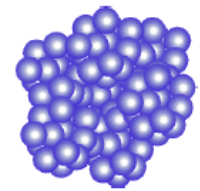
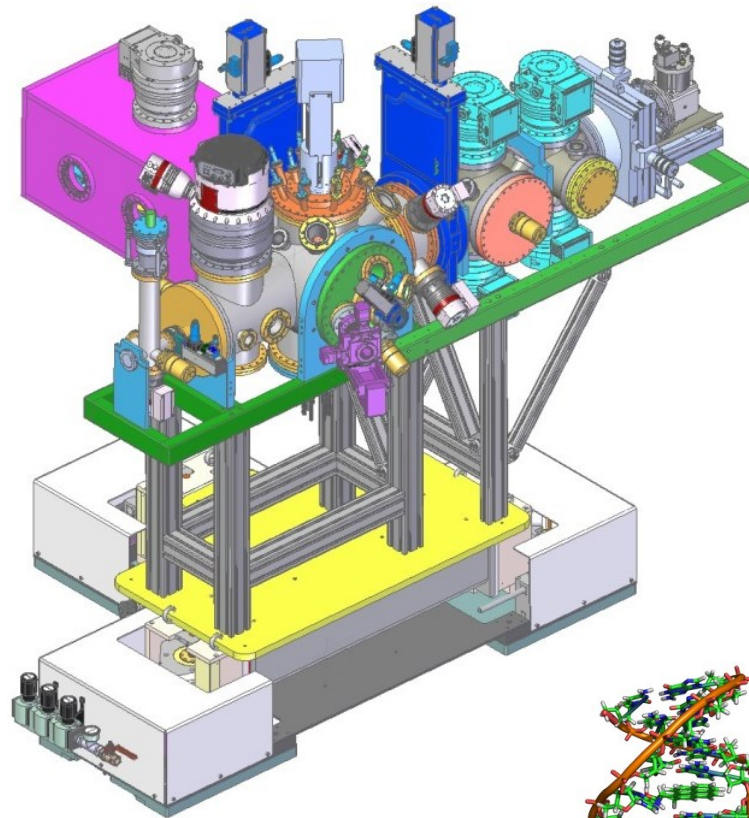


Nano-size Quantum Systems Endstation

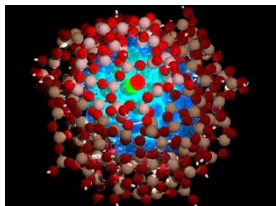


Yevheniy Ovcharenko
Scientific Instrument SQS
Instrument Engineer / Scientist

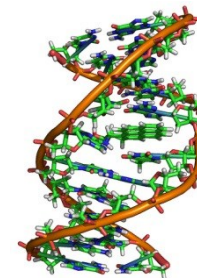
SQS Early User Workshop
Schenefeld, February 12th, 2018



Clusters



Nano-particles

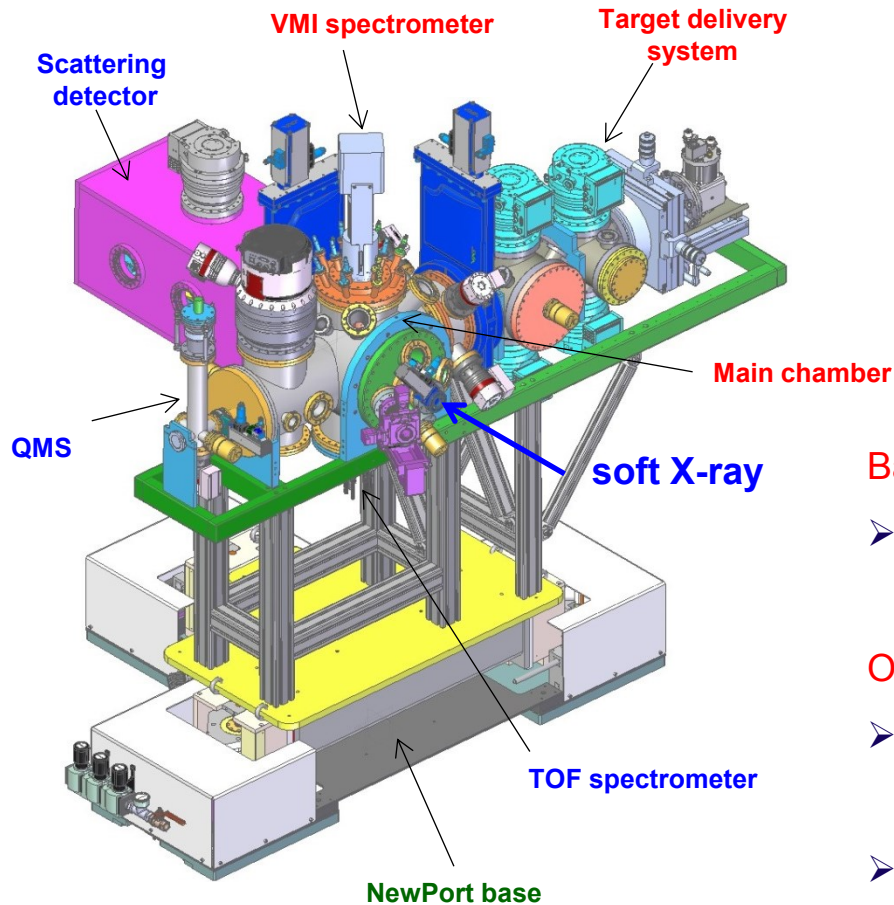


Bio-molecules

SASE 3: 250 – 3000 eV

2 - 100fs

NQS Endstation



Background vacuum: $10^{-9} \div 10^{-10}$ mbar

Experiments

- Electron spectroscopy
- Ion spectroscopy
- Single shot scattering imaging

Target delivery system

User contributions / User consortium

Baseline equipment:

- Rare gas aggregation cluster source
(in coll. with T. Möller et al., TU-Berlin)

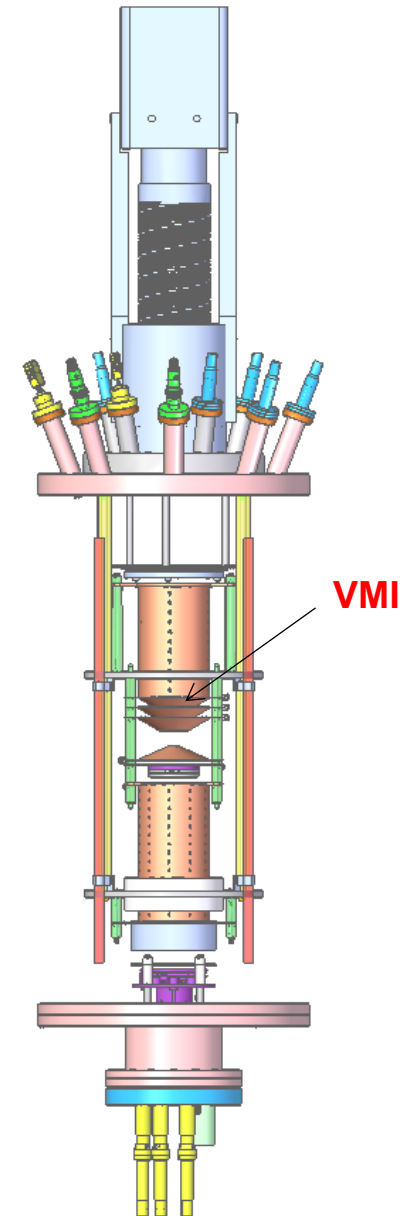
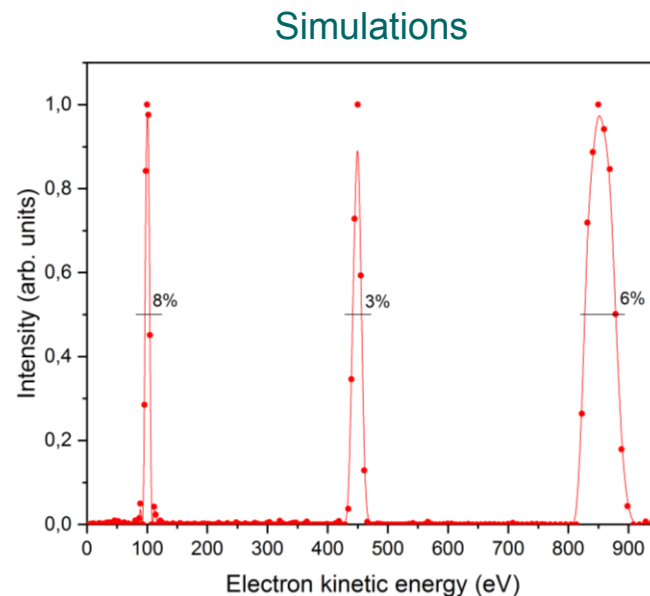
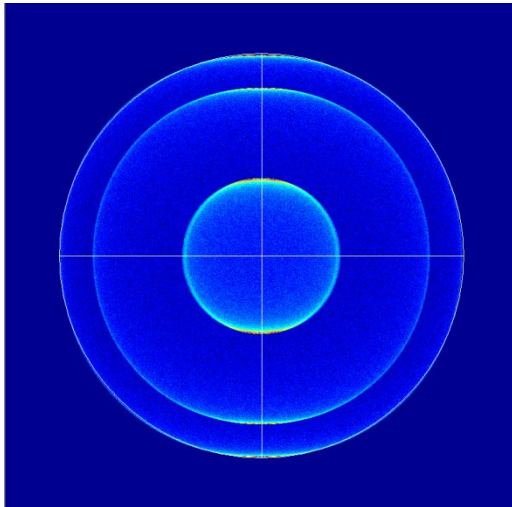
Options:

