MAX IV

Beamlines at MAX IV – optical design and commissioning

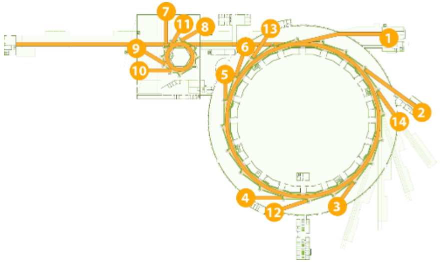
Andreas Lassesson
Beamline Project Coordinator

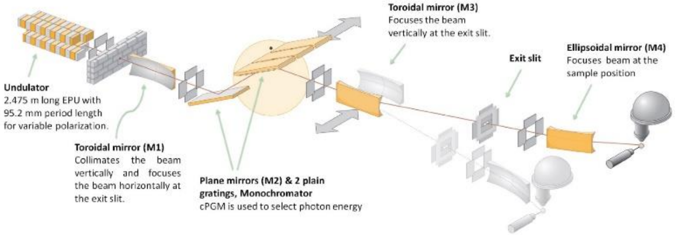
Outline

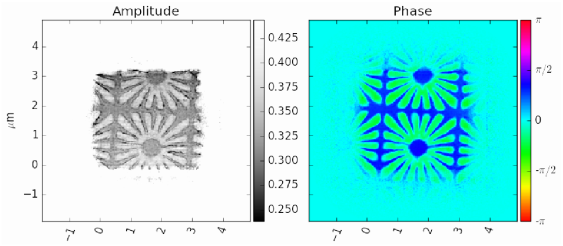
Overview of MAX IV beamlines

Beamline design philosophy

Commissioning & early users

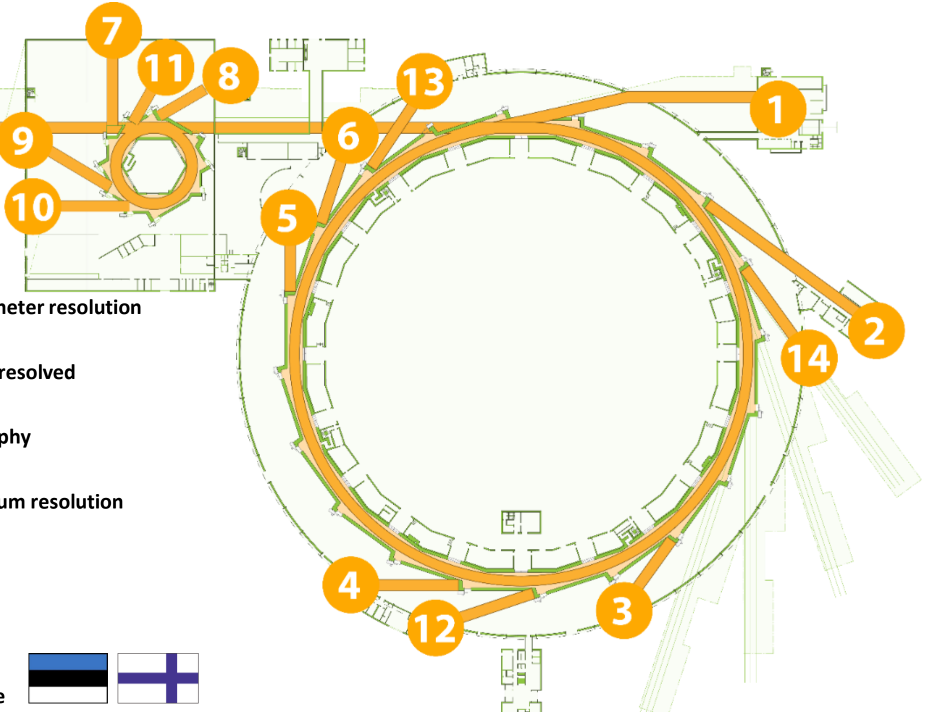







2014

The 14+ funded Beamlines

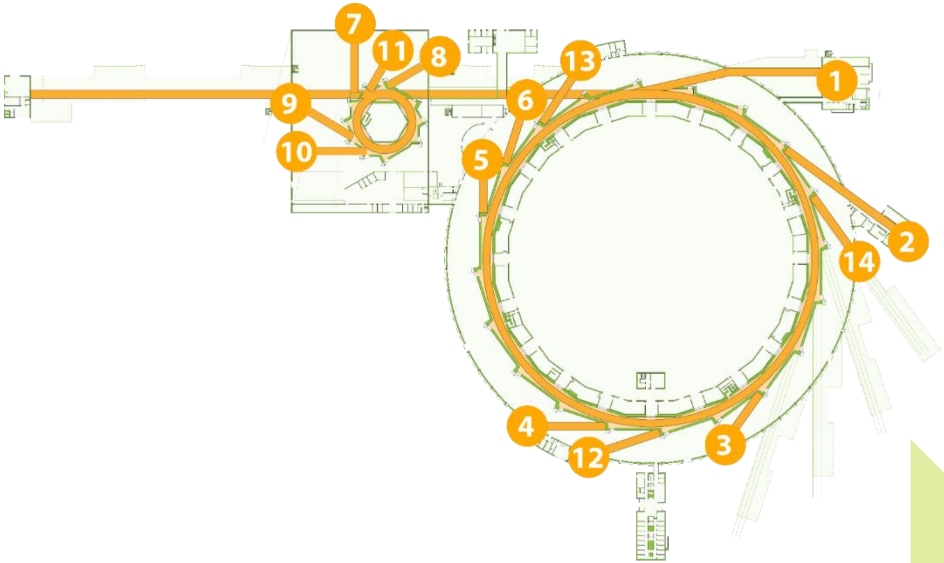


1. **FemtoMAX (2015)**
   Ultra-fast processes in materials
2. **NanoMAX (2016)**
   Imaging, spectroscopic & scattering with nanometer resolution
3. **BALDER (2016)**
   X-ray absorption spectroscopy *in-situ* and time resolved
4. **BioMAX (2016)**
   Highly automated macromolecular crystallography
5. **VERITAS (2016)**
   RIXS with unique resolving power and momentum resolution
6. **HIPPIE (2016)**
   High-pressure photoelectron spectroscopy
7. **BLOCH (2017)**
   Angle resolved photoelectron spectroscopy
8. **FinEstBeAMS (2017)**
   Estonian-Finnish Beamline for Materials Science
9. **SPECIES (2017)**
   VUV High-pressure photoelectron spectroscopy and RIXS
10. **FlexPES (2018)**
    Photoelectron Spectroscopy and NEXAFS
11. **MAXPeem (2018)**
    Photoelectron microscopy
12. **CoSAXS (2018)**
    Small angle scattering
13. **SoftiMAX (2018)**
    Coherent Soft X-Ray Scattering, Holography…
14. **DanMAX (2019/20)**

- ✓ **MicroMAX**
  Frontier MX
- ✓ **ForMAX**
  Paper and pulp
- ❑ **DiffMAX**

MAX IV

Beamline timeplan



2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

Phase I – 7 beamlines

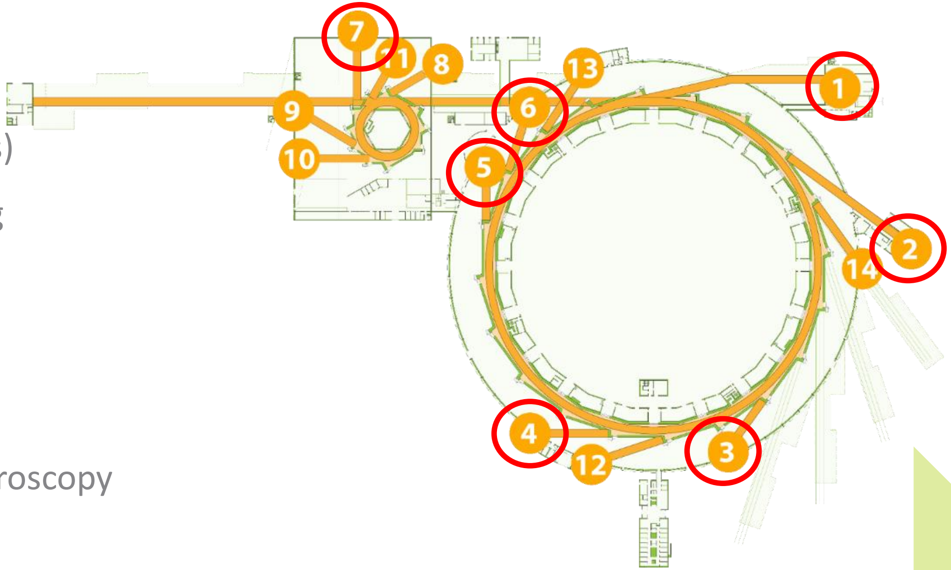
Phase IIa – 6 beamlines

Phase IIb

MAX IV

Beamline timeplan

1. Time resolved experiments (<100 fs)
2. Nano/micro diffraction and imaging
3. X-ray absorption spectroscopy
4. Protein crystallography
5. RIXS
6. High pressure photoemission spectroscopy
7. ARPES



