XFEL Operator Training - APPLE-X undulators

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XFEL Operator Training
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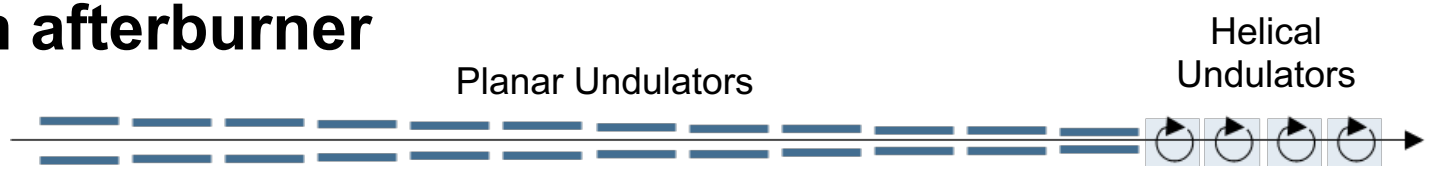
Overview

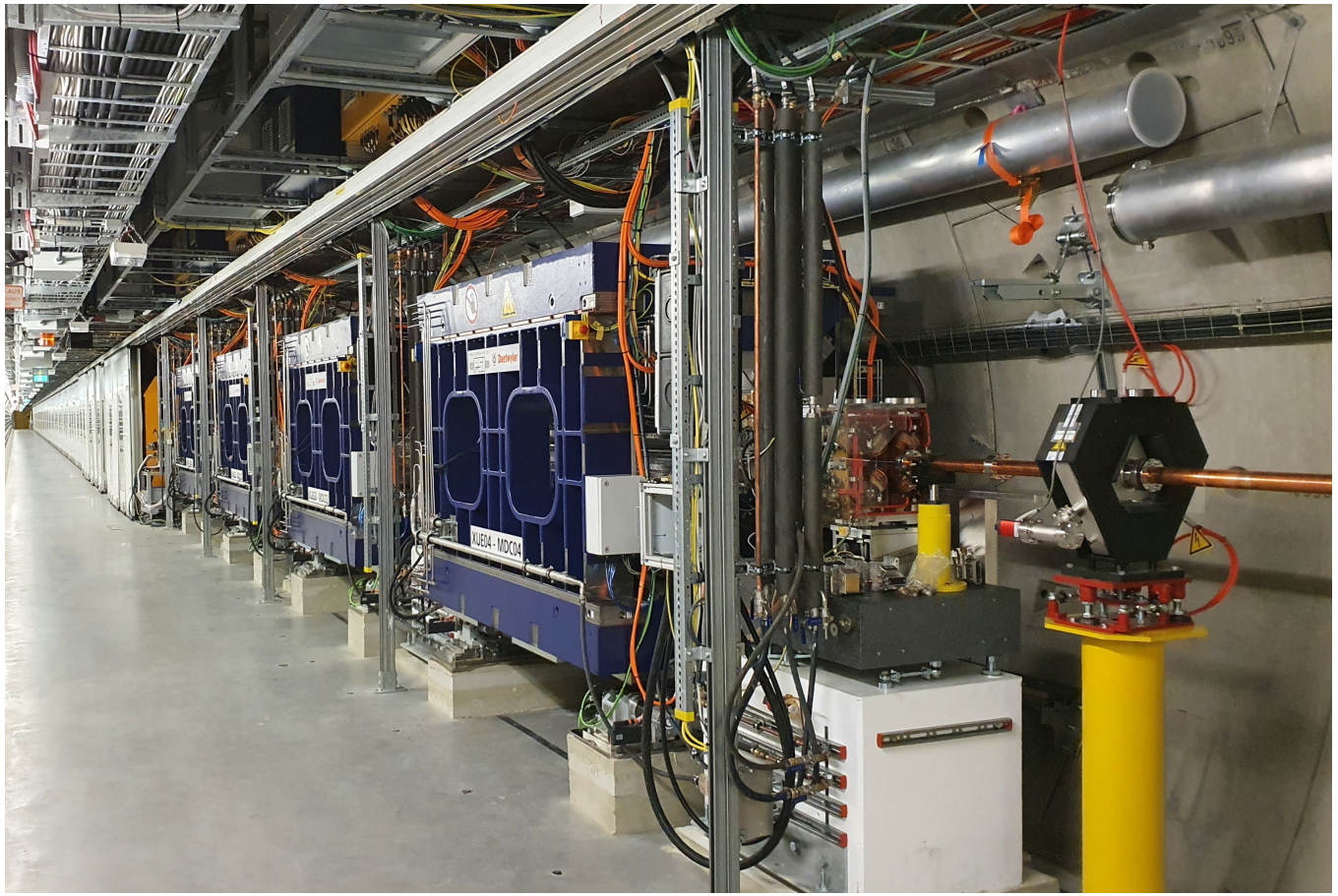
- Helical afterburner: Concept, implementation
- Design of APPLE-X Helical Undulator
- Polarization modes
- Control panels