- Pulsed microplasma metal cluster source (PMCS)
(in coll. with P. Piseri, Uni. Milano)
- Controlled molecular beam (COMO) set-up
(in coll. with J. Küpper et al., CFEL)
- Nano-particle source
(coll. between J. Hajdu et al., Uni. Uppsala & J. Schulz et al., European XFEL)

Electron Spectroscopy

■ VMI spectrometer – base-line equipment

- Conical shape electrodes
- Operate with the **scattering detector**: max. view angle is **60°**
- Electron kinetic energy range up to **850 eV**
- Energy resolution $\Delta E/E$ is **3.0 %**



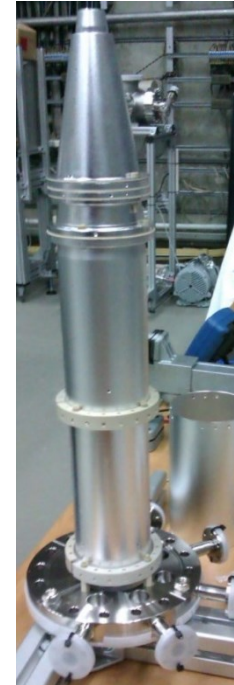
- 10 Hz solution: **1Mpix** sCMOS camera
- High. Rep. option: Hyper Vision HPV-X2 (Shimadzu Corp.) with 10Mfps read-out speed in Burst mode - **under review**

Electron Spectroscopy

Options:

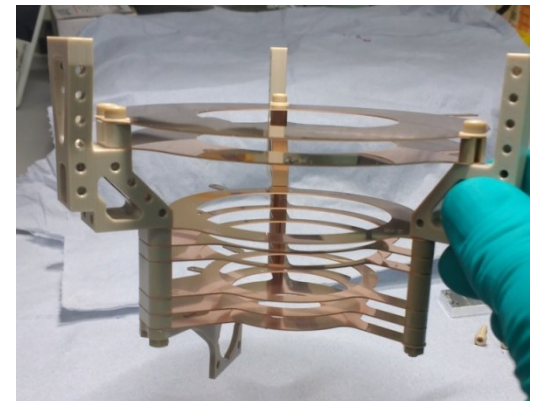
High resolution eTOF spectrometer (AQS - A.De Fanis)

- Electron kinetic energy range 0 – 3000 eV
- 0.1% of 4π sr acceptance
- $E/\Delta E \sim 10^4$ at 800 eV



High resolution VMI spectrometer (AQS – S.Deinert, T.Mazza, I.Shevchuk)

- Electron kinetic energy range up to 1.2 keV
- Energy resolution $\Delta E/E$ is 1%



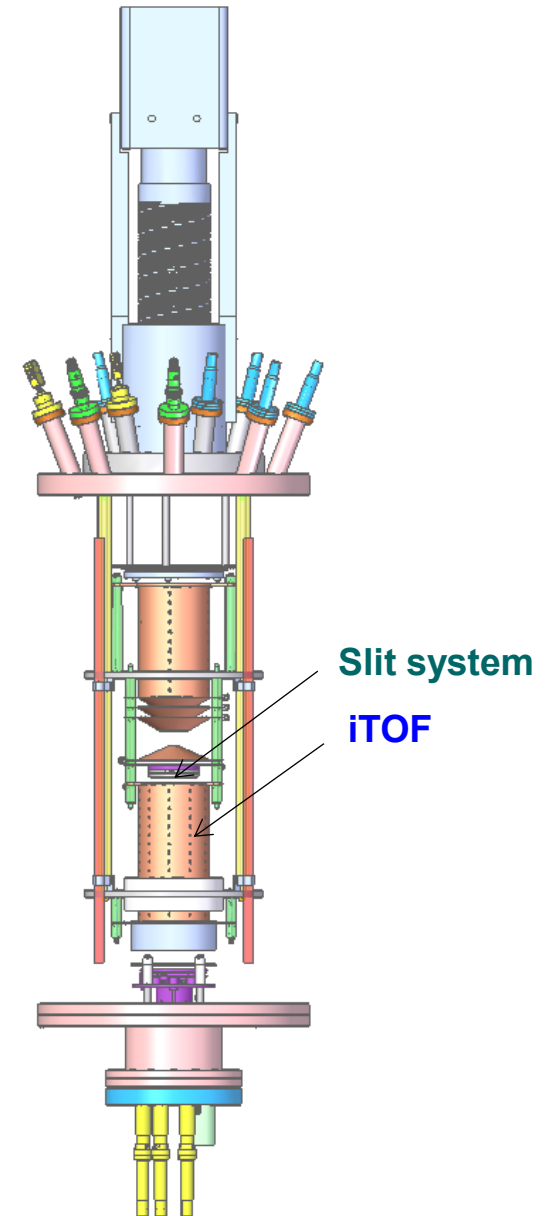
Ion Spectroscopy

■ TOF spectrometer

- Standard Wiley-McLaren design
- Operate with the **scattering detector** & **VMI spectrometer**
- Mass resolution $m/\Delta m$:
 - **450** for thermal ions in VM&iTOF mode
 - **1000** for thermal ions in iTOF mode

■ VMI spectrometer

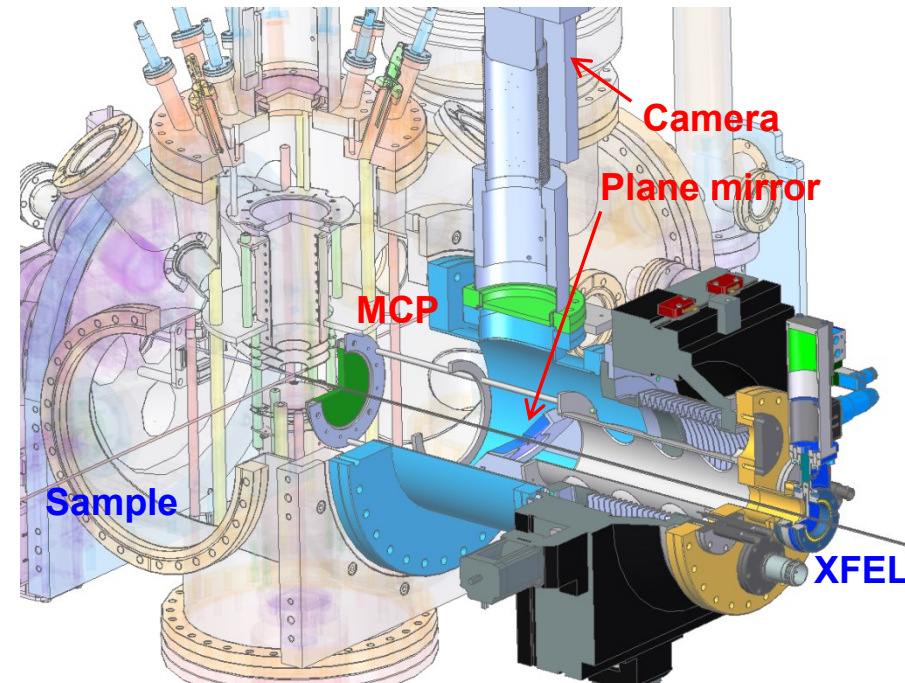
- Acceptance: 4π
- Energy resolution $\Delta E/E$ is **3.0 %**
- Mass resolution $m/\Delta m$:
 - **200** for thermal ions
 - **30** for 400 eV ion kinetic energy



Single Shot Scattering Imaging

Parameter	Value
Energy range	0.5 – 2 keV
Detection efficiency	5 – 15 %
Detector size	75 mm in diameter
Number of pixels	~ 1000 x 1000
Spatial resolution	75 x 75 μm^2
Dynamic range	< 1000 @ 1 keV
Resolution	Single photon down to 0.25 keV
Read out noise	1e ⁻ rms (sCMOS camera)
Frame rate	10 Hz
Hole in the center	3 mm in diameter
Vacuum conditions	<10 ⁻⁹ mbar (UHV comp.)

MCP stack with hole in the center
Day-one solution !



