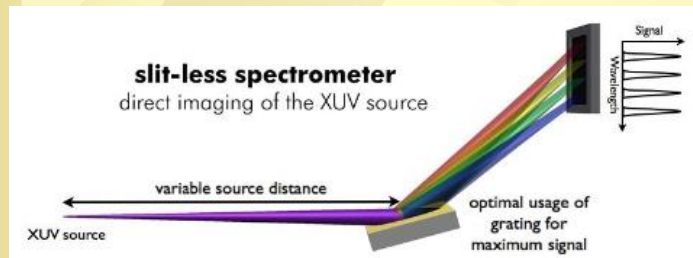


lateral resolution $25\ \mu\text{m}$
diameter 17 mm, fiber conduit 60 cm

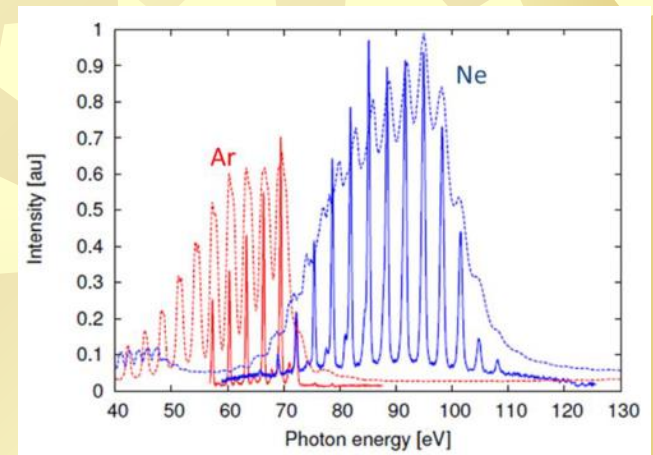


Extended ultraviolet (EUV) spectrometer

Basic idea: to observe EUV photons (1-200 nm) from EBIT and ion-surface interaction



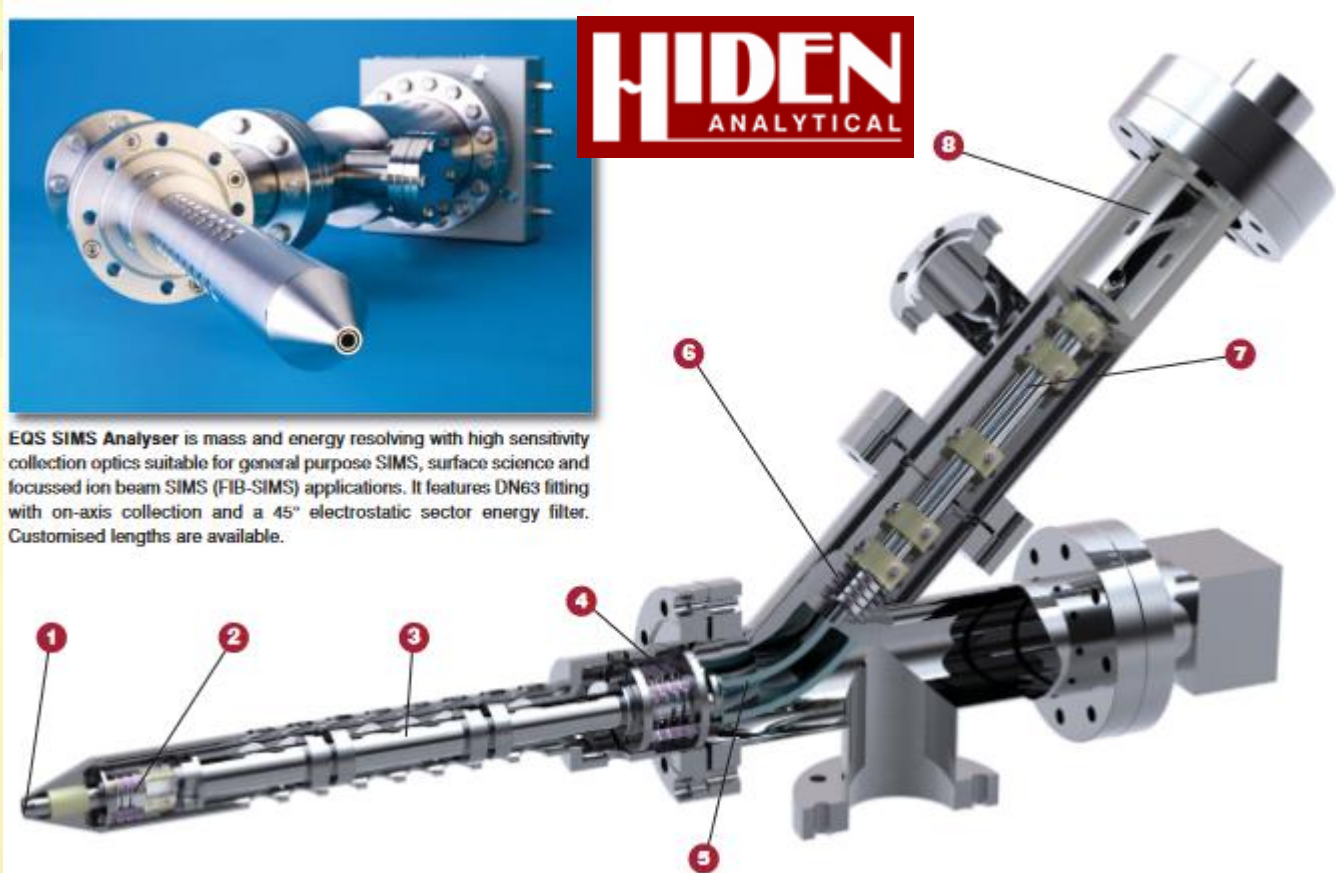
Flat-field slit-less grating EUV (10-1000 eV) spectrometer perfectly fitting EBIT/S photon emission geometry (line source !)



