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

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Principle and beamline design

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 – ‘$\pi$-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

$\rightarrow$ Contrast of diffraction pattern vertically ($\pi$) polarized SR depends on vertical beam size:

Measurement at MAX IV 3 GeV

$\sigma_y = 11.5 \pm 0.2 \text{ } \mu m$

$\varepsilon_y = 6.4 \pm 0.9 \text{ } \text{pm rad}$

$\lambda = 488 \text{ } \text{nm}$
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)

MAX IV B320B measurements in April: $\sigma_y = 11.0 \pm 0.4 \, \mu m$, $\epsilon_x = 6.4 \pm 0.9 \, \mu m$
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)

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

Horizontal & vertical intensity profiles, sensitive to $\sigma_x$ and $\sigma_y$.
Beam size and emittance

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

\[ \sigma_x = 20.86 \pm 0.14 \, \mu m \]
\[ \rightarrow \varepsilon_x = 339.4 \pm 7.1 \, \text{pm rad} \]

\[ \sigma_y = 15.70 \pm 0.15 \, \mu m \]
\[ \rightarrow \varepsilon_y = 15.7 \pm 0.3 \, \text{pm rad} \]

Next steps:
• Refine SRW model to improve agreement with measurement
• Cross-check results with 'complementary methods' \[ \rightarrow \text{estimate systematic measurement errors} \]
• 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:
$\rightarrow \varepsilon_x$ decreases by 8.6 pm rad
(calculated for a bare lattice at zero current)

First measurement attempt:

Undulator gap: 37 mm
$\sigma_x = 20.77 \pm 0.02 \mu m$

Undulator gap: 5 mm
$\sigma_x = 20.63 \pm 0.02 \mu m$

$\Delta \sigma_x \approx 0.14 \mu m \rightarrow \Delta \varepsilon_x \approx 4.5 \text{ pm rad}$
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**!

\[ \beta_x \approx 1.5m \]
\[ \beta_y \approx 15m \]
\[ \eta_x \approx 3mm \]

**B320B** in achromat 20
-> under commissioning

\[ \beta_x \approx 1.3m \]
\[ \beta_y \approx 10m \]
\[ \eta_x \approx 25mm \]

**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 ...
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)

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

Valuable diagnostic tool for
• Longitudinal instability investigations
• Future studies of bunch lengthening by harmonic cavities at MAX IV
Thank you for your attention!