Inter. zone to detector distance = 65mm

SQS team

T. Möller et al.



C. Bostedt et al., J. Phys. B: At. Mol. Opt. Phys. **43**, 194011 (2010)

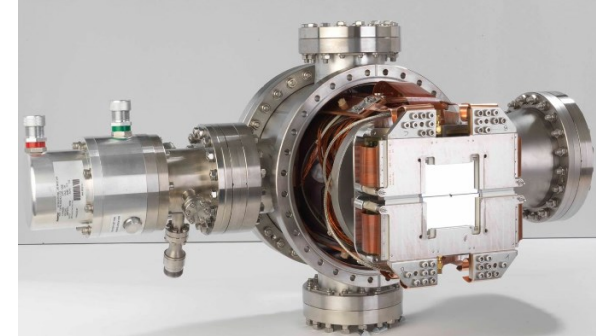
D. Rupp, Ph.D. thesis, TU Berlin, 2013

Imaging Detector: pnCCD Detector

Parameter	Value
Energy range	0.03 – 25 keV
Detection efficiency	> 80% @ 0.7 – 12 keV
Detector size	78 x 78 mm ²
Number of pixels	1024 x 1024
Sensor pixel shape	Rectangular
Sensor pixel size	~ 75 x 75 μm ²
Dynamic range	Up to 10.000 @ 1 keV
Resolution	Single photon from 50 eV to 25 keV
Read out noise	3 e ⁻ rms (high gain)
Frame rate	Up to 150 Hz
Minimum center gap	2 mm
Vacuum conditions	Goal < 10 ⁻⁸ mbar (UHV comp.)

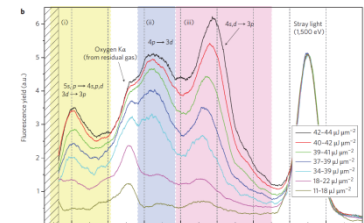
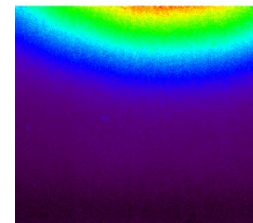
“Low Speed” Imagers for 10 Hz Applications

Beginning 2019



L. Strüder et al., Nucl. Instr. Meth. Phys. Res. A **614**, 483 (2010)

imaging & spectroscopy



Rupp, D., New Journal of Physics, vol. 14, Issue 5, pp. 055016 (2012)

B. Rudek, et al. *Nat. Photonics* **6** (2012) 858

Detector
Development

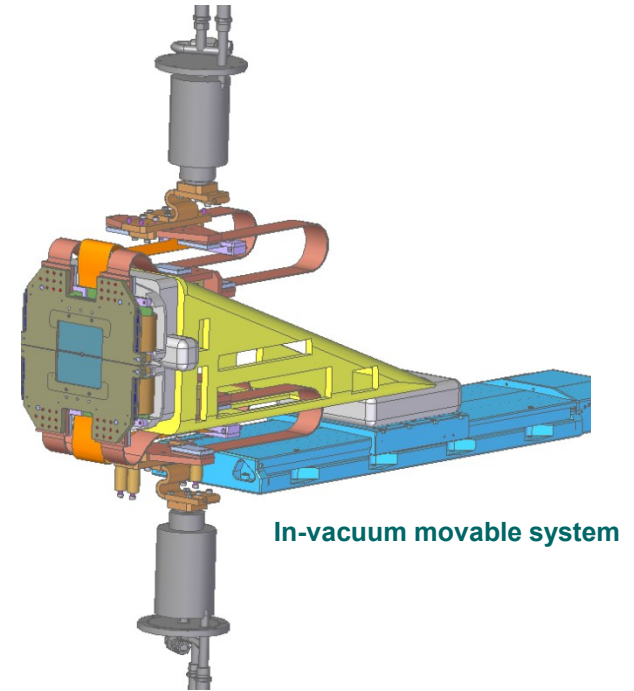
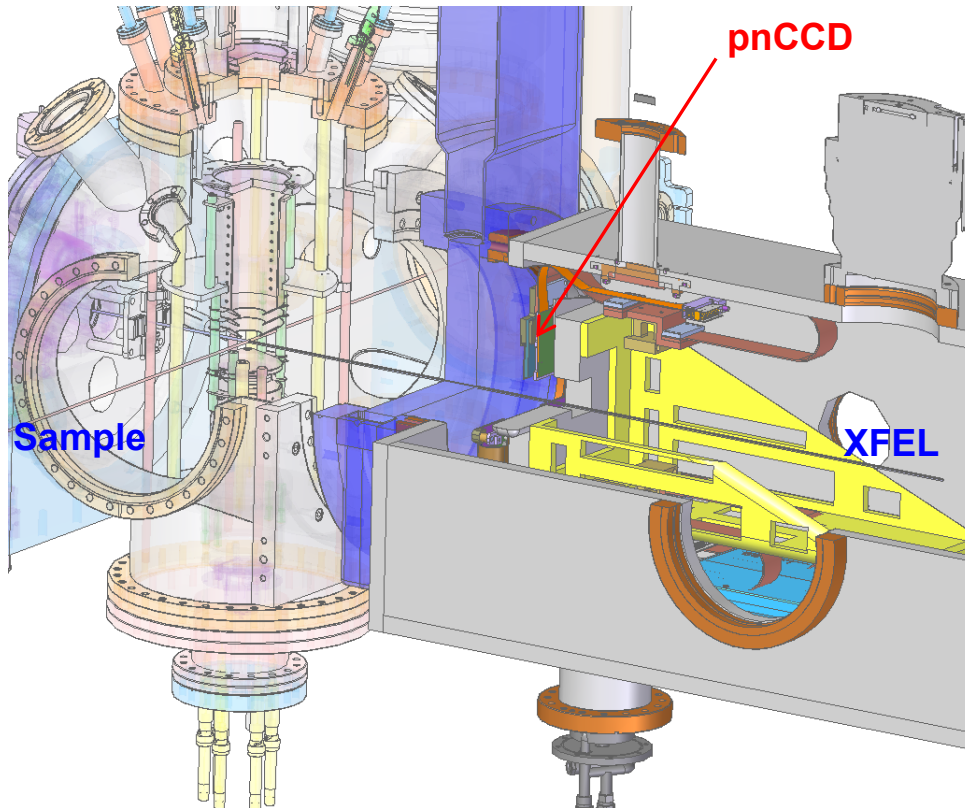


PNSensor

Robert Hartmann

Lothar Strüder

pnCCD Detector Integrated to NQS Set-up



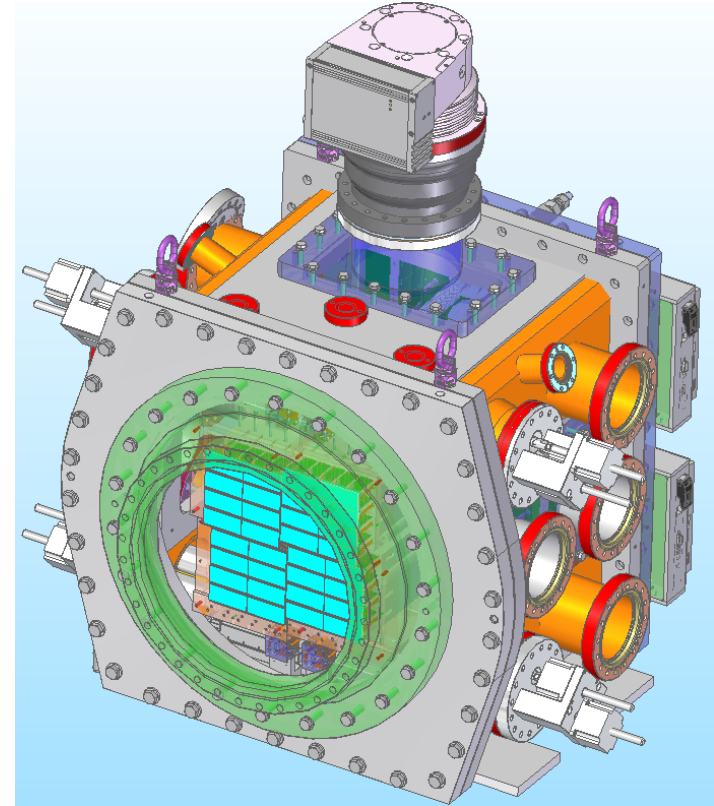
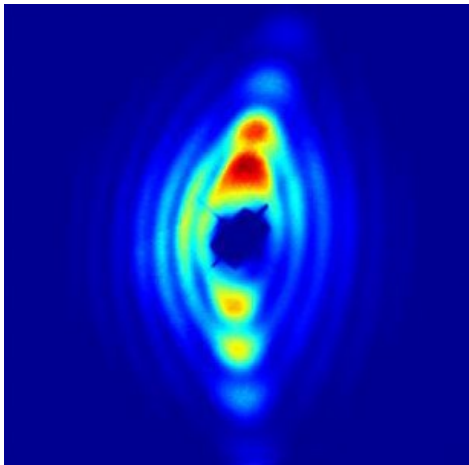
- Linear translation along the FEL beam 300mm
- Up/down movement of 20mm / pnCCD module
- Lateral translation +/- 5mm

Inter. zone to detector distance = 50 ÷ 350 mm

UHV compatible design !