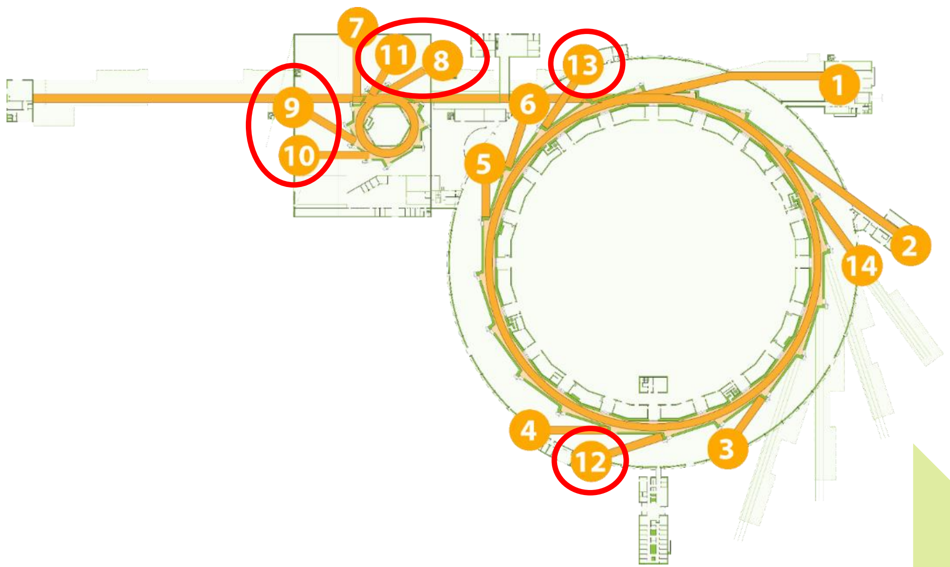
2011	2012	2013	2014	2015	2016	2017	2018	2019	2020

Phase I – 7 beamlines

Phase IIa – 6 beamlines

Phase IIb – >2 beamlines

Beamline timeplan



- SAXS
- Imaging; STXM, CXI
- Photoemission spectroscopy
- RIXS
- XPEEM
- Gas phase spectroscopy

2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

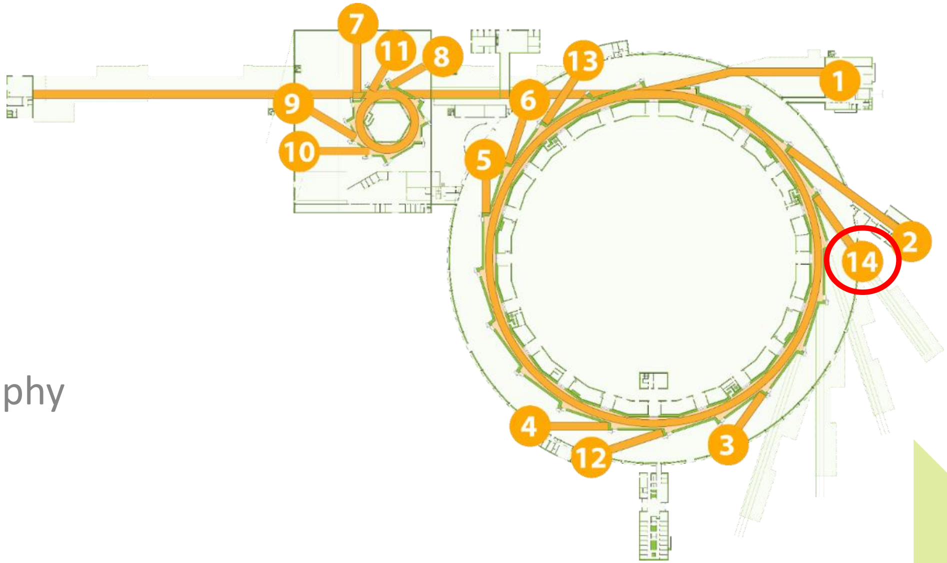
Phase I – 7 beamlines

Phase IIa – 6 beamlines

Phase IIb – >2 beamlines

Beamline timeplan

- Imaging; tomography
- Diffraction
- SAXS
- Micro-crystal protein crystallography



2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

Phase I – 7 beamlines

Phase IIa – 6 beamlines

Phase IIb – >2 beamlines

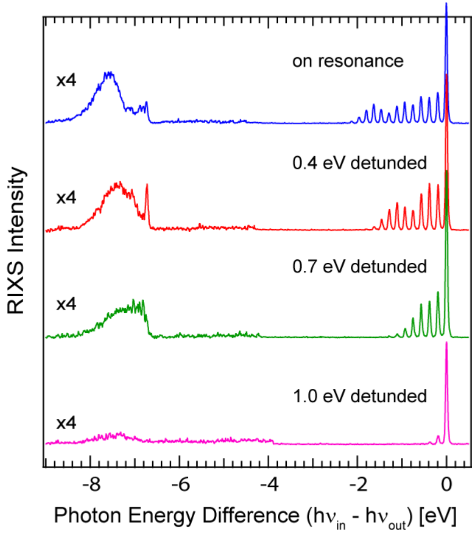
Commissioning status

- 4 beamlines with external or expert users in 2017
- 2 beamlines have commissioned optics & are finishing endstations
- 3 beamline is about to commission optics with endstations mostly in place

MAX IV

Low emittance: high flux, small source, low divergence

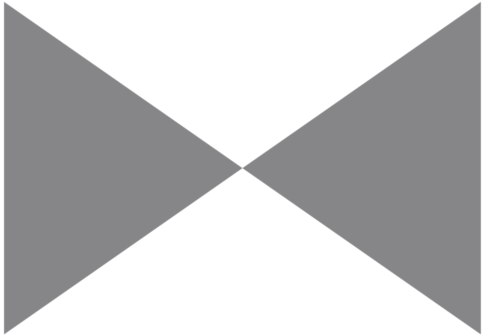
Energy resolution



PRL **104**, 193002 (2010)

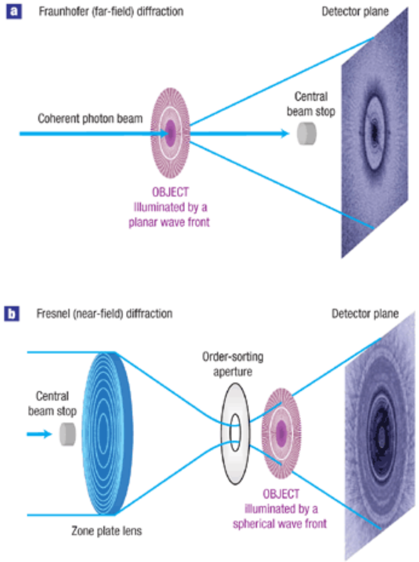
Spatial resolution

Small spot with low divergence:



Micro diffraction w/ high resolution

Coherence



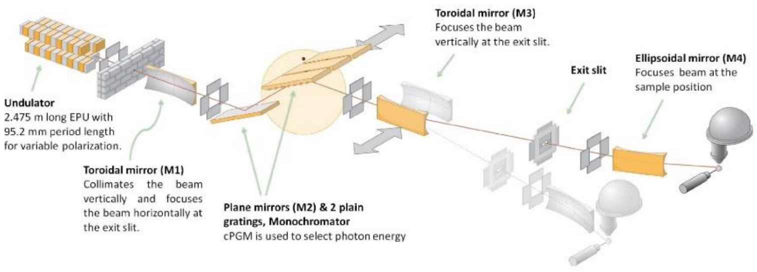
Nat Phys 4, 351 - 353 (2008)

Optical design

- The optics in MAX IV beamlines are designed to meet scientific design targets while exploiting the properties of the MAX IV sources

