MAX IV 3 GeV ring emittances: Diagnostics based on near-visible synchrotron radiation

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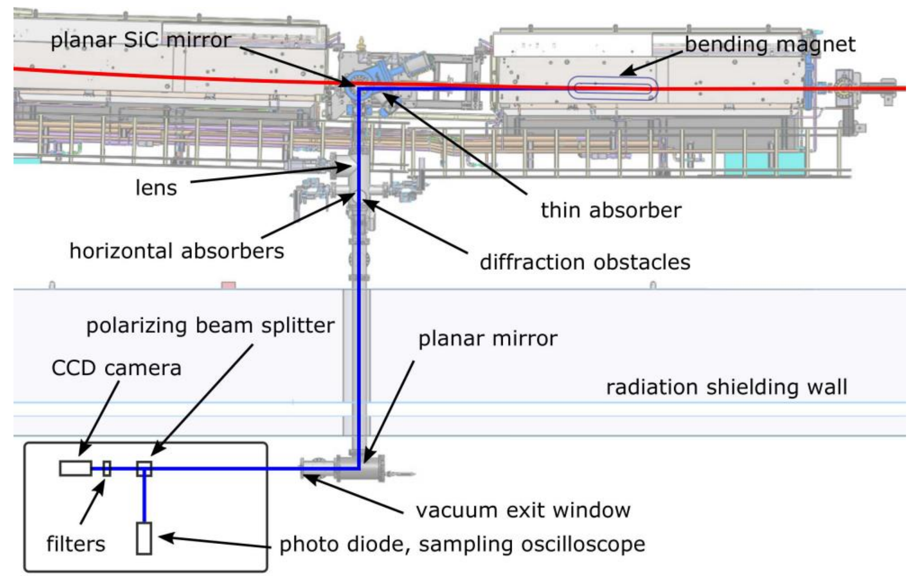
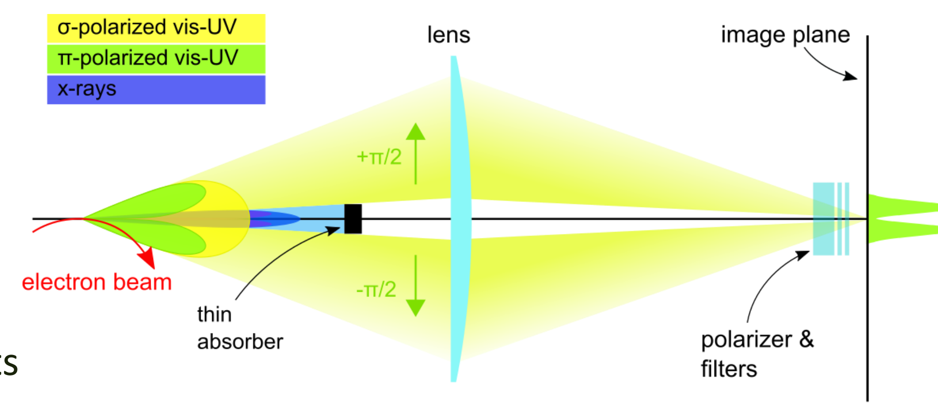
Principle and beamline design

MAX IV B320B

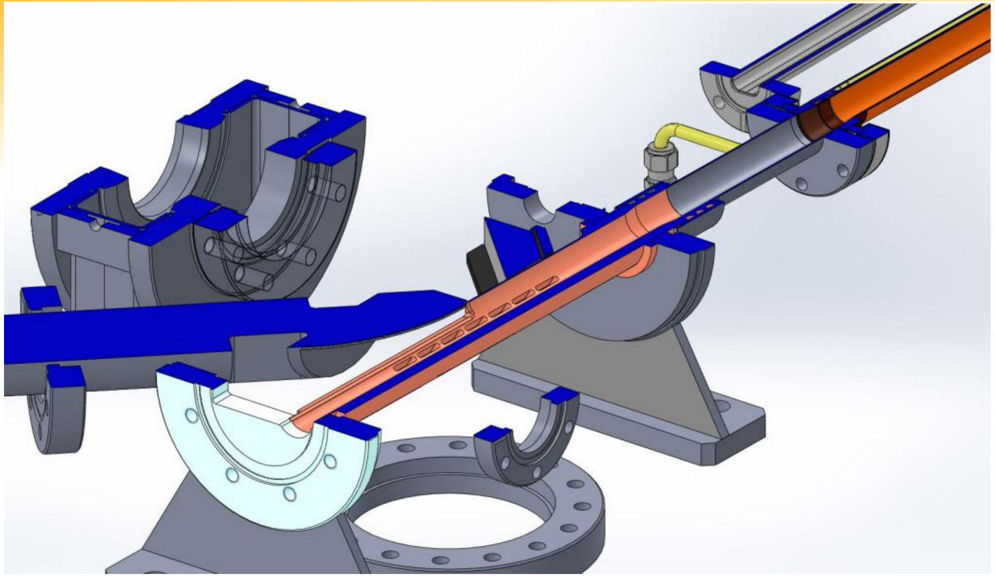
Imaging IR-visible-UV synchrotron radiation from a bending magnet

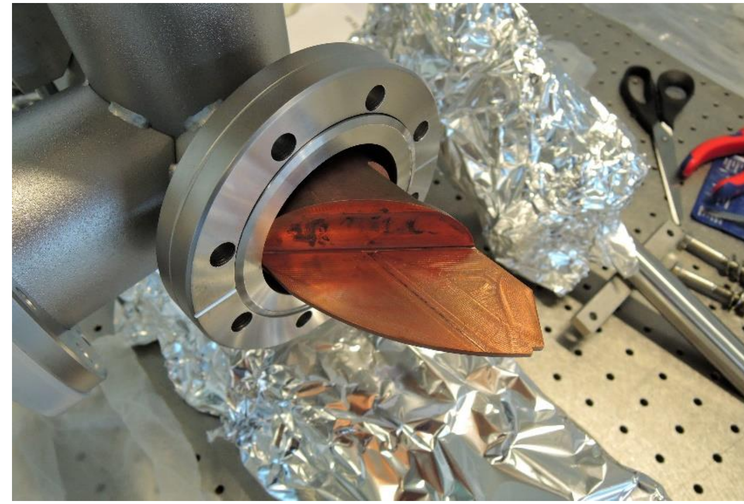
- 1st mirror: chamfered SiC
- FS spherical lens
  - Optical magnification: 1.81 @ 488 nm
- acceptance angles:
  - up to 9 mrad vertical
  - ≈18.5 mrad horizontal
- thin absorber (retractable) to take x-ray at small vertical angles, protect beamline optics
- optical table in the experimental hall
  - Transverse beam profile measurements
  - Time-resolved measurements