Single Shot Scattering Imaging Future Upgrade !

DSSC Camera: middle of 2020

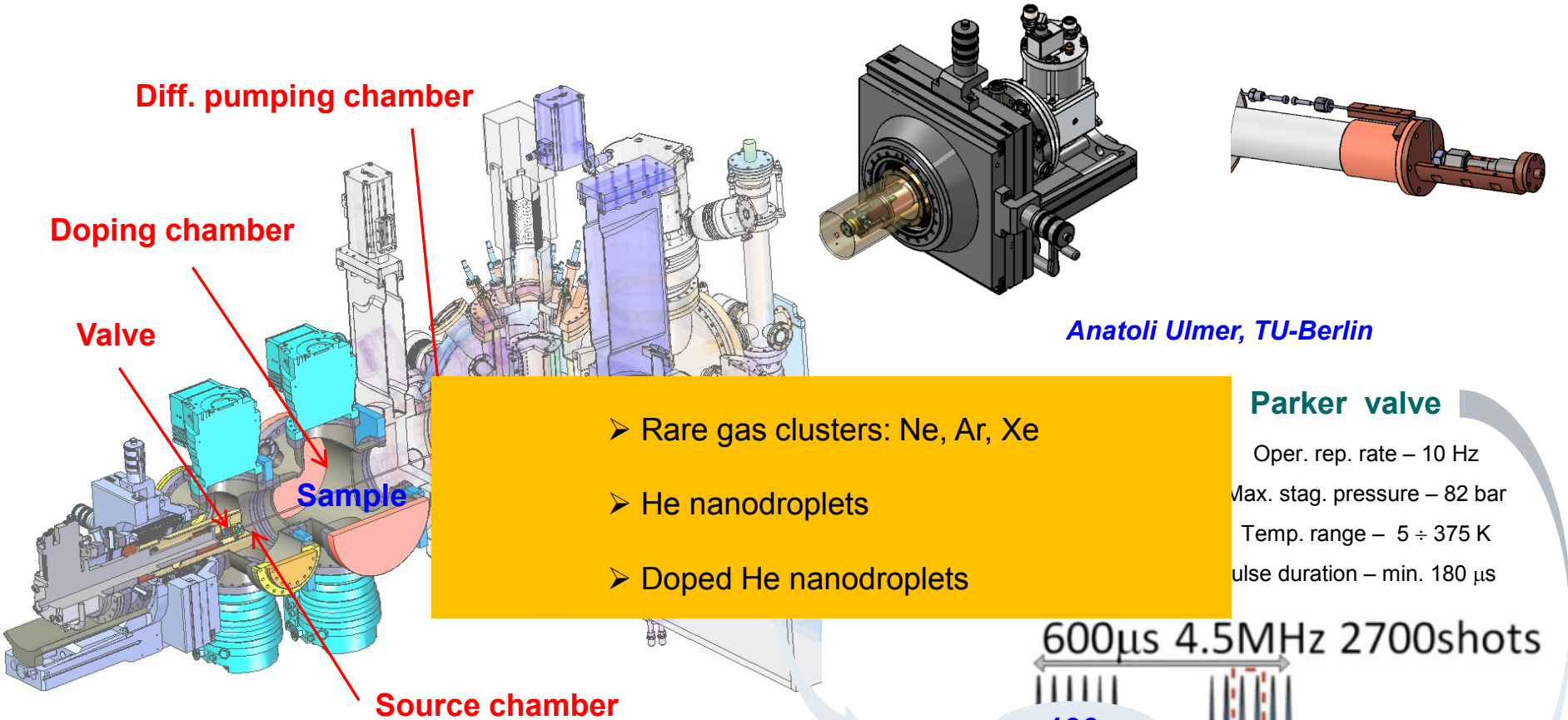


PNSensor

Detector
Development



Target Delivery System – Rare Gas Cluster Source & Doping Option



Anatoli Ulmer, TU-Berlin

Parker valve

Oper. rep. rate – 10 Hz
 Max. stag. pressure – 82 bar
 Temp. range – 5 ÷ 375 K
 pulse duration – min. 180 μs

- Rare gas clusters: Ne, Ar, Xe
- He nanodroplets
- Doped He nanodroplets

600μs 4.5MHz 2700shots

136

FEL pulse train

2700

300

Day 1

User contribution:

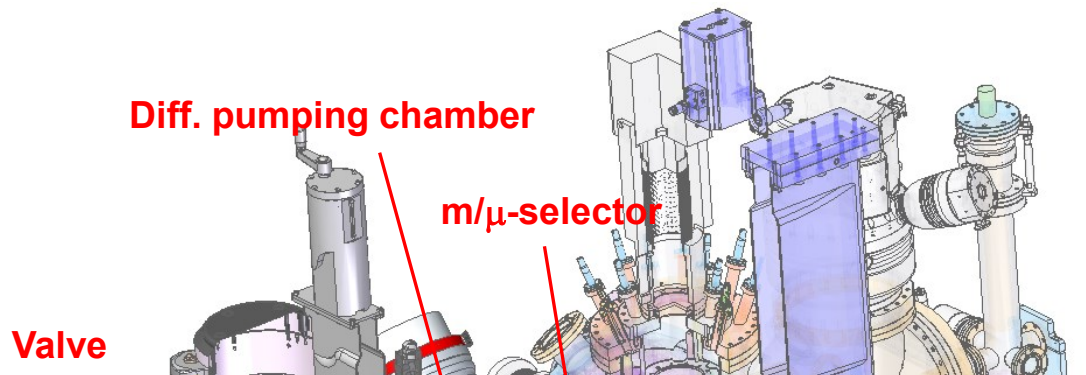
T. Möller et al., TU-Berlin





Target Delivery System – Controlled Molecular Beam (COMO) Set-up

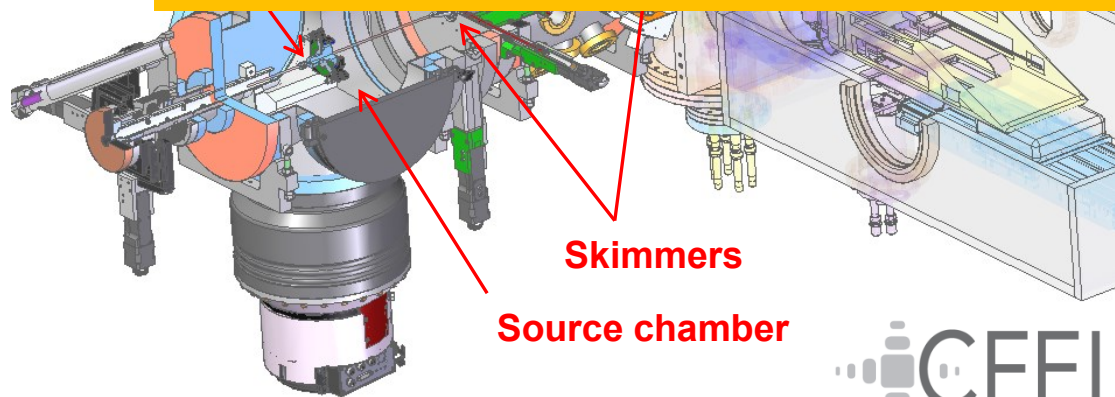
State-, size-, and isomer-selected samples of polar molecules and clusters



<https://sites.google.com/site/evenlavievalve>

Even-Lavie valve (special design)

- neutral molecules with only one single conformer (structural isomer)
- dipole moment differences is used to separate the individual conformers