Soft X-ray variable polarization afterburner



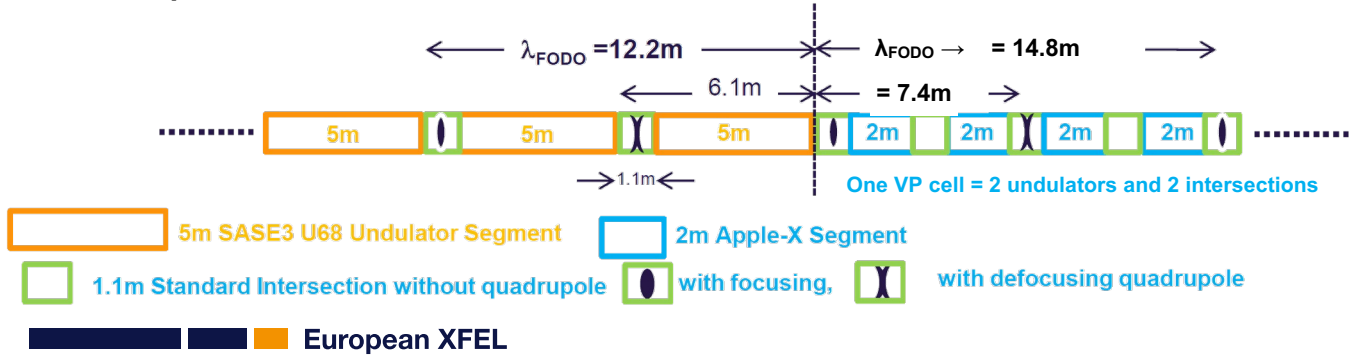
- The idea is to use a micro bunched electron beam after a system of planar undulators and direct it into a system of helical undulators tuned to the resonant frequency

- A reverse tapering is used to suppress linearly polarized radiation from the planar undulators and obtain a high degree of circular polarization *(E. A. Schneidmiller and M. V. Yurkov, Phys. Rev. ST+AB 2013, 16: 110702)*