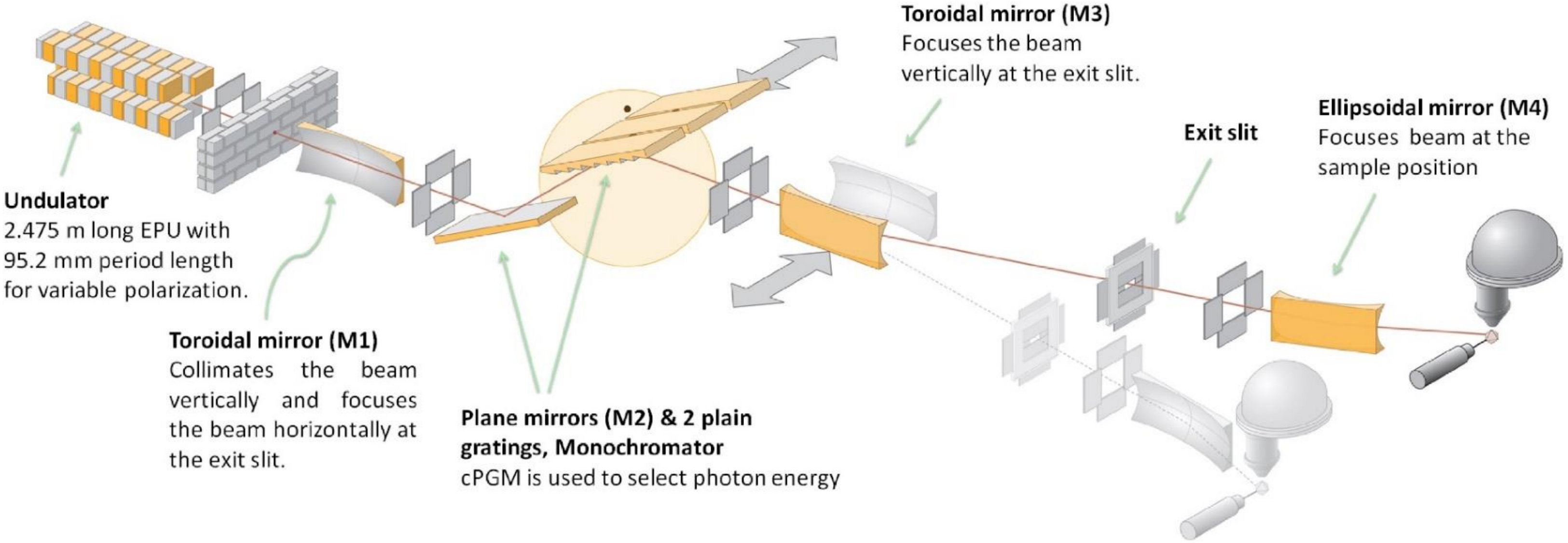
- Simulations are typically done by beamline project managers with assistance of experts in various simulation software:
  - Ray – ray tracing, Rami Sankari
  - XRT – ray tracing & wavefront propagation: Konstantin Klementiev
  - MESH - ray tracing and heat load calculations: Peter Sondhauss

- Output:
  - Beamline layout
  - Shape & type of optical elements
  - Min. slope errors & roughness
  - Spot size, beam divergence etc.



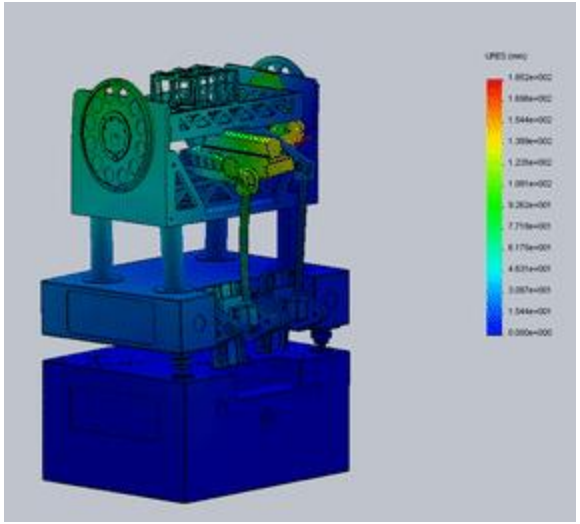
Optical design – soft X-ray beamlines

- Standardized design criteria
- cPGMs – blazed and laminar gratings
- 8 beamlines



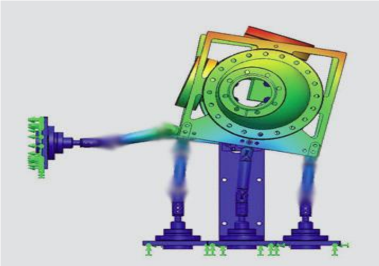
Stability – optical systems

- Stiff (high spring constant) & light (low mass): high eigenfrequencies
- Design process in collaboration with vendors



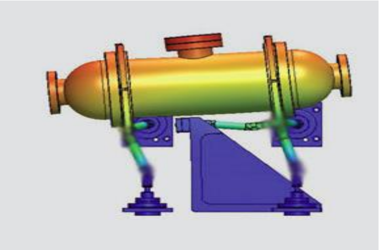
Grating monos: Toyama

Mirror chamber: FMB (Prototype)



FEA: 112Hz

Measured: 95Hz



FEA: 119Hz

Measured: 100-120Hz

Stability responsible: Brian N Jensen

Gratings

Helmholtz Zentrum Berlin

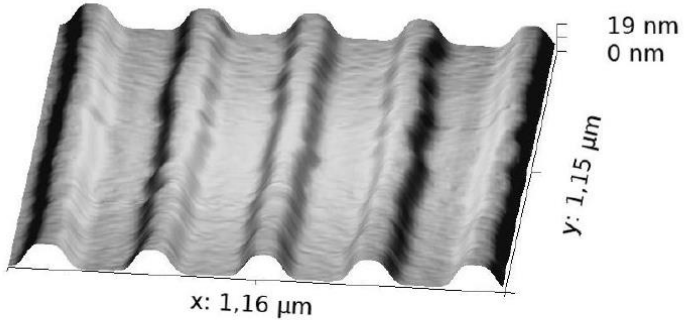
Blazed and laminar gratings from HZB are used at all 8 soft X-ray beamlines at MAX IV

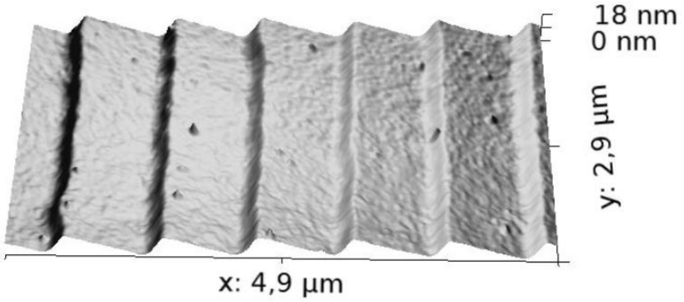
Substrates:

- Plane & curved
- Slope errors <0.02 arcsec substrates

Specifications:

- Blaze angles: 0.5 – 6 degrees
- Line density: <100 – 4000 l/mm
- Length: 120 – 300 mm
- Energy: <5 - 2000 eV
- Coatings: 40nm Au, Rh





Technology Center for
Optical Precision Gratings, HZB

MAX IV

Gratings - design

Example 1:

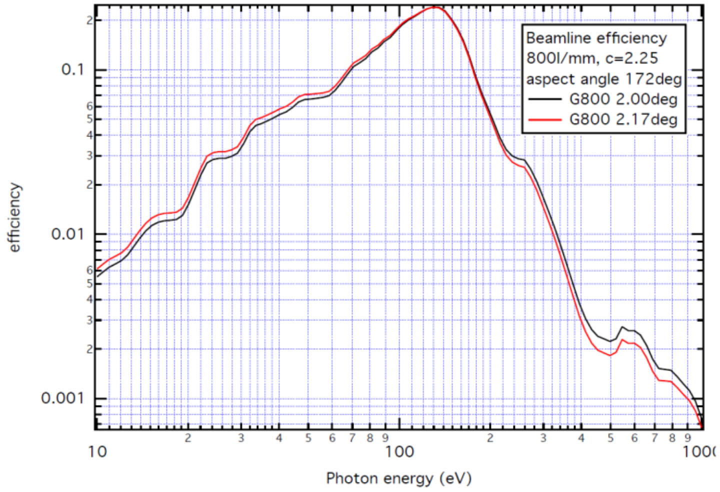
"Work horse" grating for the BLOCH beamline:

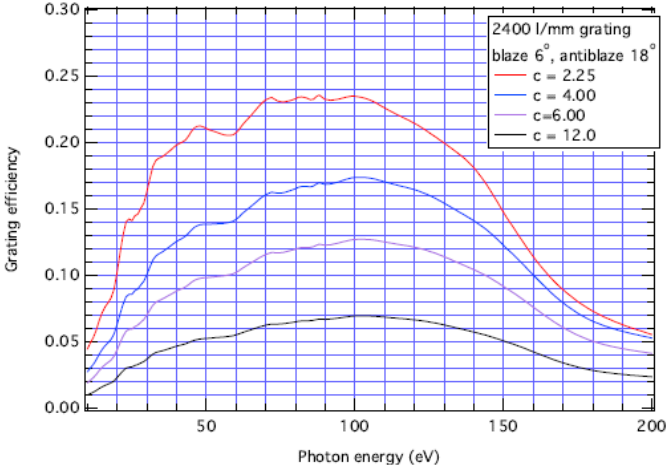
- Blaze angle: 2 degrees
- Line density: 800 l/mm
- Length: 140 mm
- Energy: 10 - 1000 eV
- E/dE: 1E4
- Flux: 1E13 ph/s

Example 2:

High energy resolution at low energies at the BLOCH beamline:

- Blaze angle: 6 degrees
- Line density: 2400 l/mm
- Length: 140 mm
- Energy: 10 - 200 eV
- E/dE: 1E5
- Flux: 1E11 ph/s

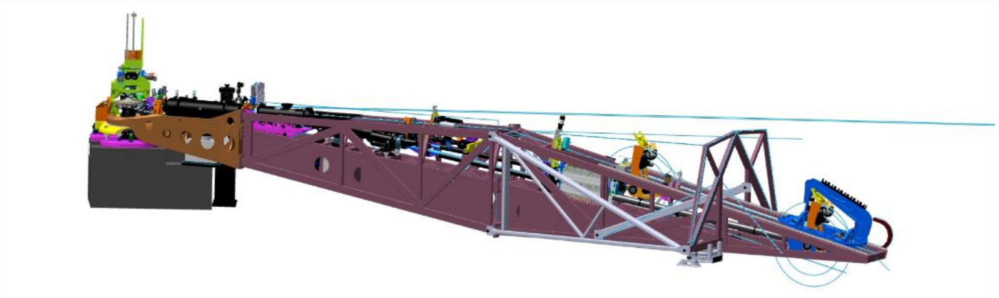




Simulations by Rami Sankari

High energy resolution (VERITAS)

- RIXS beamline
- Energy range 250 – 1600 eV at 3 GeV ring
- Team:
  - Marcus Agåker (Uppsala U)
  - Conny Såthe
  - Shih-Wen (Winnie) Huang
  - Nial Wassdahl



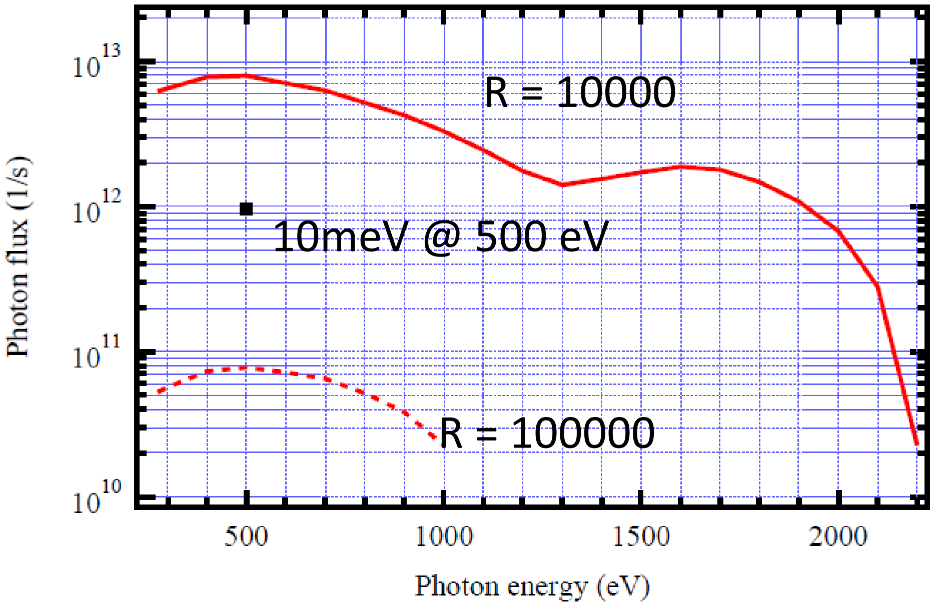
High energy resolution (VERITAS)

Resolution contributions:

- Source size (diffr. limited)
- (slope errors of the) optics
- Slit size
- Mono: (moderately) high resolution, high flux, small spot
- Gratings: 1200 l/mm & 2400 l/mm

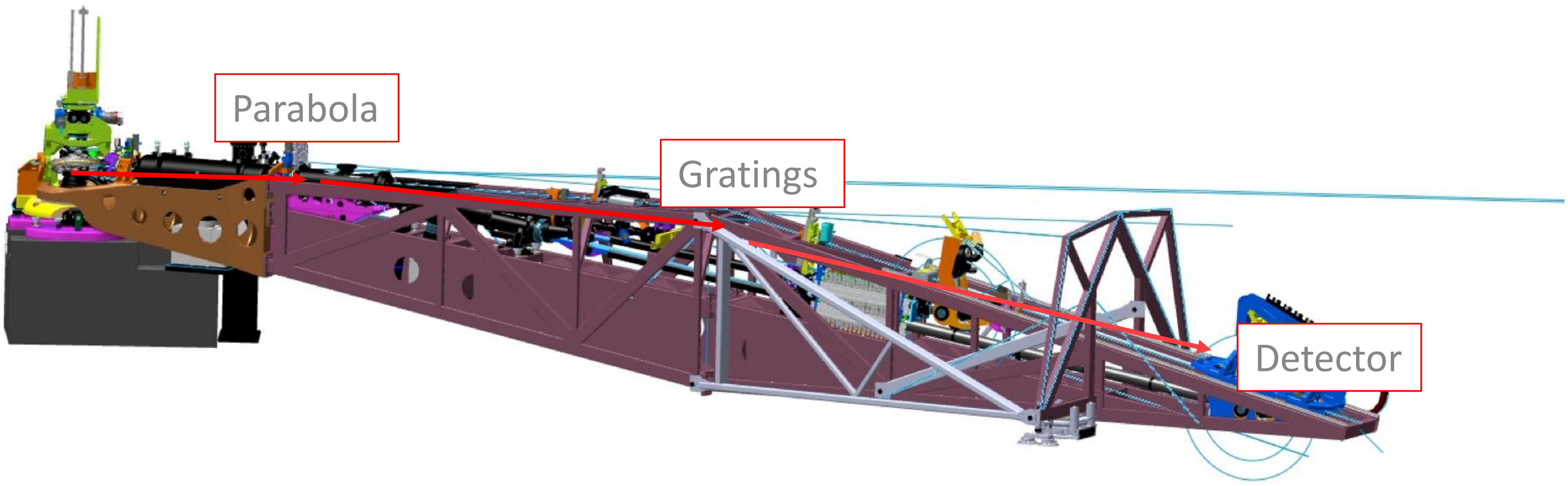
Early commissioning results:

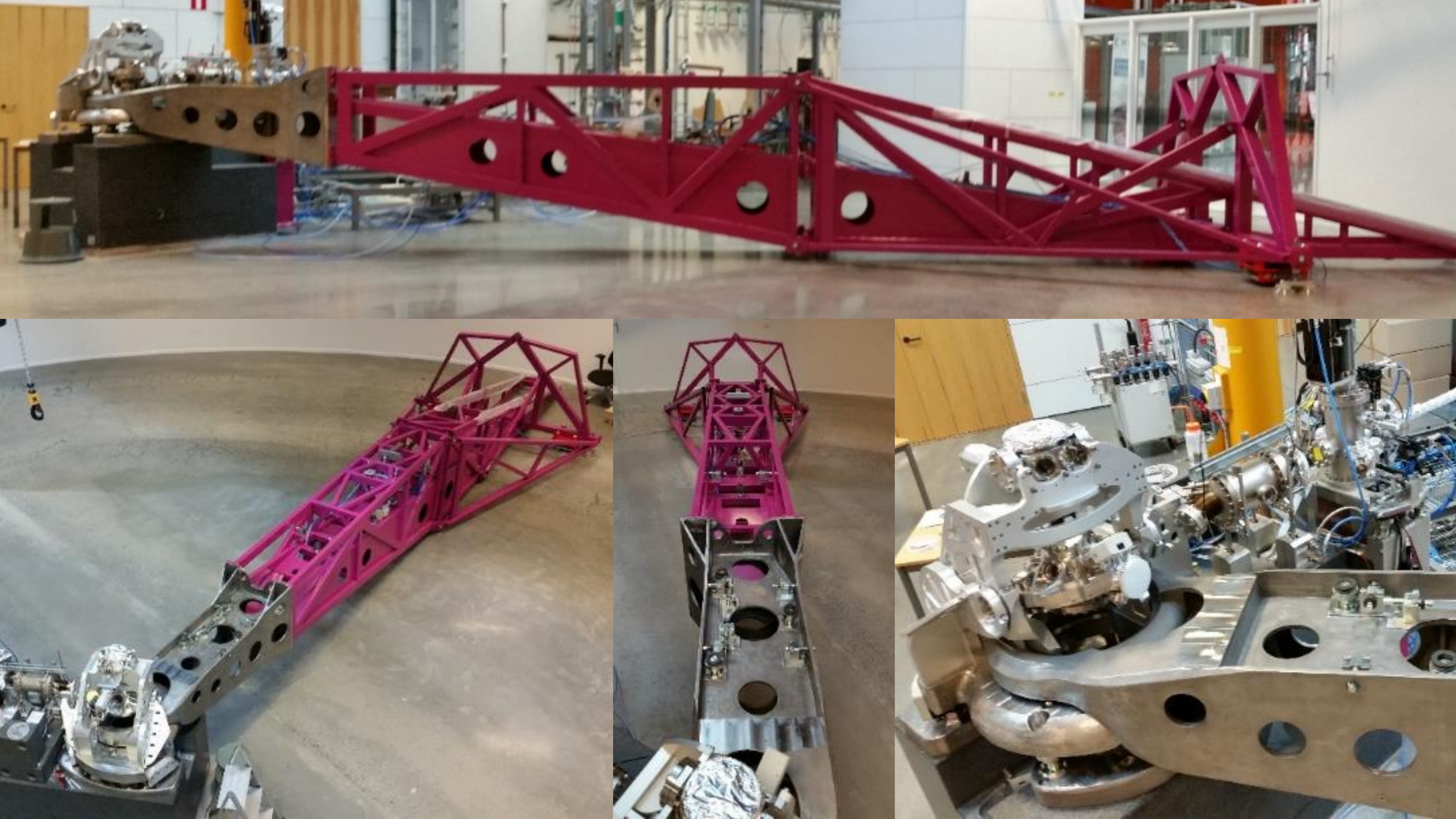
- Approx. 30000



The VERITAS spectrometer

- 10 m long, Rowland type
- > 35 000 resolving power
- 980 mm long collimating mirror to increase collection efficiency
- 2 cylindrical gratings
- MCP based detector with 2D DLD readout (150 ps time resolution)

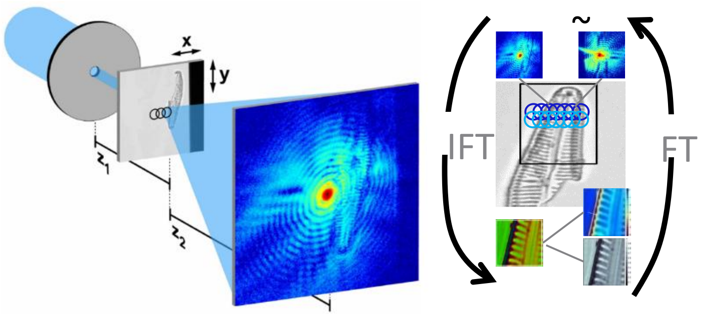




High spatial resolution (SoftiMAX)

Karina Thånell
Jörg schwenke

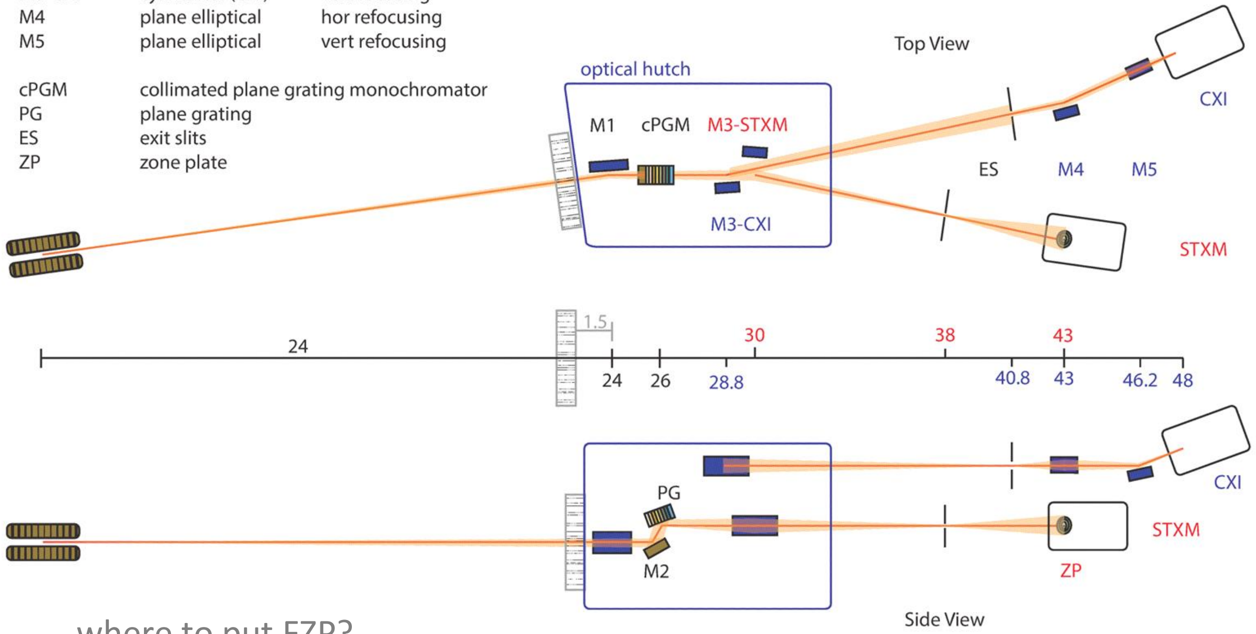
- Imaging beamline
- Beam size: ≥10 nm (STXM) - 20 μm (CXI)
- Energy range: 275 – 2500 eV
- First users: 2019
- Two branchlines for:
  - Scanning Transmission X-ray Microscopy (STXM)
  - Ptychography (STXM)
  - Fourier Transform Holography (CXI)
  - Resonant soft X-ray scattering (CXI)



K. Giewekemeyer, et al., Optics Express 19, 1037 (2011).

SoftiMAX – optical design

M1	cylindrical	vertical collimation
M2	plane	deflecting
M3-STXM	toroidal (STXM)	hor and vert focusing
M3-CXI	cylindrical (CXI)	vert focusing
M4	plane elliptical	hor refocusing
M5	plane elliptical	vert refocusing
cPGM	collimated plane grating monochromator	
PG	plane grating	
ES	exit slits	
ZP	zone plate	



where to put FZP?

what is the result if finite beam emittance?

what are the coherence properties?

how to isolate the coherent part?