Pulse duration > 100 μs

> 450 pulses / pulse train

Amsterdam PiezoValve

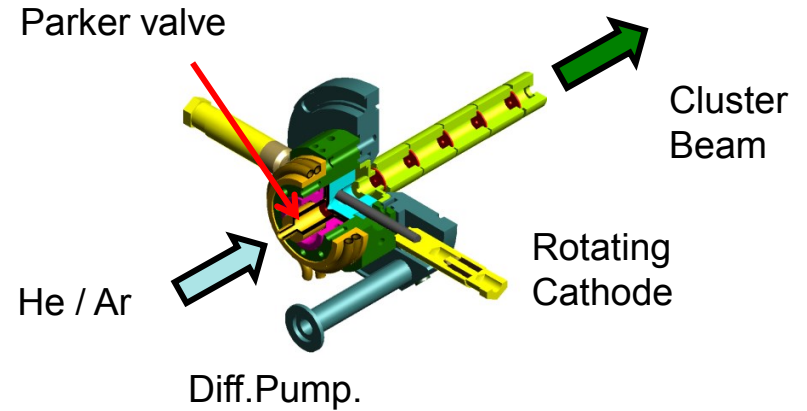
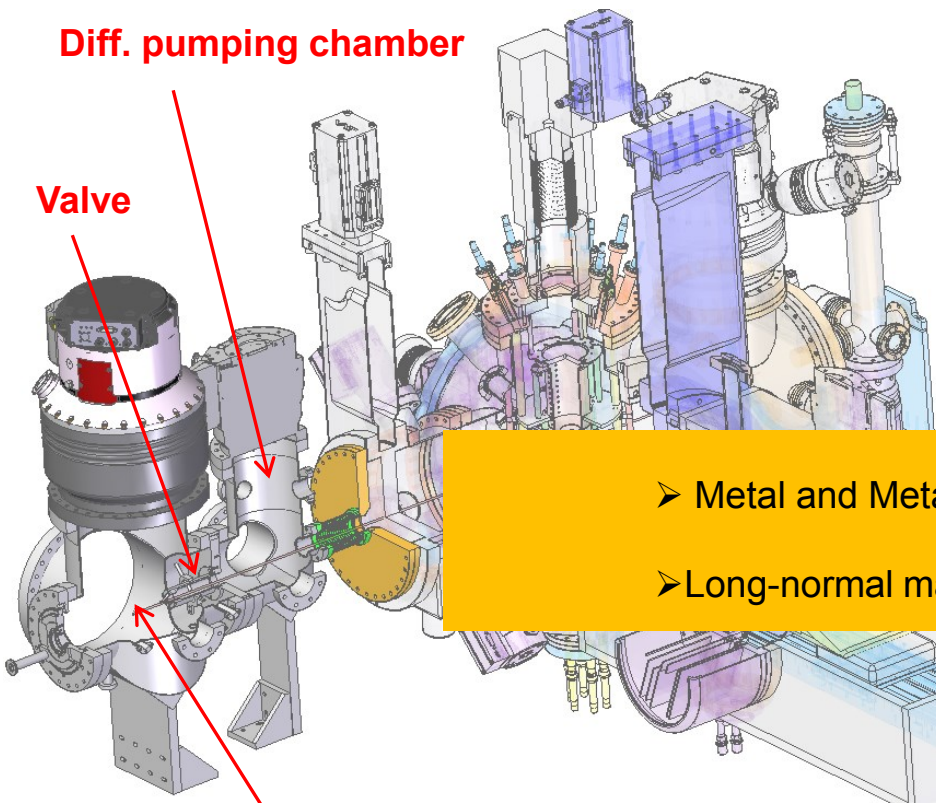
- Rep. rate – 10 kHz
- Nozzle diameter – 150, 200, 300 μm
- Max. stag. pressure – 15 bar
- Temp. range – room temperature
- Pulse duration – < 20 μs up to continuous

Whole FEL pulse train

User consortium: J. Küpper et al., CFEL



Target Delivery System – Pulsed Microplasma Cluster Source (PMCS)



- Metal and Metal oxide clusters Al, Ti, Fe...
- Long-normal mass distribution, $\mu \sim 10^2 - 10^3$ atoms

Source chamber

User contribution:

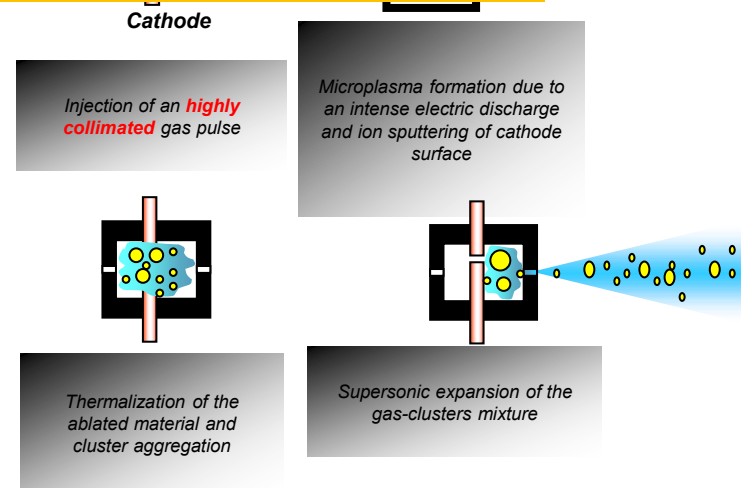
P. Piseri, U Milano



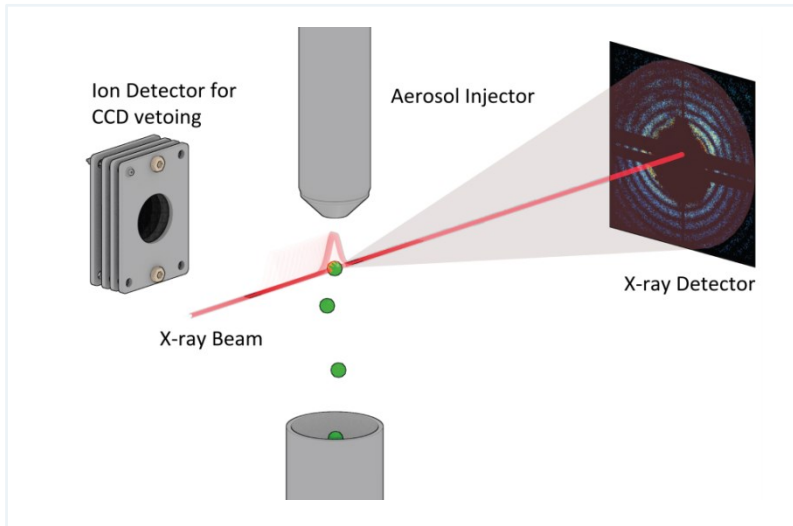
UNIVERSITÀ DEGLI STUDI
DI MILANO



European XFEL



Target Delivery System – Aerosol Sample Delivery

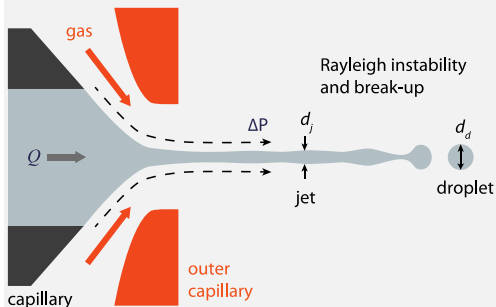


- Sample in gas phase through droplet atomization
- Naked particles focused by an aerodynamical lens
- Ion time-of-flight detector veto
- 4.5 MHz at final operation mode

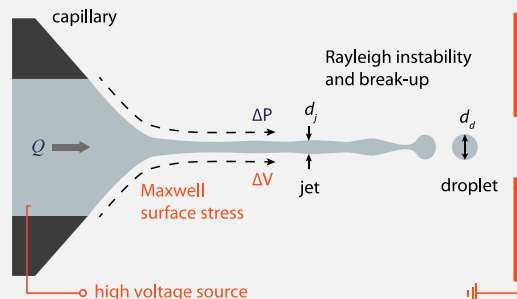
Has been already used at SPB !

Different ways of droplet generation

GDVN (flow focusing)



Electrospray (Electrostatic focusing)



	GDVN	Electrospray
Flowrate	~1 μl/min	~60 nl/min
Droplet diameter	~1 μm	~150 nm
Optimal Sample Conc. (Particles/ml)	~1 · 10 ¹²	~4 · 10 ¹⁴

Johan Bielecki, Uppsala In-kind-contribution

Day 1 Experimental Conditions

FEL beam performances

Parameter	Unit	Value
Photon energy	eV	1000 (&few more)
Pulse duration	fs	50 – 100 (FWHM)
Pulse energy	mJ	Up to 3
Number of pulses		300 / pulse train
Repetition rate	MHz	1
Polarization		Linear (horizontal)
Focus size	μm	1.5 – 2.5
Power density	W/cm^2	$> 10^{17}$

Electron spectroscopy:

- VMI spectrometer
- eTOF spectrometer

Ion spectroscopy:

- iTOF spectrometer
- VMI spectrometer

Single shot scattering imaging

- MCP stack with a hole
- pnCCD detector

Target delivery options:

- Rare gas cluster source
- Metal cluster source
- COMO set-up
- Aerosol source

Acknowledgments

SQS team

A. Achner
 T. M. Baumann
 R. Boll
 S. Deinert
 A. De Fanis
 P. Grychtol
 M. Ilchen
 T. Mazza
 M. Meyer
 J. Montaño
 Y. Ovcharenko
 N. Rennhack
 R. Wagner
 P. Ziolkowski



Anatoli Ulmer
Daniela Rupp
Thomas Möller



Detector Development

Monica Turcato
 Markus Kuster

Sample Environment

Johan Bielecki
 Joachim Schulz



UNIVERSITÀ DEGLI STUDI
 DI MILANO

Paolo Piseri



Sebastian Trippel
 Thomas Kierspel
 Jochen Kupper

PNSensor

Robert Hartmann
Lothar Strüder

Supplemental materials

Detector options

Electron Spectroscopy

- double VMI spectrometer
- high kinetic energy range VMI spectrometer (AQS)
- magnetic bottle (*R. Feifel et al., U Göteborg*)
- SCIENTA analyser (*K.H. Meiwes-Broer et al., U Rostock*)