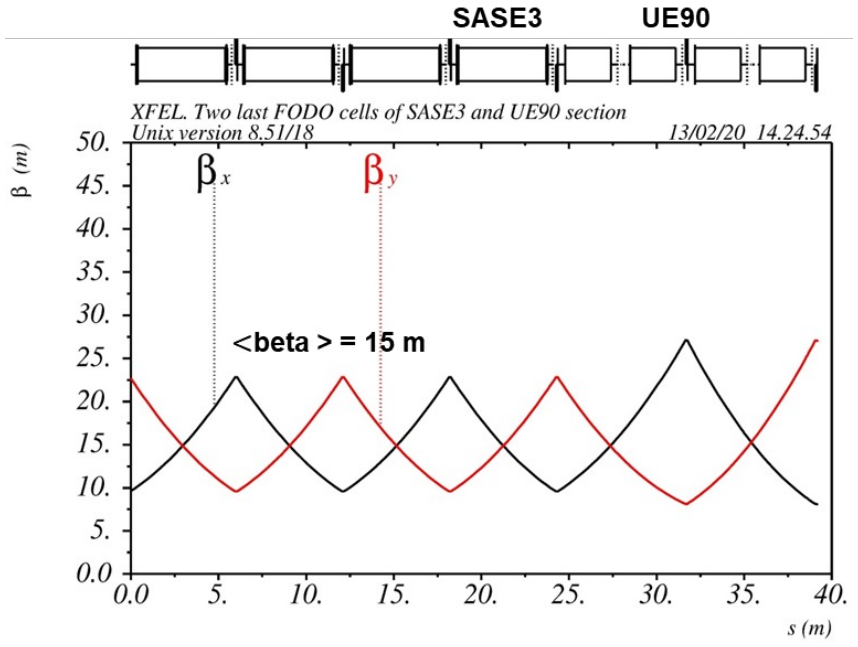


Electron beam optics

- Four APPLE-X undulators are installed directly after the last SASE3 undulator cell
- No matching section in between
- Optics in afterburner section is defined by optics in SASE3 undulator system
- Quadrupoles are installed behind each planar undulator and a pair of Apple-X undulators
- Phase shifters are installed behind every undulator except the last one

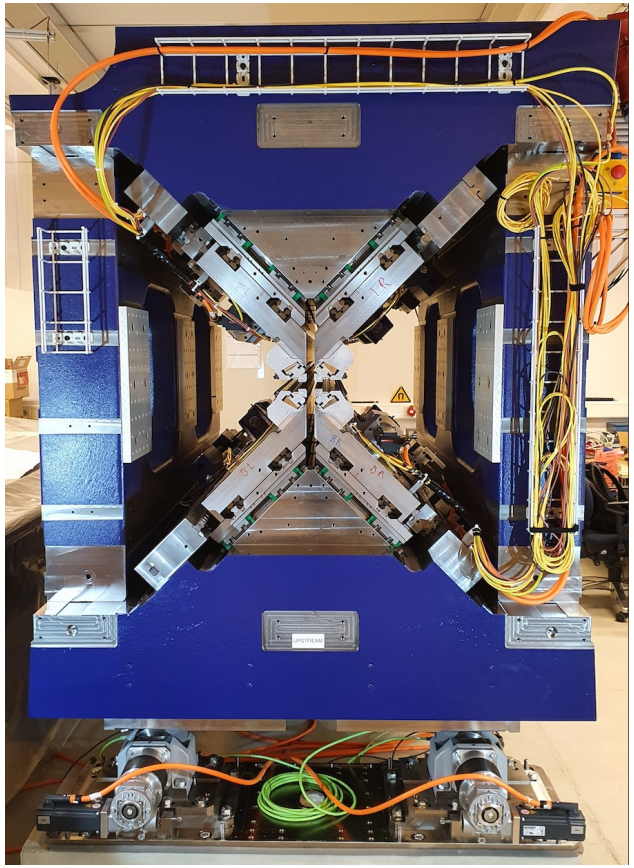


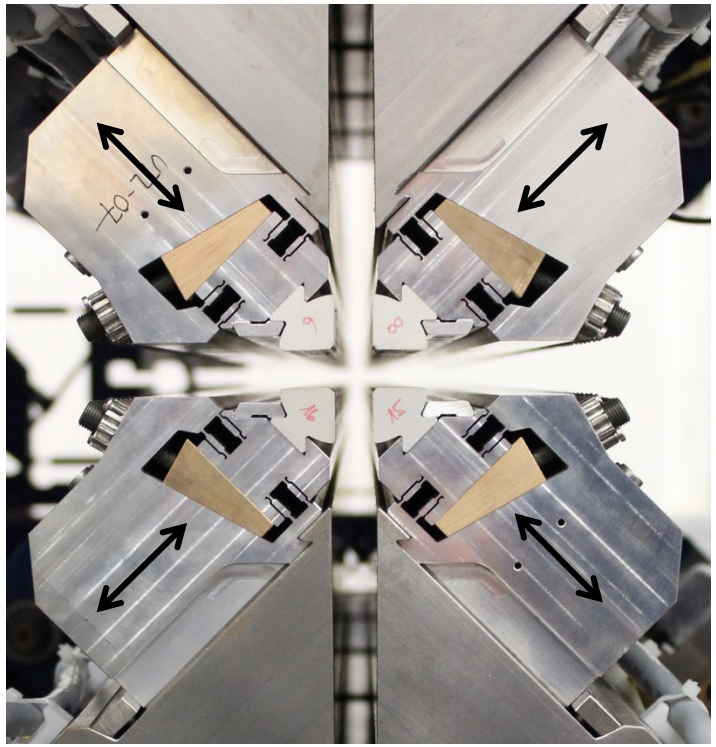
- FODO lattice configuration for afterburner section
  - Space of 2.6 m is reserved for the placement of Apple-X
  - 2 undulators between quadrupoles (QA)
  - 1.1 m long intersection between undulators (either with or without quadrupole)
  - Length of FODO period: 4*(1.1+2.6) = 14.8 m