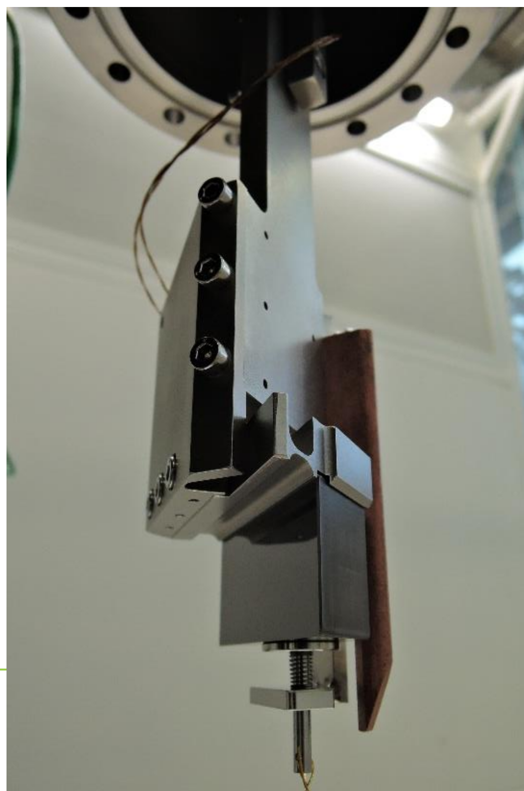


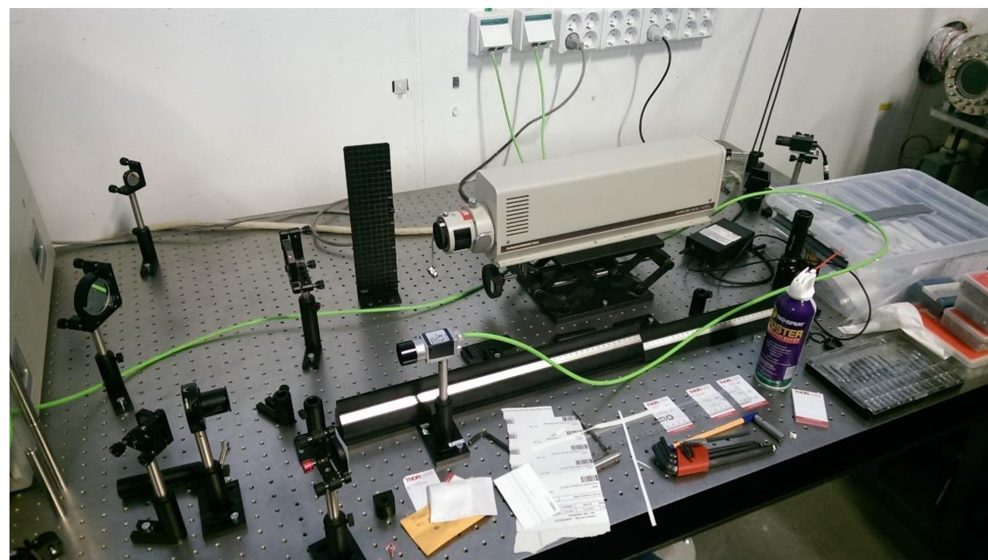


MAX IV B320B







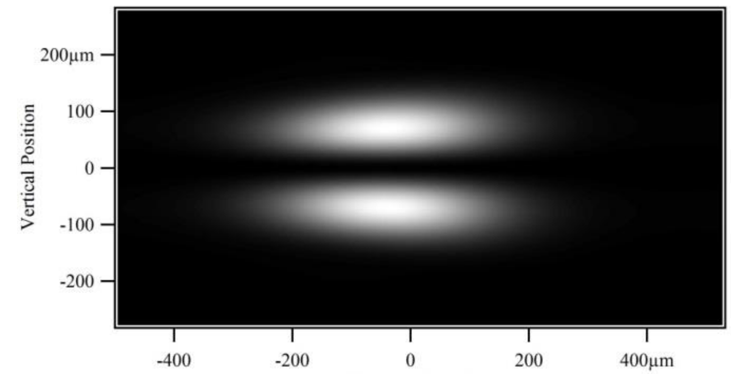


Vertical beam size – ‘π-polarization method’

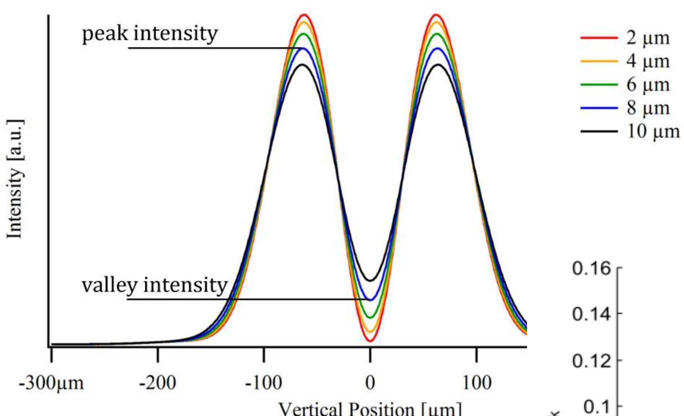
Images of SR in the near visible spectral range are dominated by inherent diffraction.