Simulations by:

- Karina Thånell
- Rami Sankari
- Konstantin Klementiev
- Walan Grizolli

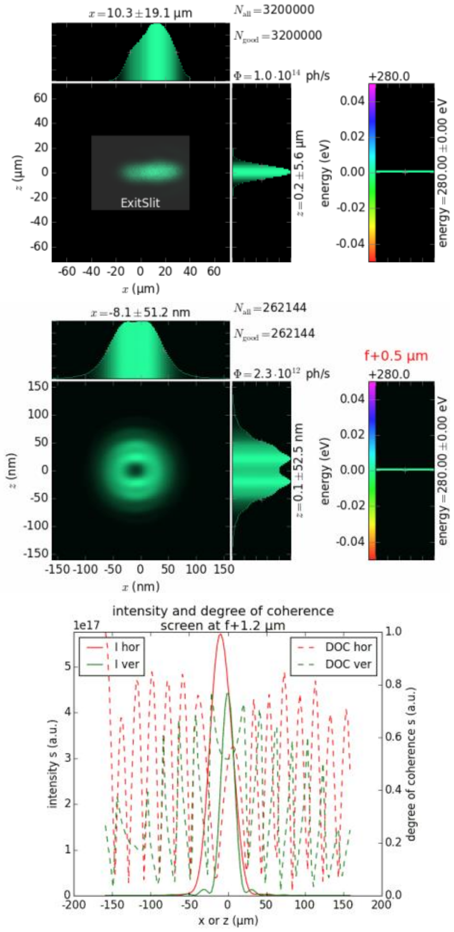
Using:

Ray & XRT

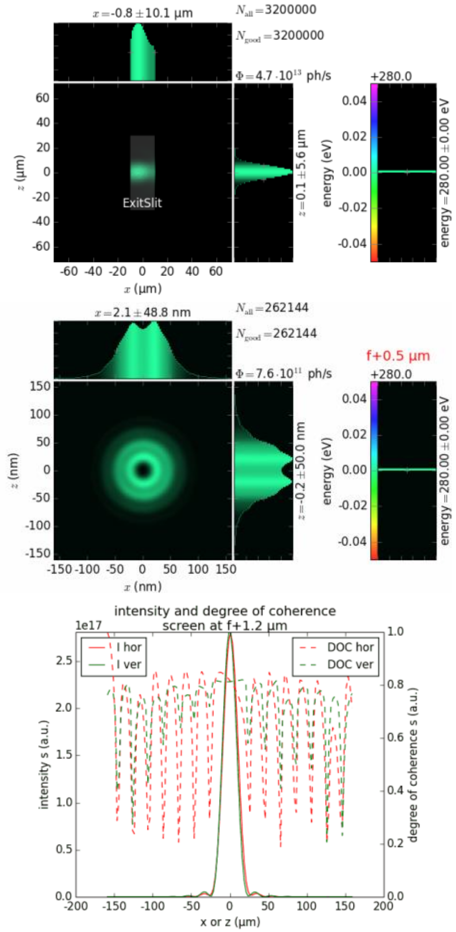
MAX IV

How to isolate the coherent part? - XRT

80 µm exit slit



20 µm exit slit



Simulations by:

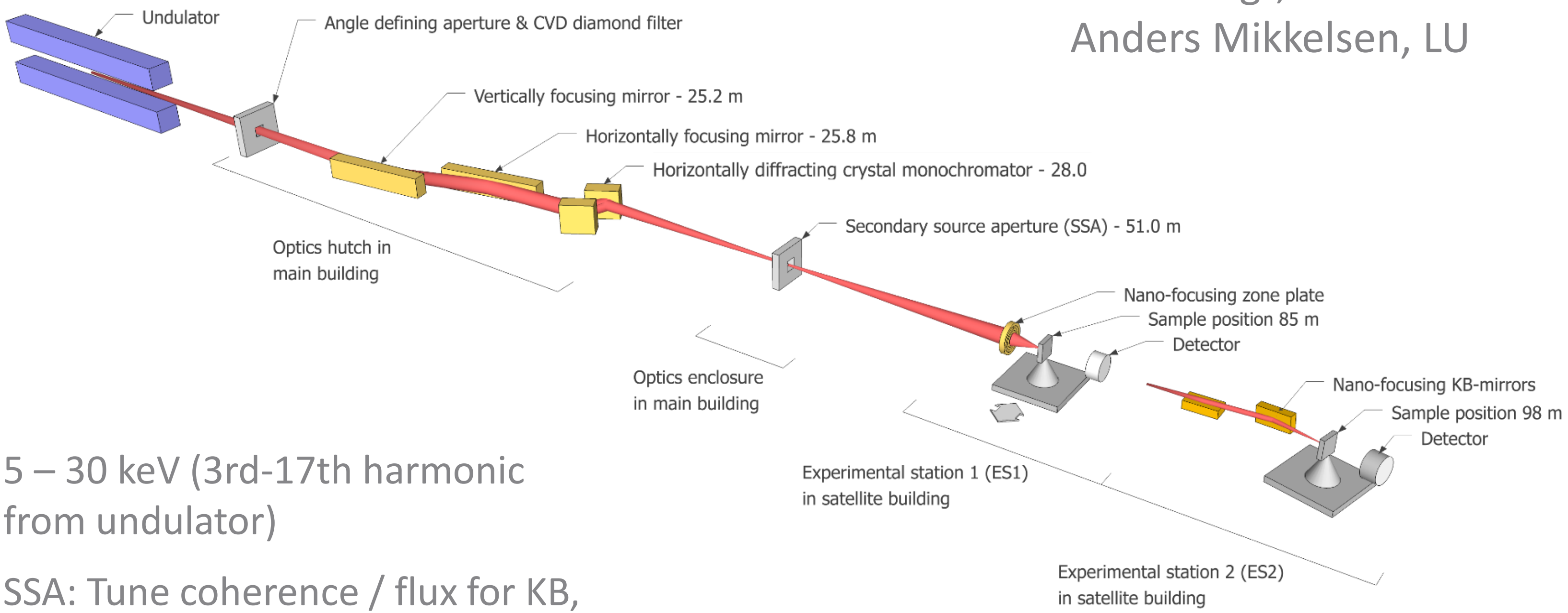
Konstantin Klementiev

Using XRT:

https://pypi.python.org/pypi/xrt

High spatial resolution (NanoMAX)

Ulf Johansson
Gerardina Carbone
Sebastian Kalbfleisch
Alexander Björling
Ulrich Vogt, KTH
Anders Mikkelsen, LU



- 5 – 30 keV (3rd-17th harmonic from undulator)
- SSA: Tune coherence / flux for KB, ZP and different wavelengths

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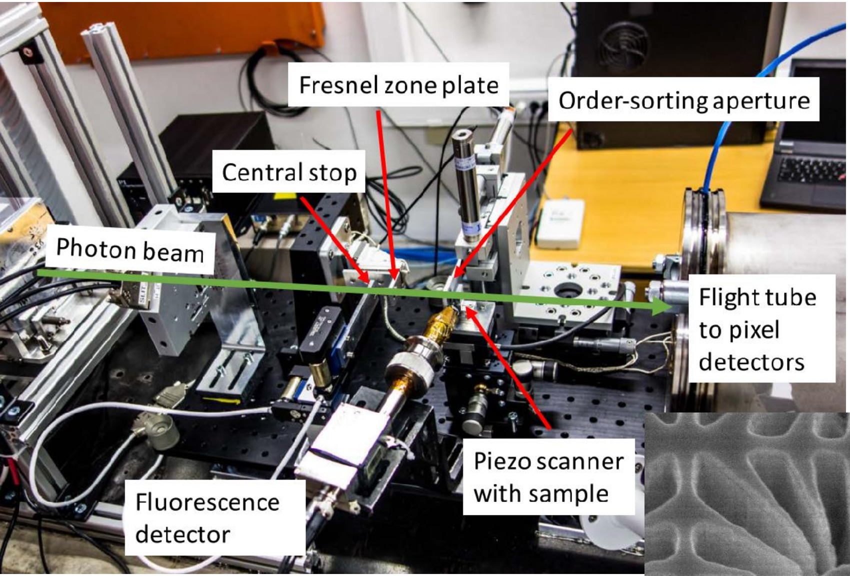
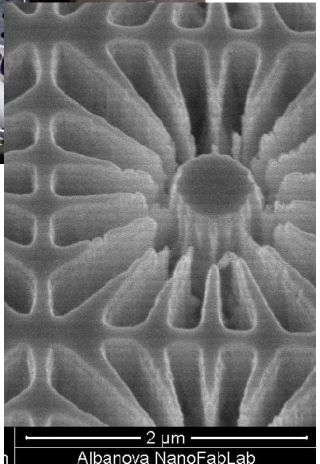
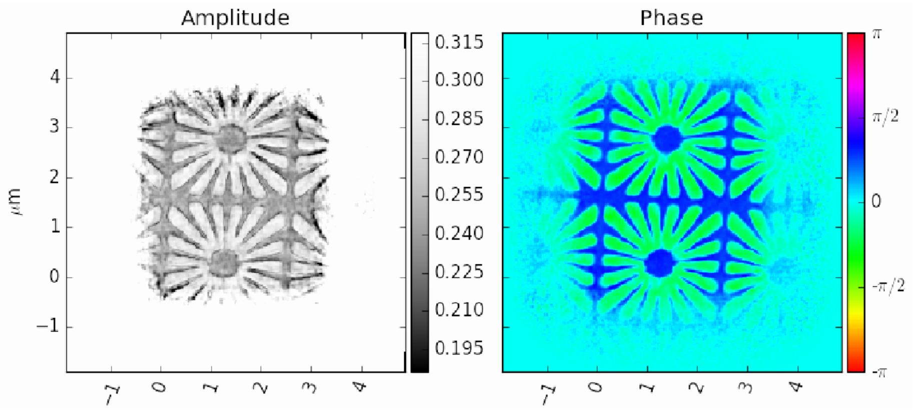
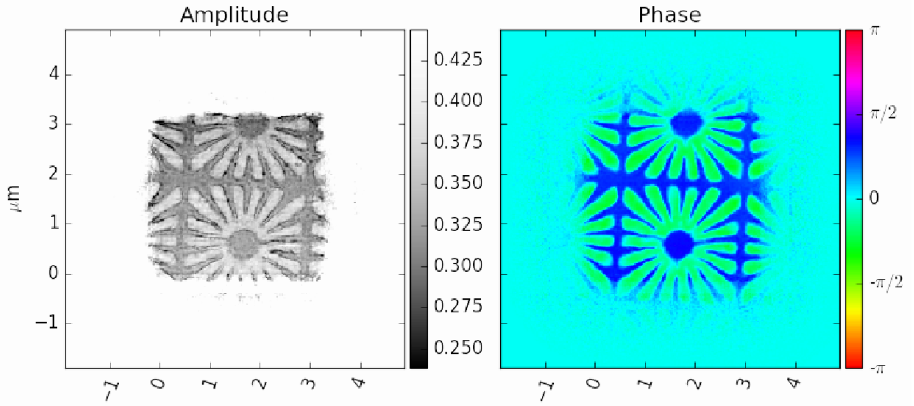
NanoMAX – commissioning: ZP test setup (11/2016)