Ion Spectroscopy

- Magnetic deflection TOF (B-TOF) spectrometer
 - ▶ mass resolution:
 - possible to distinguish ions with energies between 1 eV and 1 MeV and charge states between 1⁺ and 30⁺
 - the spectrometer is very flexible (changing the magnetic field)
 - compatible with TOF and VMI spectrometers
- Thomson parabola (*E. Rühl et al., FU-Berlin*)

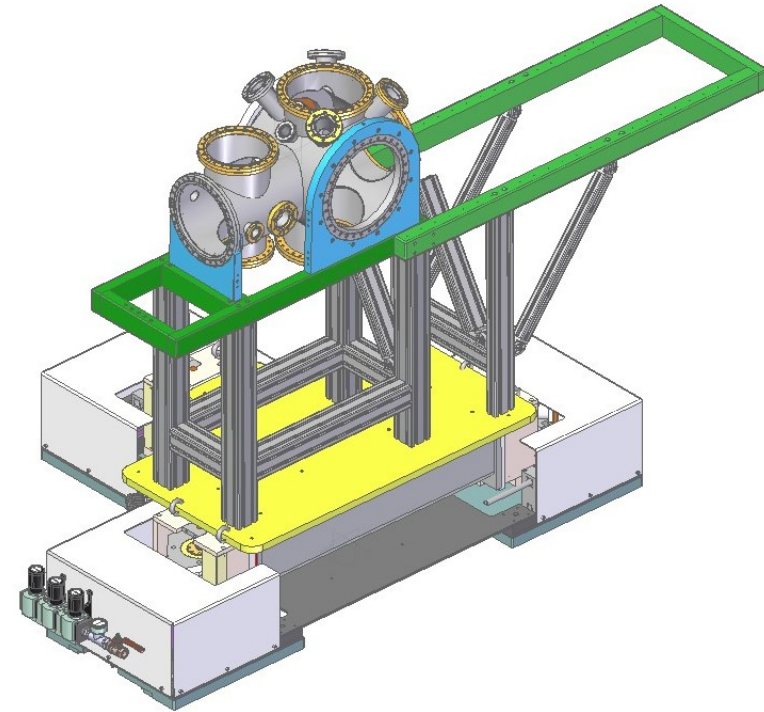
NQS support & chamber alignment

NewPort high load XYZ support

Axis	Traveling range	Resolution	Reproducibility
X	± 50 mm	1 μ m	5 μ m
Y	± 50 mm	1 μ m	5 μ m
Z	+ 92 mm – 58 mm	1 μ m	5 μ m
R _x	$\pm 1^\circ$	1 m $^\circ$	5 m $^\circ$
R _y	$\pm 1^\circ$	1 m $^\circ$	5 m $^\circ$
R _z	$\pm 1^\circ$	1 m $^\circ$	5 m $^\circ$

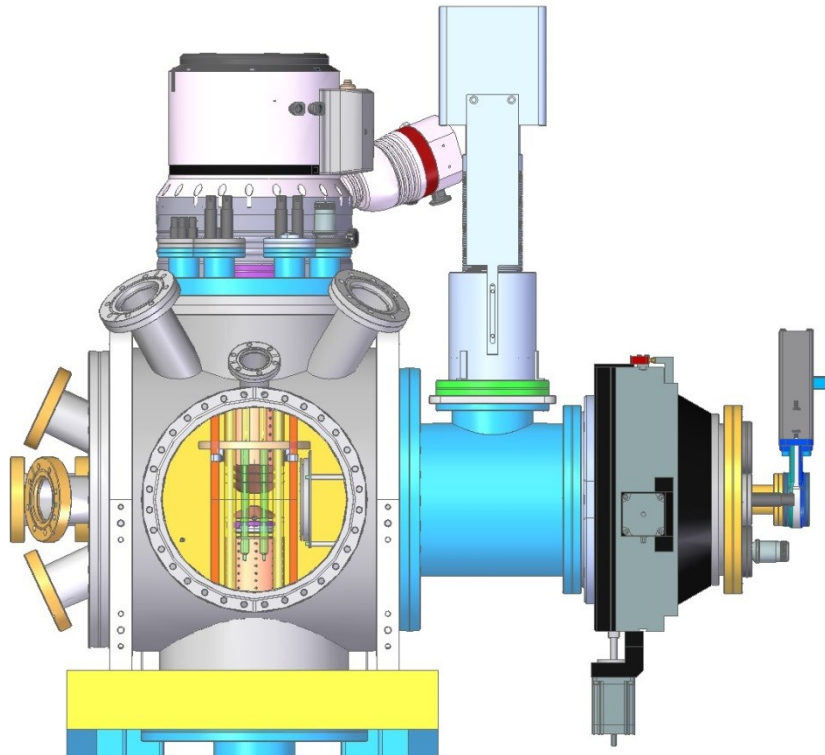
Maximum payload 1500 kg

Max foot print: 2100 x 1500 x 350 mm approx.



- Air pads
- NewPort support
- Alignment laser
- Paddle (YAG screen)