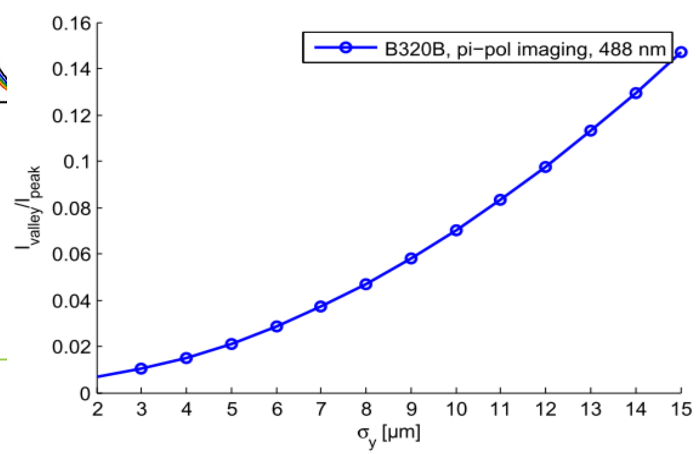
Diffraction effects can be

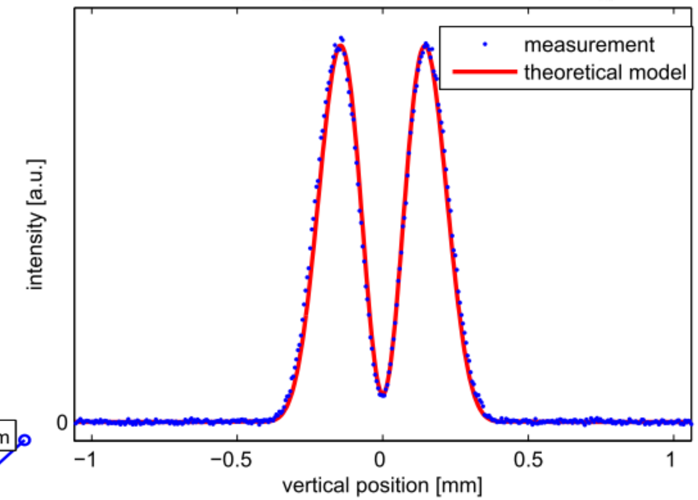
- simulated (Synchrotron Radiation Workshop)
- used to determine the (vertical) electron beam size



→ Contrast of diffraction pattern vertically (π) polarized SR depends on vertical beam size:







Measurement at MAX IV 3 GeV

$\sigma_y = 11.5 \pm 0.2$ µm

$\varepsilon_y = 6.4 \pm 0.9$ pm rad

$\lambda = 488$ nm

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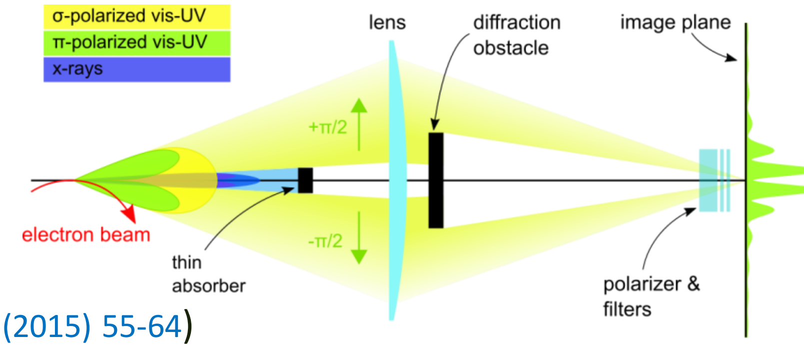
Vertical beam size – ‘Obstacle diffractometer methods’

Diffraction obstacles of variable height

- varying but predictable diffraction patterns
- complementary vertical beam size measurements
- potentially higher sensitivity to the vertical beam size