hpspectroscopy

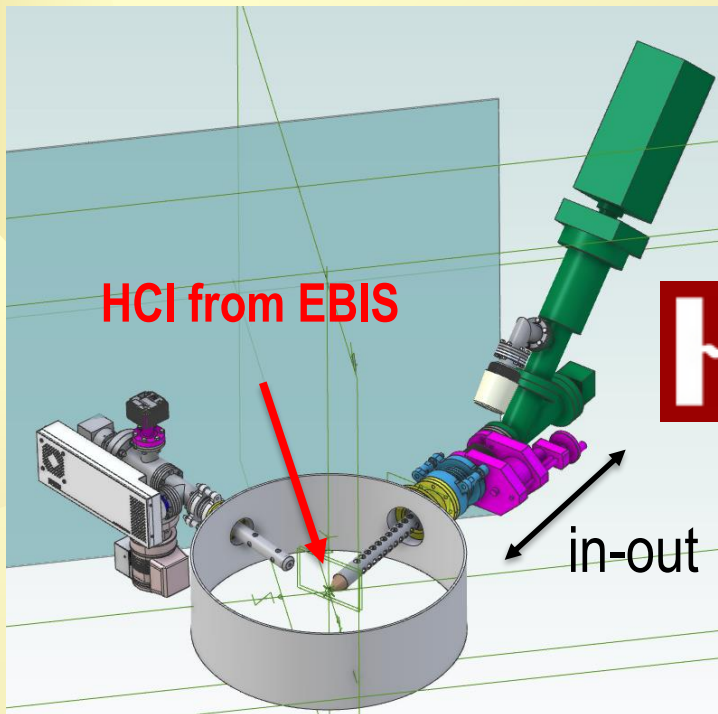
Mass Spectrometry: SIMS/SNMS

- ✿ Sputtered secondary ions, or ionised neutrals, can be measured by quadrupole mass spectrometer (EQS)



Installation of SIMS/SNMS

- besides of HCI from EBIS installed SIMS quadrupole spectrometer (EQS) will be equipped with single-charged ion gun (IG) for „standard” sputtering experiments



EQS

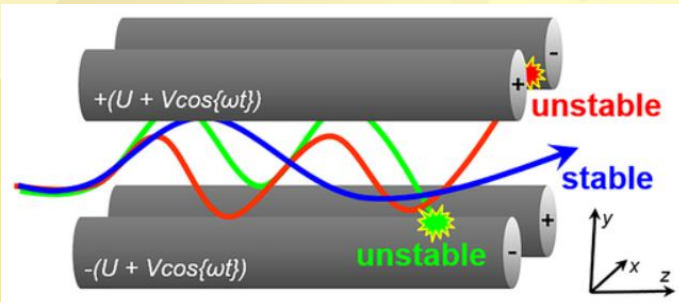


IG



Fundamentals of quadrupole SIMS

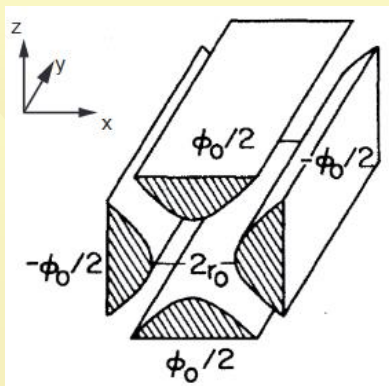
How does it work?