Imaging detector: MCP base detector



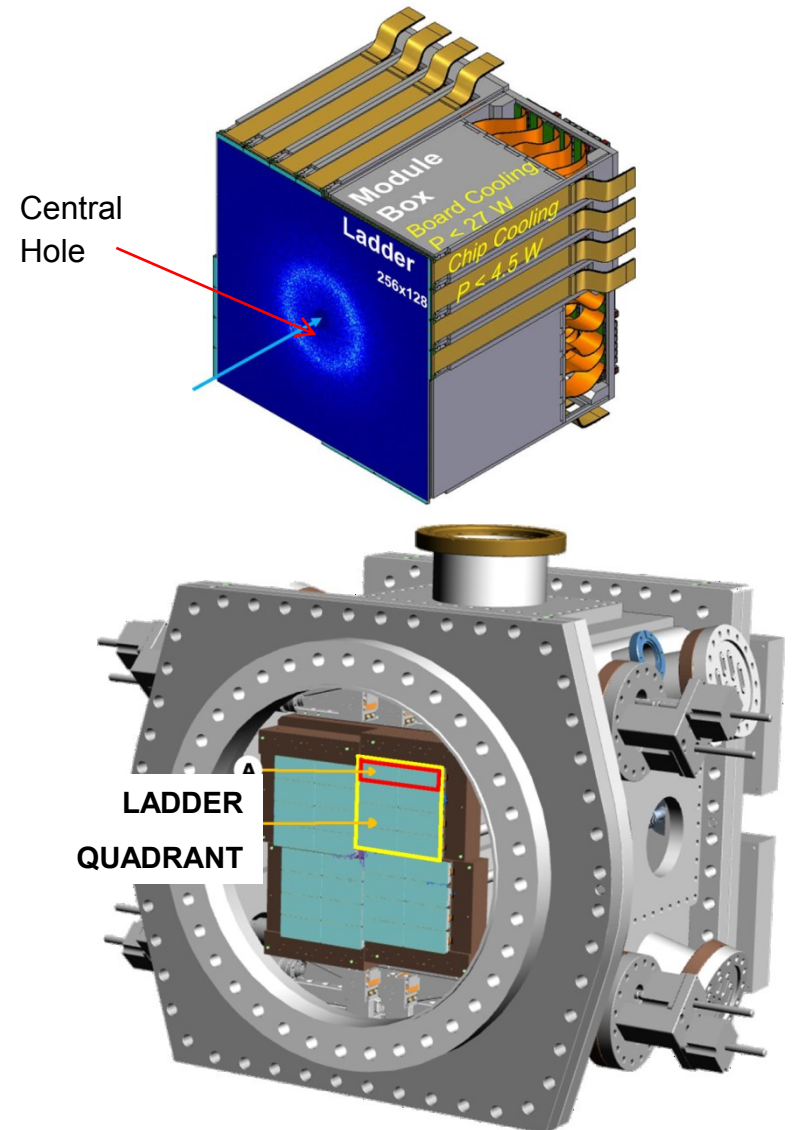
Slow sCMOS & fast CMOS cameras

DSSC – DEPFET Sensor

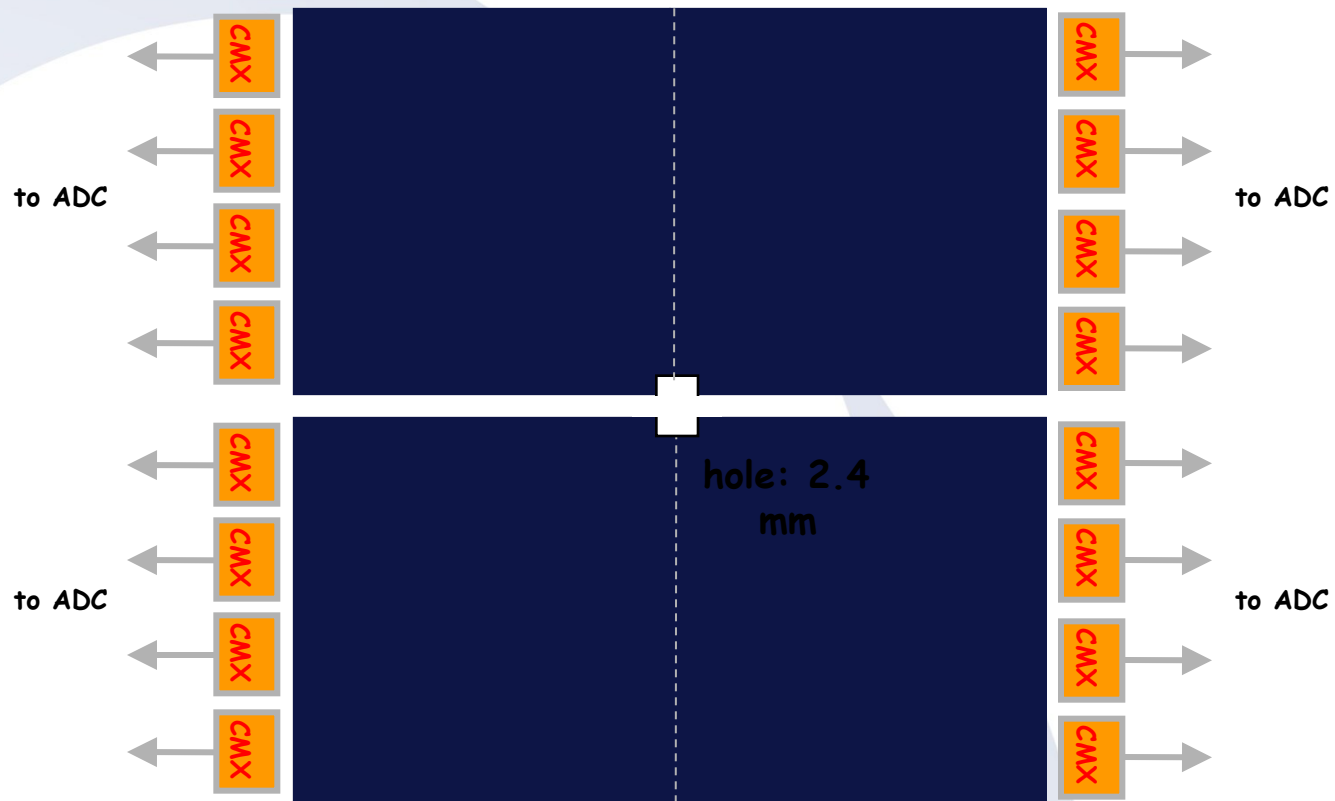
Parameter	Value
Energy range (optimized for)	0.5 – 6 keV
Detection efficiency	100 %
Detector size	210 x 210 mm ²
Number of pixels	1024 x 1024
Sensor pixel shape	Hexagonal
Sensor pixel size	~ 204 x 236 μm ²
Dynamic range	~ 5000 @ 0.5 keV > 10000 @ 1 keV
Resolution	Single photon down to 0.25 keV
Frame rate	0.9 – 4.5 MHz
Stored frames/train	800
Vacuum conditions	~ 10 ⁻⁶ mbar