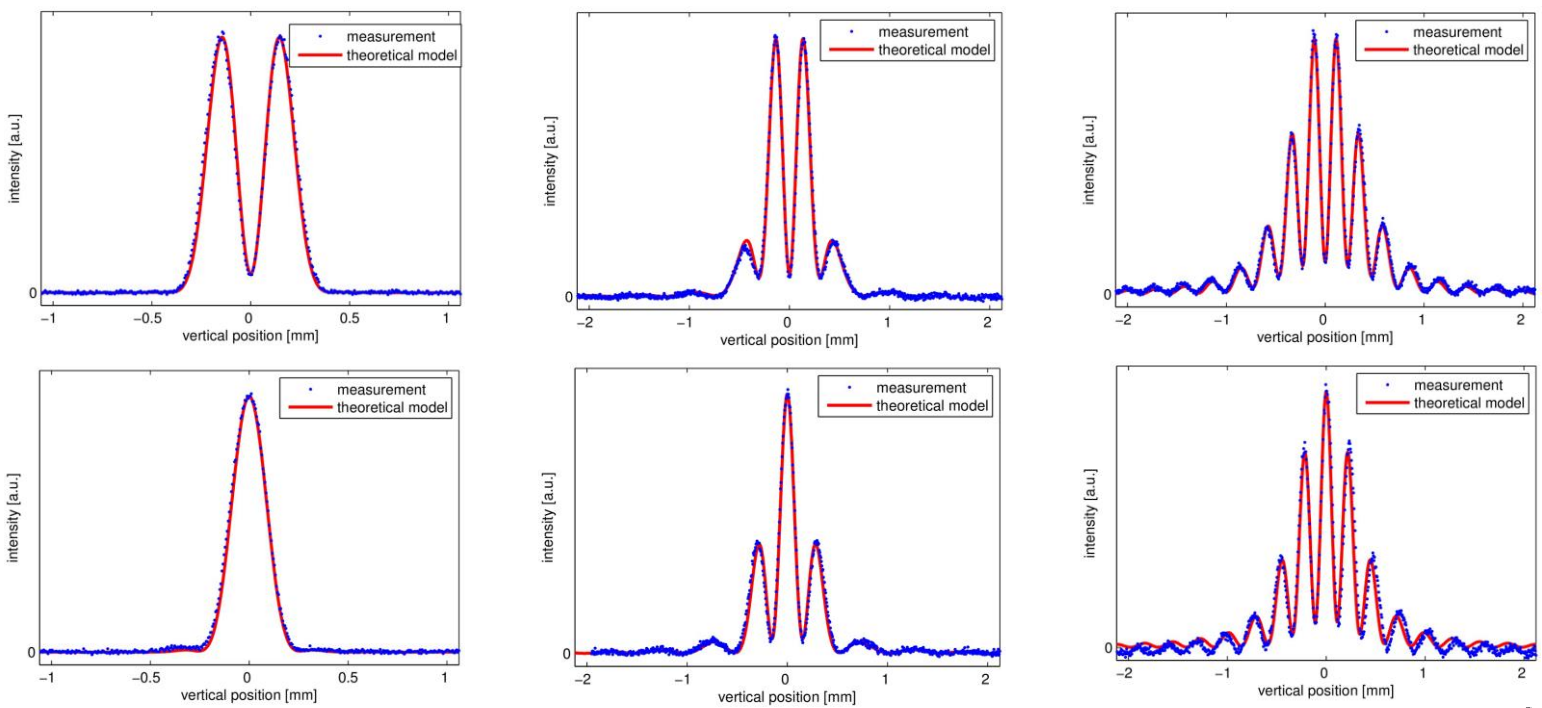


Successfully applied at the SLS diagnostic beamline (NIM-A 803 (2015) 55-64)

Adapted for MAX IV diagnostic beamlines (IPAC 2016, WEPOW034)

imaging | 2.1 mrad obstacle | 3.8 mrad obstacle

π-polarized / σ-polarized



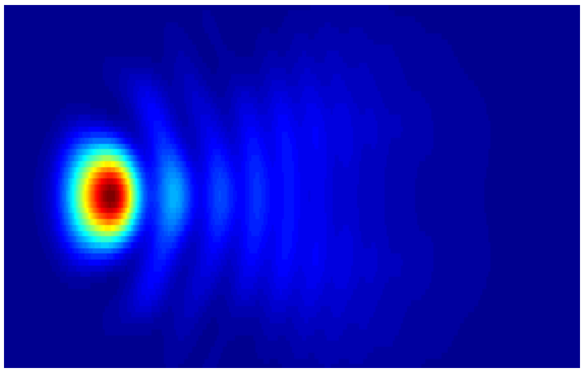
MAX IV B320B measurements in April: $\sigma_y = 11.0 \pm 0.4$ µm, $\varepsilon_x = 6.4 \pm 0.9$ pm

Horizontal beam size – ‘wide horizontal acceptance angle’

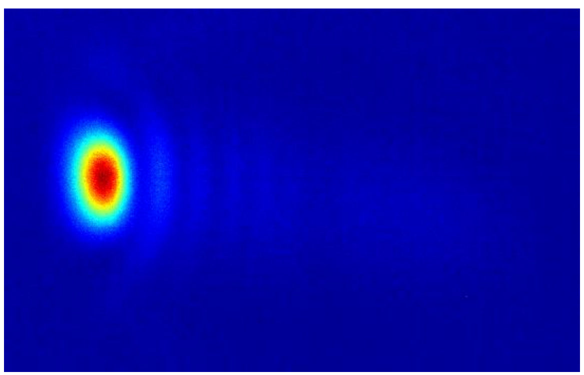
Deduce horizontal beam size from infrared (930 nm) SR fringe contrast

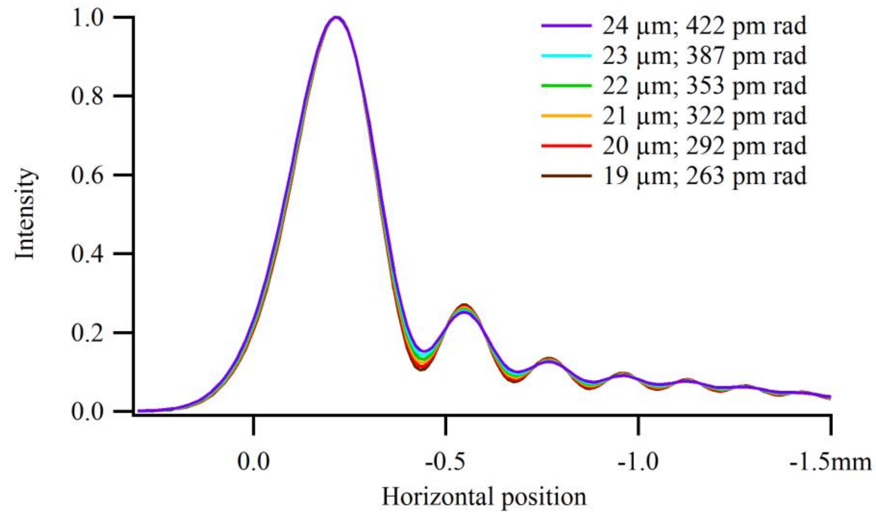
Large horizontal acceptance angle (up to 18.5 mrad in B320B)

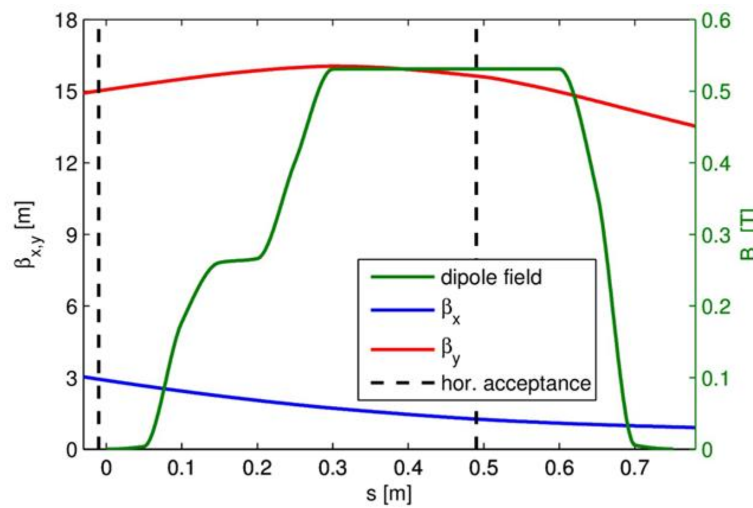
calculation



measurement







Challenges:

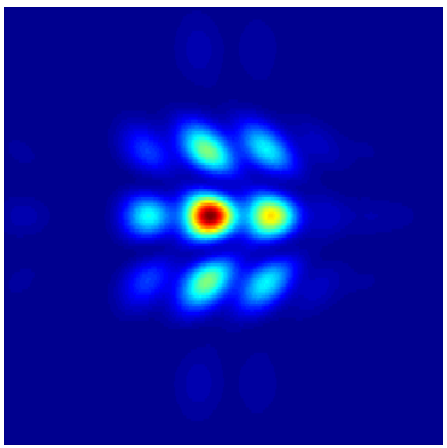
- Vertical acceptance restrictions
- Variation of magnetic field
- Variation of electron beam size

Horizontal & vertical beam size

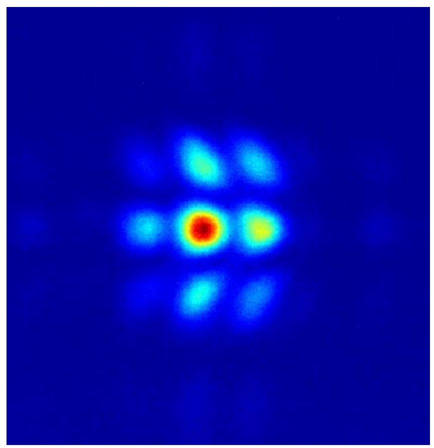
Everyday beam size monitoring scheme:

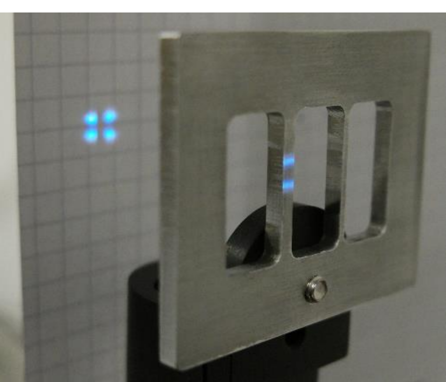
- Wavelength 488 nm, horizontal acceptance 6 mrad
- Diffraction from
  - Vertical obstacle, 2.1 mrad
  - Horizontal obstacle, 2 mrad