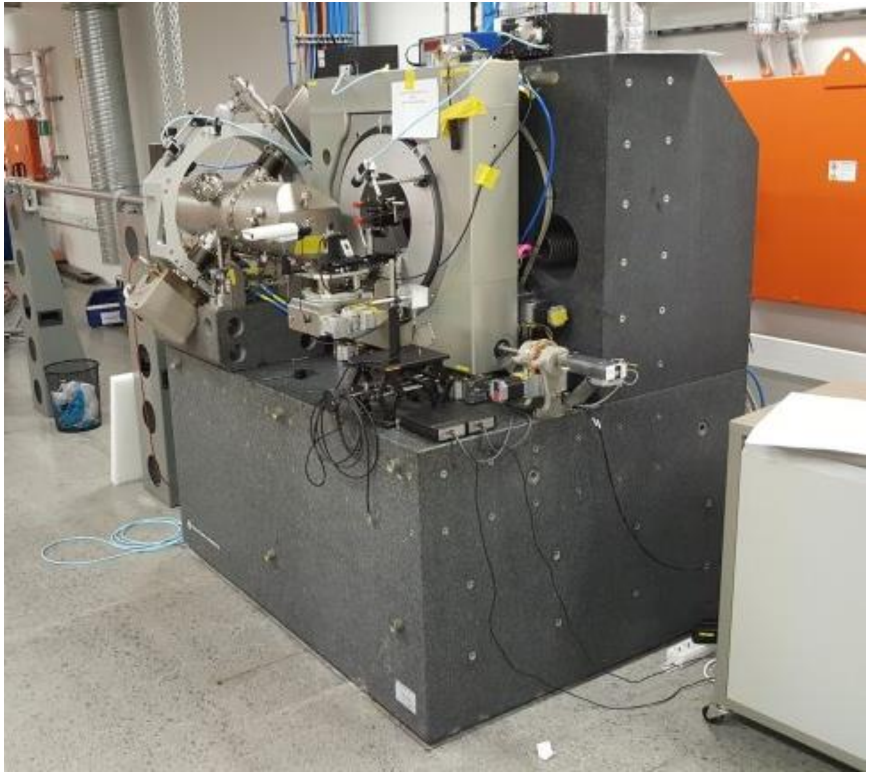


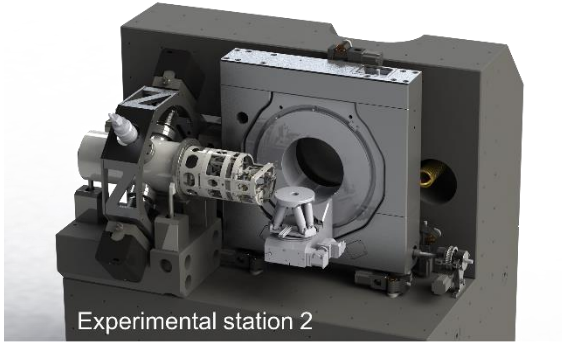
100 nm zone plate



30 nm zone plate

NanoMAX - KB endstation

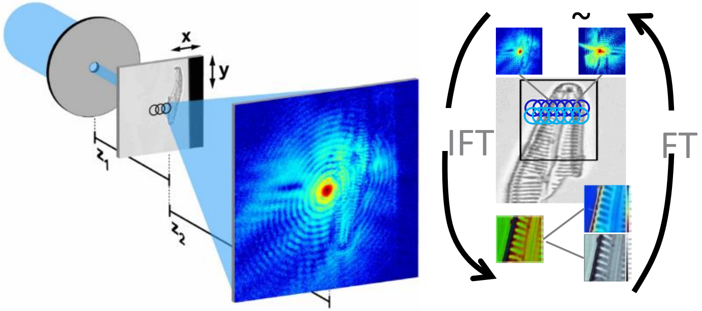




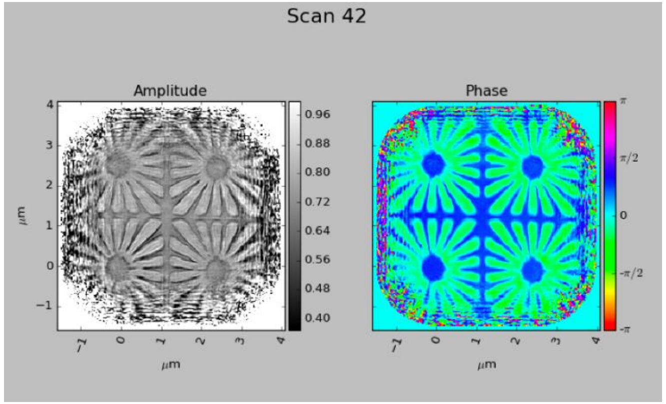
- Hyperpolished mirrors in KB configuration
- Focal spot: 40-200 nm
- Sample holder: Goniometer, <5 kg
- 2D pixel detector on robot arm
- Fluorescence detector