M. Porro et al, IEEE Trans. Nucl. Sci., Rev. Sci. Instrum., **59** (6), 3339 (2012)

1 Mpixel Module

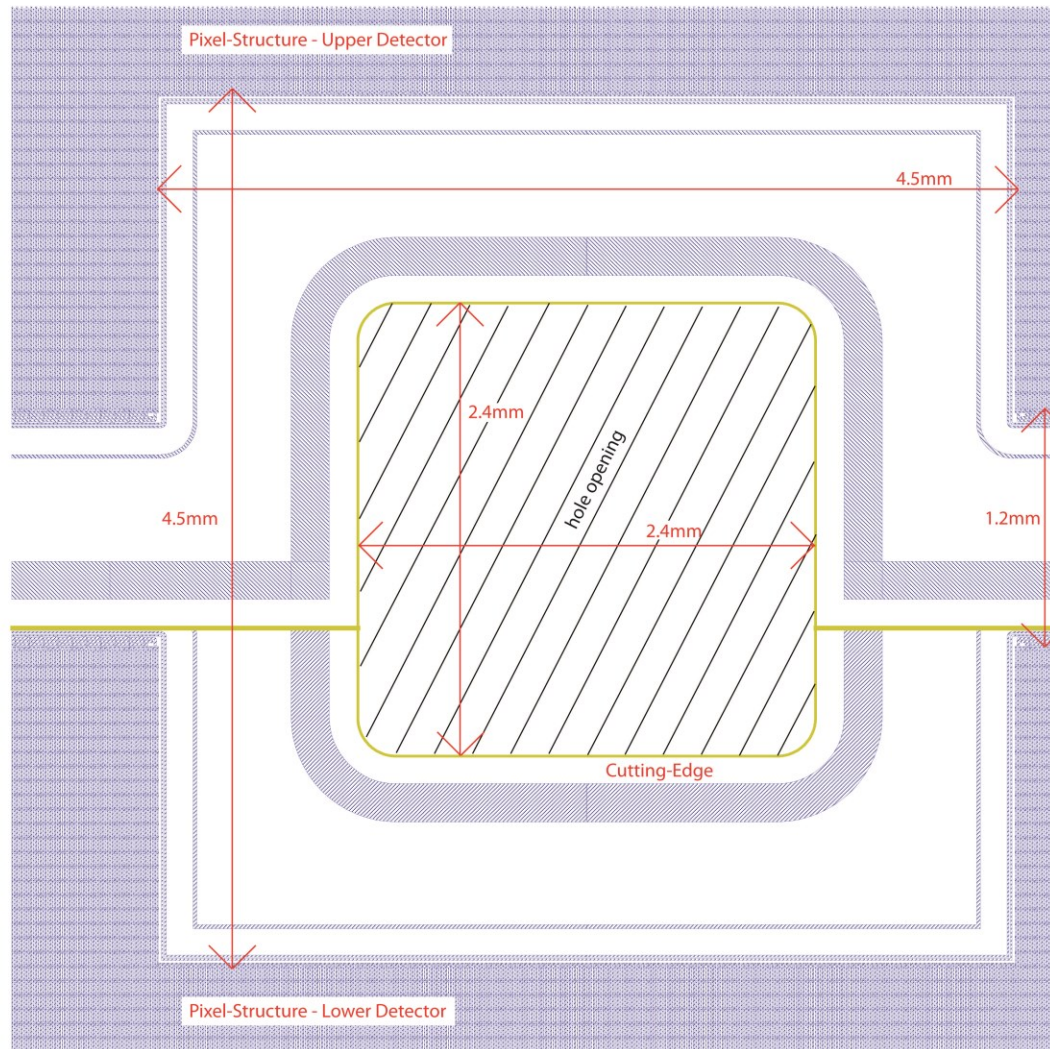


1-Mega-Pixel pnCCD Camera - Layout

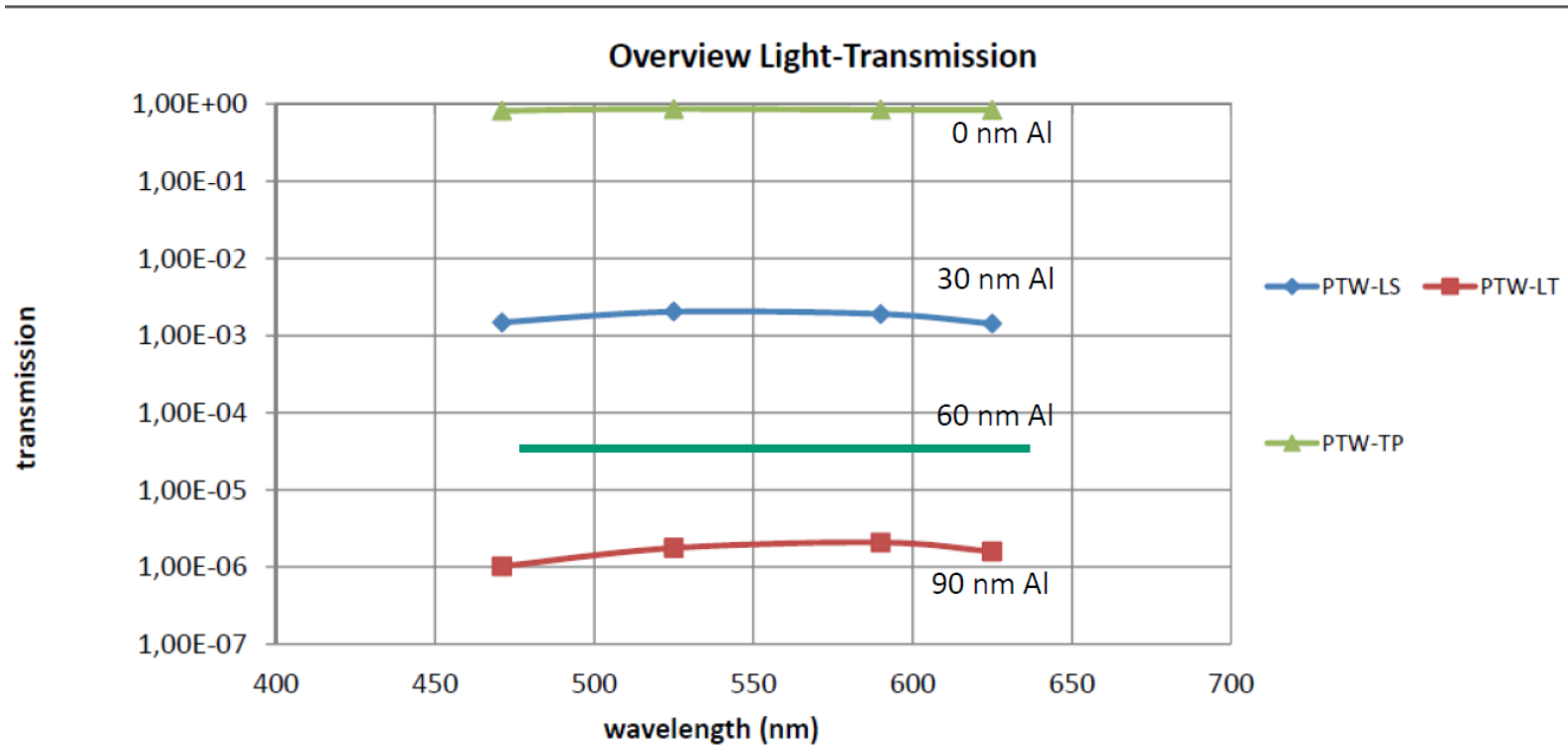


- Image area 59 cm²
- Format: 1024 x 1024
- 16 analog Output-Channels (8 per module)
- Frame Rate up to 150Hz

1-Mega-Pixel pnCCD Camera - Layout

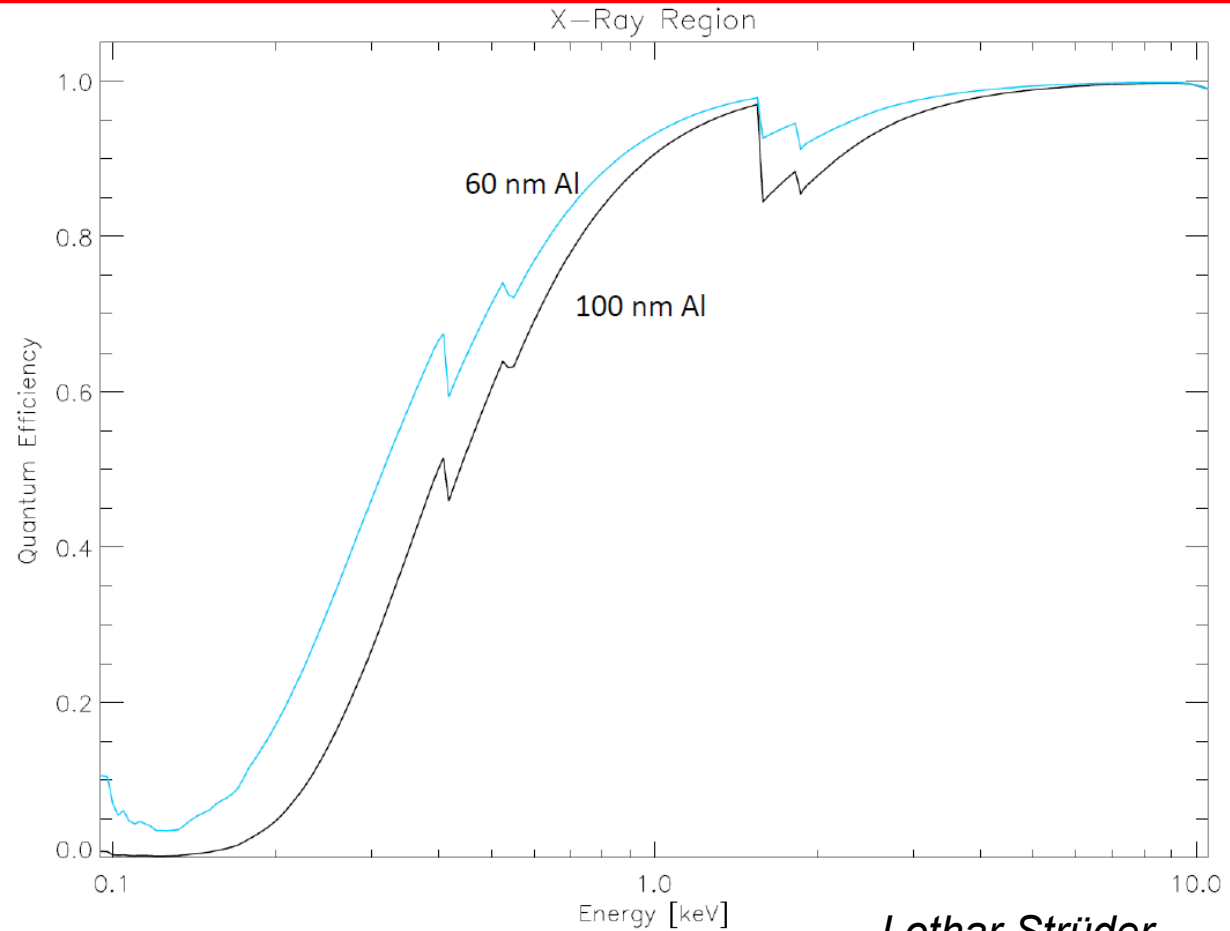


Optical light attenuation, measured



Lothar Strüder

QE with optical light filter, simulated



Lothar Strüder

Scattering Detector Options

Parameter	DSSC	Fast CCD	pnCCD	MCP stack
Detector size, mm ²	210 x 210 4 quadrants 4 ladders in quadrant	57.6 x 28.8	78 x 78	∅75
Pixel size, μm ²	204 x 236	30 x 30	75 x 75	Spatial resolution is expected to be 75 x 75
Number of pixels	1024 x 1024 4 quadrants 4 ladders in quadrant	1920 x 960	1024 x 1024	≈ 750 x 750
Detection efficiency	100% for 0.5 – 6 keV	>50% for 250 – 600 eV >94% for 1 – 6 keV	>80% for 0.3 – 12 keV	15 – 5 % for 0.5 – 1.5keV
Single photon resolution	0.5 keV at 2.5 MHz 1 keV at 4.5 MHz	> 1 keV	yes, in whole energy range	-
Dynamic range photons/pixel/pulse	6000 (up to 12000) at 1 keV	1000 at 0.5 keV	5x10 ⁴ at 0.2 keV 5x10 ³ at 2 keV	expected to be 1000
Read out noise, rms	?	30e ⁻	Low gain – 25 e ⁻ High gain – 3 e ⁻	1 e ⁻ (Andor camera)
Read out frequency	800 frames/ bunch train 10Hz	60 Hz	Up to 150 Hz	Up to 100 Hz
Min. center gap	2 x 2.5 mm ²	hole - 1.8 mm active area - 2.4 mm	< 2 mm	hole - 3.0 mm active area - 6.0 mm
View angle	0.2° - 35° at 300 mm 0.06° - 12° at 1000 mm	1.0° - 24° x 1.0° - 12° at 65 mm	3° - 67° at 20mm (min.) 0.9° - 36° at 65 mm 0.6° - 25° at 100 mm 0.2° - 9° at 300 mm	2.5° - 30° at 65 mm
Angle resolution	0.052° at 300 mm 0.016° at 1000 mm	0.026° at 65 mm	0.21° at 20mm (min.) 0.066° at 65 mm 0.043° at 100 mm 0.014° at 300 mm	0.044° at 65 mm
Vacuum, mbar	10 ⁻⁶ - 10 ⁻⁷	10 ⁻⁷ - 10 ⁻⁸	10 ⁻⁹ - 10 ⁻¹⁰	10 ⁻¹⁰ - 10 ⁻¹¹
Bakeable	No	No	Yes	Yes
Availability	-	first day	-	first day

Quadrupole mass spectrometer

Why we need it?

Source characterization:

- Estimation of the cluster size;
- Doping level characterization;
- Time arriving measurements;
- Bio-molecules and nanoparticles ?

Extrel Quadrupole mass spectrometer

Hidden Analytical Quadrupole mass spectrometer

- Triple filter mass spectrometer;
- for the molecular beam studies / characterization;
- 50, 300, 500, 1000, 2500 and 5000 amu options;
- 7 decade dynamic range;
- 650 measurements/s;
- Detection down to 2×10^{-14} mbar;
- HAL 1001-9 RC (9mm) -> high mass / high resolution;
- Ethernet interface;