calculation



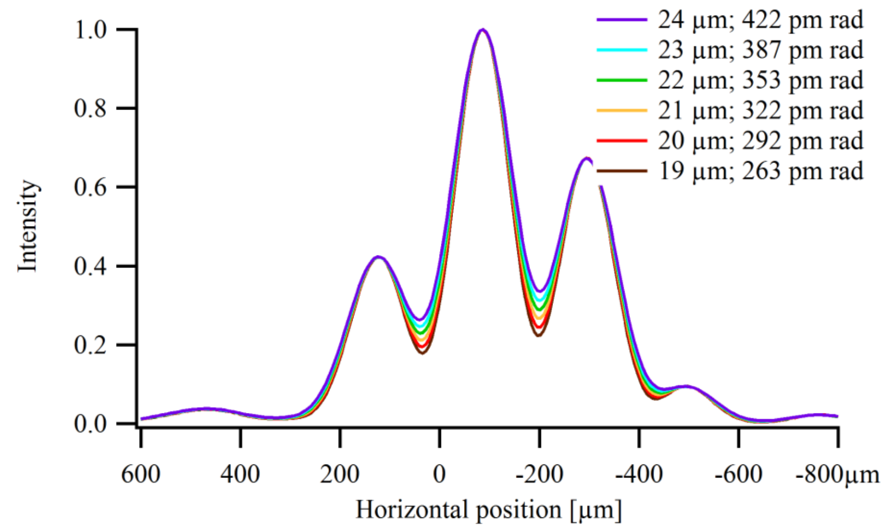
measurement



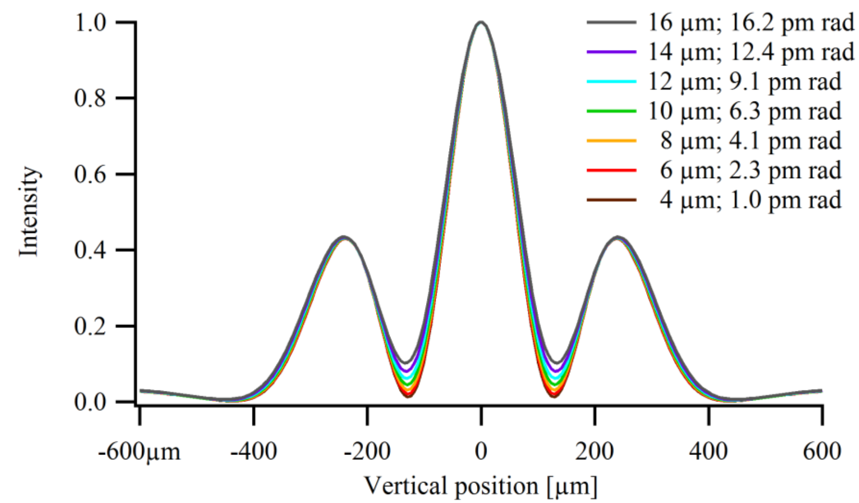


Horizontal diffraction obstacle and ‚footprint‘ of the SR

Horizontal intensity profile, sensitive to σ_x



Vertical intensity profile, sensitive to σ_y

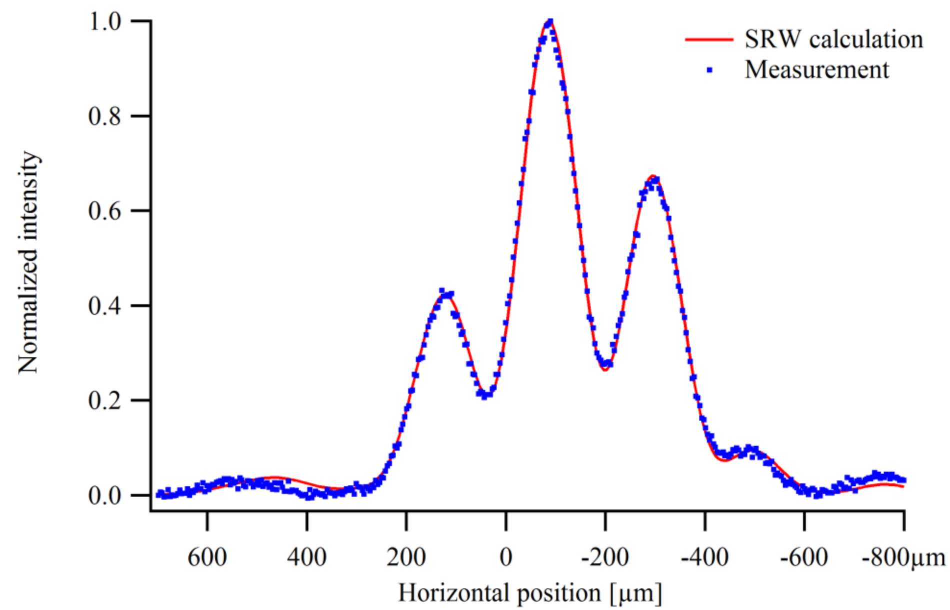


Beam size and emittance

Beta functions and dispersion from LOCO fits, model-based beam energy spread

$\sigma_x = 20.86 \pm 0.14$ µm
$\rightarrow \varepsilon_x = 339.4 \pm 7.1$ pm rad

$\sigma_y = 15.70 \pm 0.15$ µm
$\rightarrow \varepsilon_y = 15.7 \pm 0.3$ pm rad



Next steps:

- Refine SRW model to improve agreement with measurement
- Cross-check results with ‚complementary methods'
  → estimate systematic measurement errors
- Optimize electron beam orbit at the SR source point

Horizontal beam size, sensitivity test

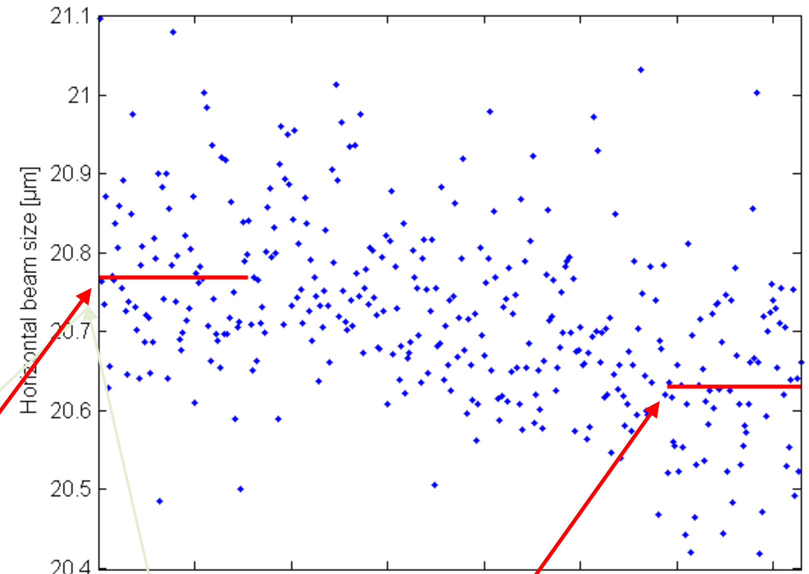
Gap change in BioMAX undulator

(in-vacuum, 2m magnetic length, 18mm period)

Closing gap to 4.2 mm:

→ ε_x decreases by 8.6 pm rad

(calculated for a bare lattice at zero current)



First measurement attempt:

Undulator gap: 37 mm

$\sigma_x = 20.77 \pm 0.02$ µm

Undulator gap: 5 mm

$\sigma_x = 20.63 \pm 0.02$ µm

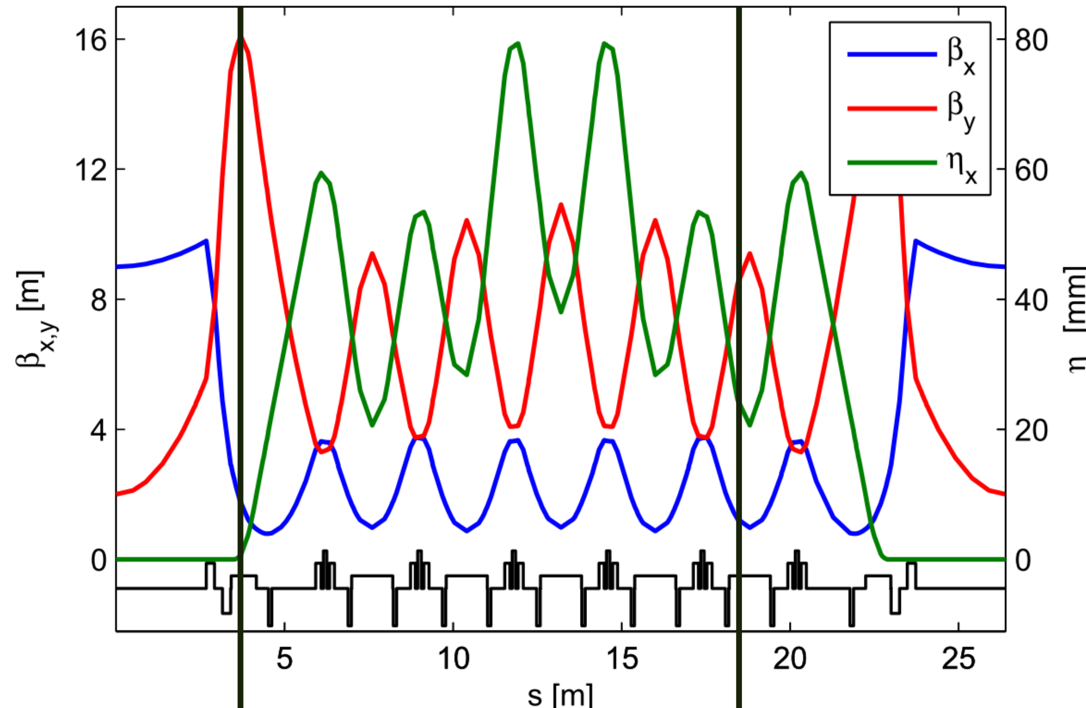
$\Delta\sigma_x \approx 0.14$ µm → $\Delta\varepsilon_x \approx 4.5$ pm rad