quadrupole potential:

$$\varphi(x, y) = \varphi_0 (x^2 - y^2) / 2r_0^2$$

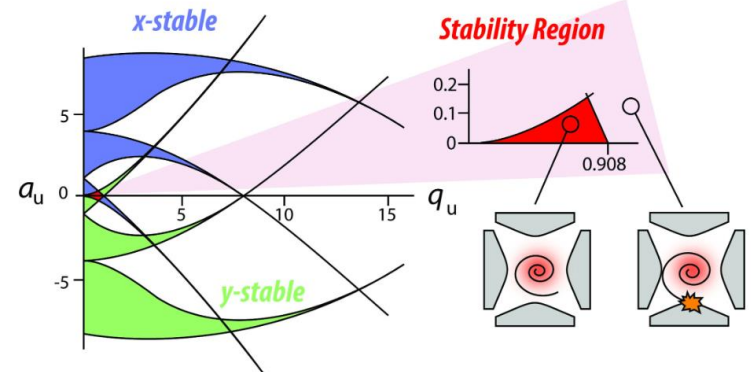
$$\varphi_0(t) = U + V \cos(\Omega t)$$



Stable transmitting ion trajectories are described by the solutions of canonical Mathieu differential equation

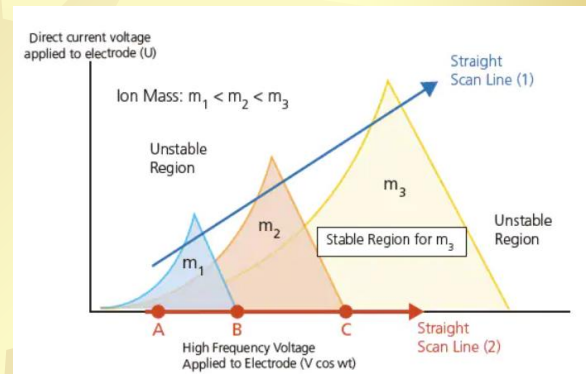
Canonical Mathieu equation:

$$\frac{d^2 u}{d\xi^2} + (a_u - 2q_u \cos 2\xi)u = 0$$



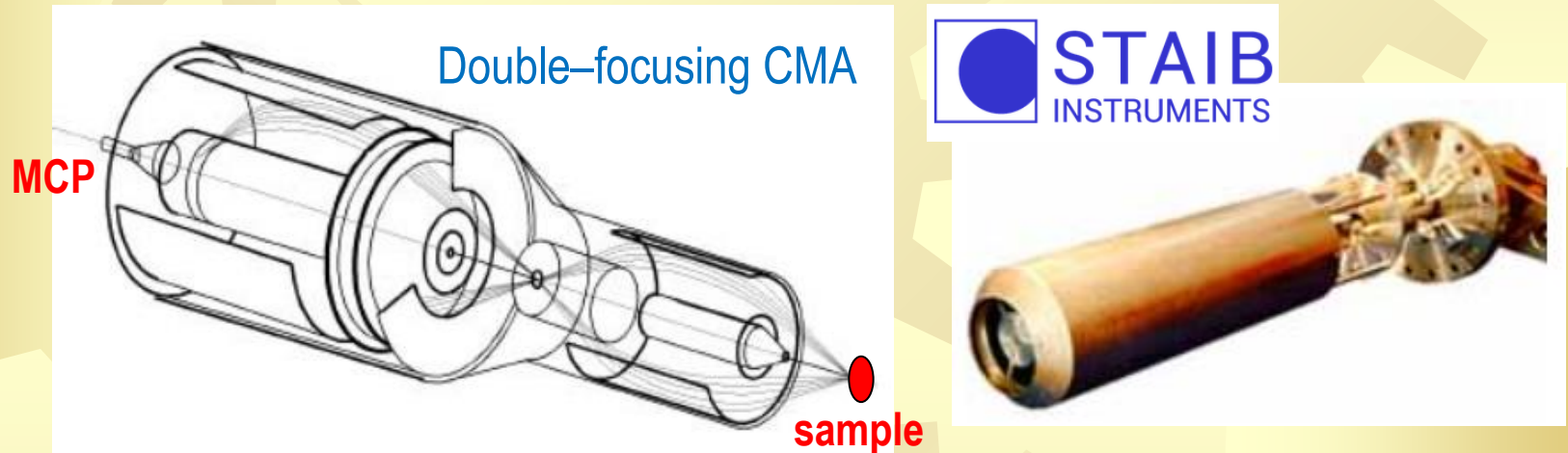
$$u = x, y \quad \xi = \Omega t / 2$$

$$a_u = \frac{8eU}{mr_0^2 \Omega^2} \quad q_u = \frac{4eV}{mr_0^2 \Omega^2}$$



Cylindrical mirror analyzer (CMA)

Compact electron spectrometer to measure electron emission from the surfaces at EBIS



Highly versatile Auger, XPS, UPS, REELS, SAM, ISS analyzer with internal electron gun to study HCl-bombarded surfaces and emission of electrons from relaxation of Rydberg hollow atoms via Auger (A) and Interatomic Coulombic Decay (ICD) processes

The background of the slide features a light yellow-to-gold gradient with several faint, semi-transparent gear shapes scattered across it. On the far left, there is a vertical strip with a colorful, abstract, and somewhat pixelated pattern in shades of red, orange, blue, and green.

No conclusions