NanoMAX – commissioning KB setup

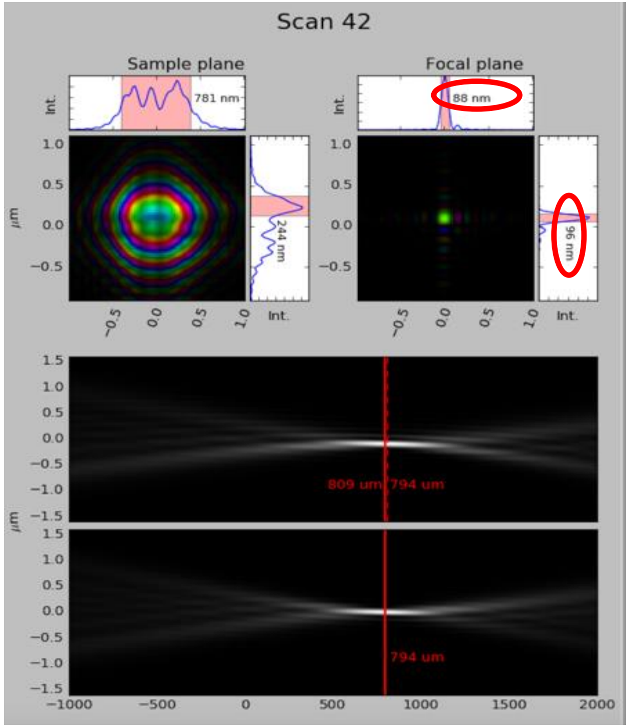
Ptychography at 9.5 keV



Imaging of Siemens stars



Beam properties close to focus



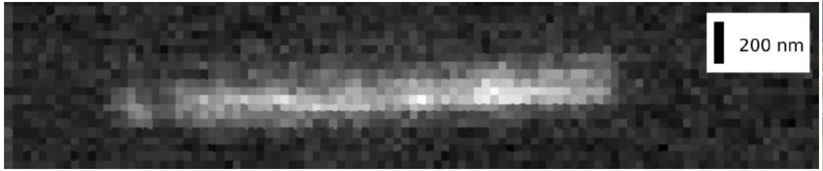
Spot size and phase

Beam sideview

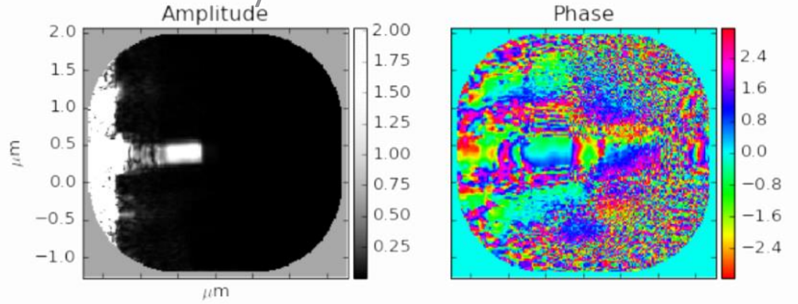
NanoMAX – first user results at KB endstation

Nano wires: Jesper Wallentin, NanoLund, Lund University

Direct resolution: XRF map:

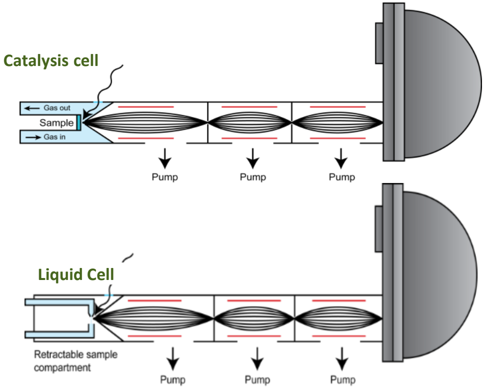


Preliminary 2D reconstructions:



HIPPIE

Source	EPU53
Energy	110 – 2,000 eV (LP)
Resolving power	30,000 – 40,000
Flux (500 mA)	> 10^{12} @ R = 10,000
Spot size	50 x 50 μm^2

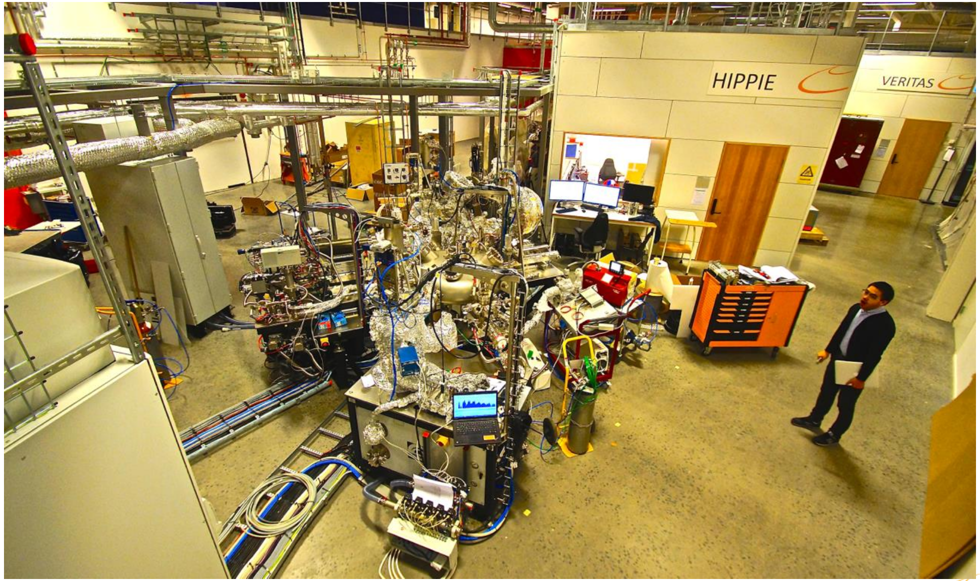



Andrey Shavorskiy
Beamline Manager


Jan Knudsen
Beamline Scientist


Suyun Zhu
Research Engineer

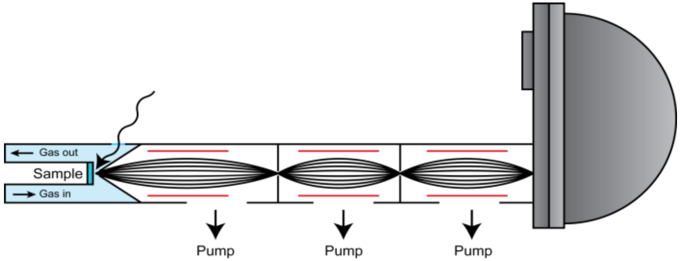

Joachim Schnadt
Spokes Person

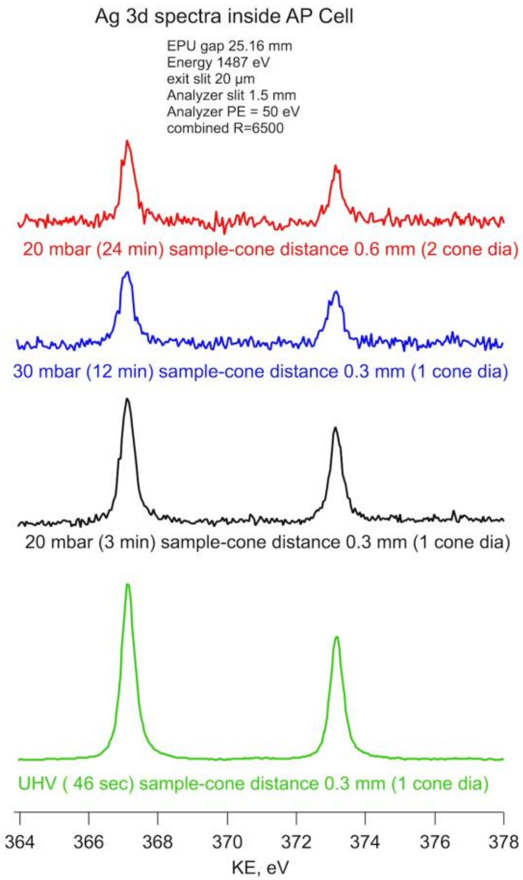


MAX IV

HIPPIE - AP XPS endstation

- General Purpose/Catalysis cell available
- Electrochemical/Liquid/Jet cell testing 2018
- AP-XPS up to 30 mbar (N2) tested
- Gas dosing system for up to 8 individual gases and their mixtures
- 4 user groups so far, more to come in 2018 !





HZB Helmholtz Zentrum Berlin

PAUL SCHERRER INSTITUT PSI

ESRF

SOLEIL SYNCHROTRON

Elettra Sincrotrone Trieste

BROOKHAVEN NATIONAL LABORATORY

ALBA

Argonne NATIONAL LABORATORY

European XFEL

DESY

diamond

LCLS

MAX IV

MAX IV Laboratory is a national research infrastructure hosted by Lund University

- Accelerators and basic lab infrastructure:

Vetenskapsrådet VINNOVA LUNDS UNIVERSITET REGION SKÅNE

- Beamlines

Knut och Alice Wallenbergs Stiftelse

SLU LUNDS UNIVERSITET UPPSALA UNIVERSITET LINKÖPINGS UNIVERSITET CHALMERS GÖTEBORGS UNIVERSITET

KARLSTADS UNIVERSITET Karolinska Institutet KTH VETENSKAP OCH KONST LULEÅ TEKNISKA UNIVERSITET STOCKHOLMS UNIVERSITET UMEÅ UNIVERSITET

Vetenskapsrådet

- International beamlines:

MAX IV

Thank you!