Beam energy spread measurement

Diagnostic beamlines measure electron beam sizes and dispersions

$$\sigma_x{}^2 = \varepsilon_x \beta_x + \eta_x{}^2 \sigma_E{}^2$$

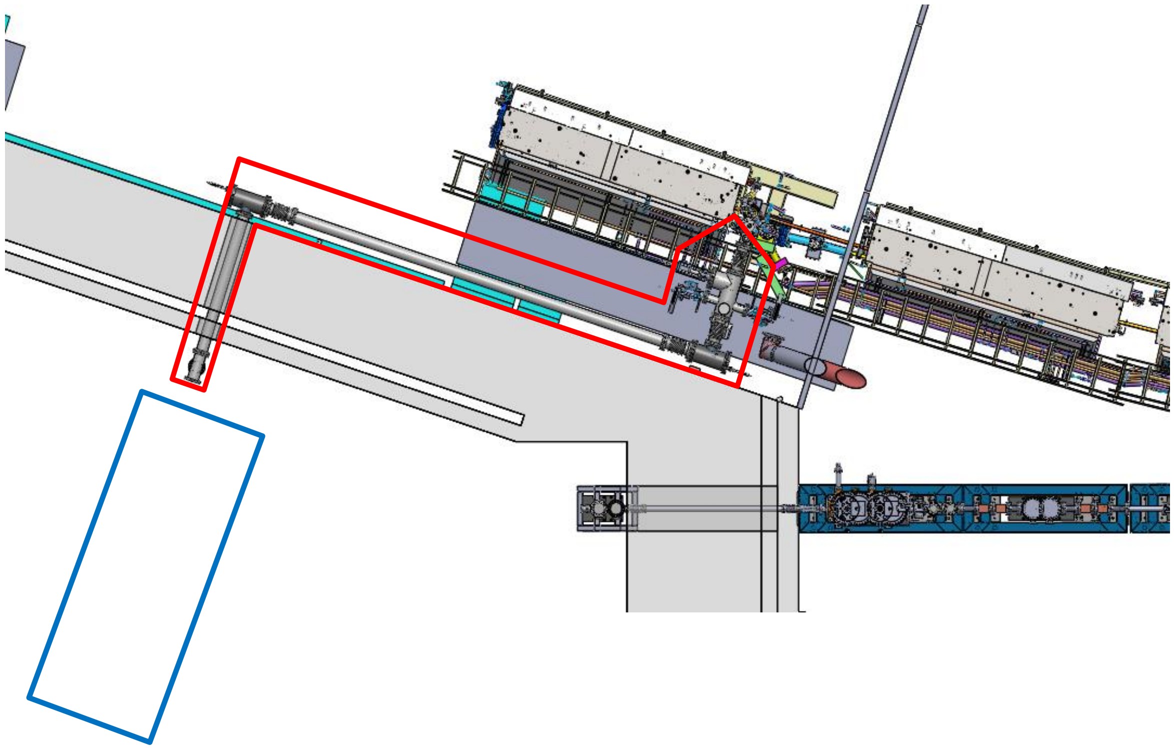
With two beamlines at different horizontal dispersions we can deduce **emittances and energy spread!**



$\beta_x \approx 1.5$m
$\beta_y \approx 15$m
$\eta_x \approx 3$mm
B320B in achromat 20
-> under commissioning

$\beta_x \approx 1.3$m
$\beta_y \approx 10$m
$\eta_x \approx 25$mm
B302B in achromat 2
-> delayed

Diagnostic beamline B302B



Vacuum chamber in the unit cell 5 bending magnet deformed under vacuum force

→ spare chamber without SR outlets had been installed instead

New chamber is available, waiting for a time slot to replace …

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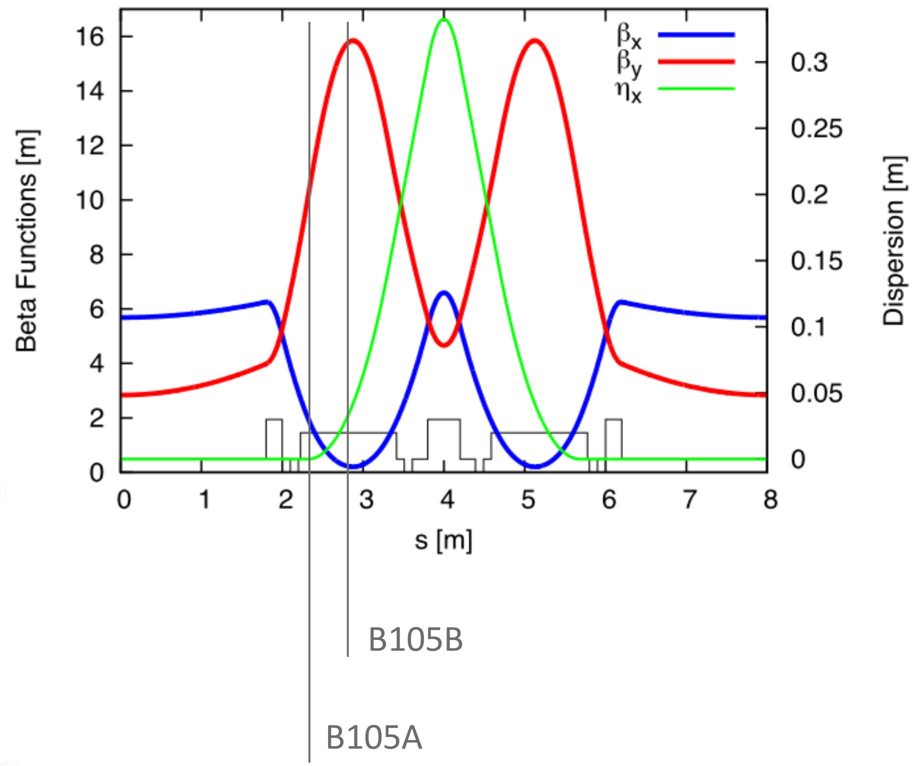
Diagnostic beamlines, 1.5 GeV ring

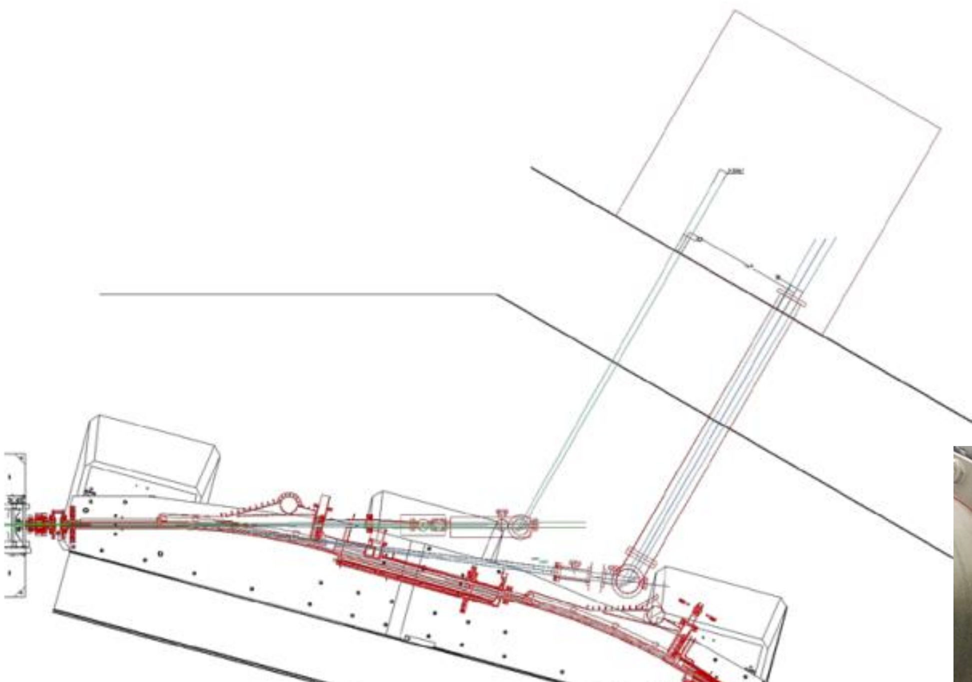
Status:

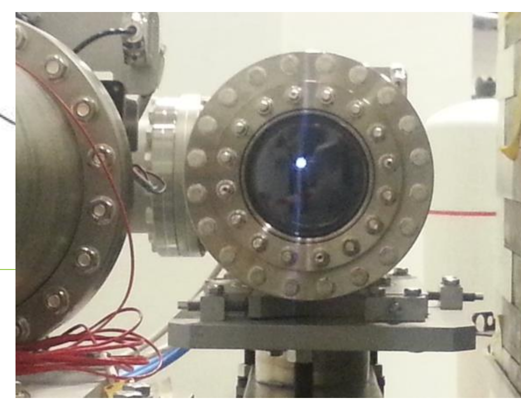
In-vacuum installations complete

First light passed through

Motion tests of in-tunnel equipment ongoing





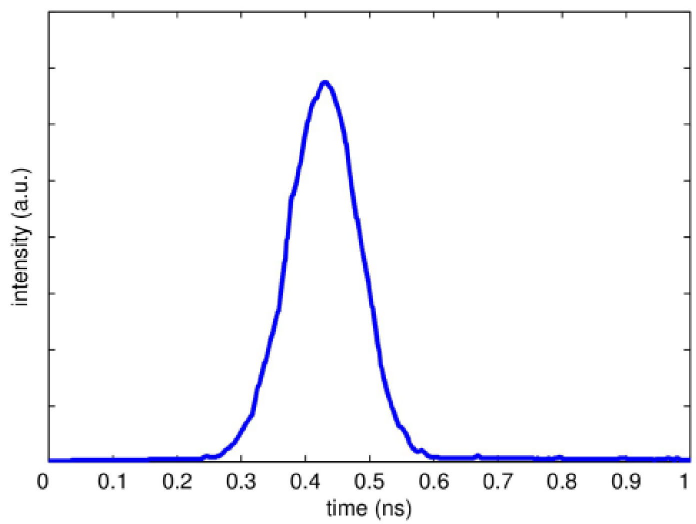


Longitudinal measurements

Using the ‚discarded' ray from the polarizing beam splitter → Simultaneous operation

Instruments:

- Optical sampling oscilloscope
- photo diode and oscilloscope for single-shot (planned)



$\sigma_s = 55\ \text{ps}$ at < 1mA stored beam current

Valuable diagnostic tool for

- Longitudinal instability investigations
- Future studies of bunch lengthening by harmonic cavities at MAX IV

Thank you for your attention!