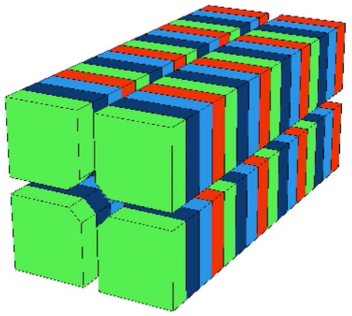
Example for average betatron functions of 15 m in SASE3
N. Golubeva, W. Decking

Design of APPLE-X Undulator

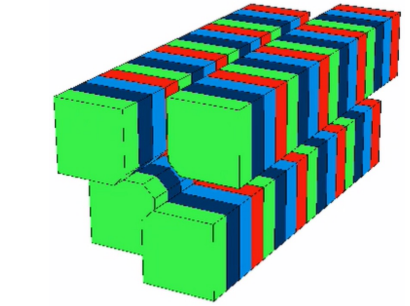


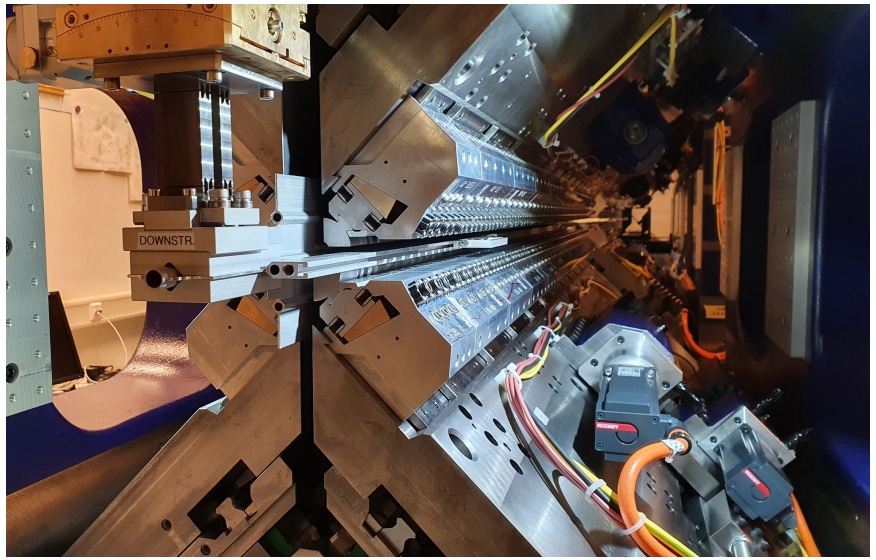


Linear Horizontal mode



Linear Vertical mode

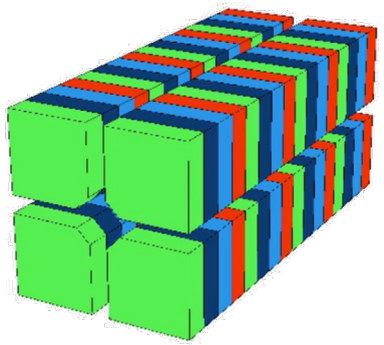




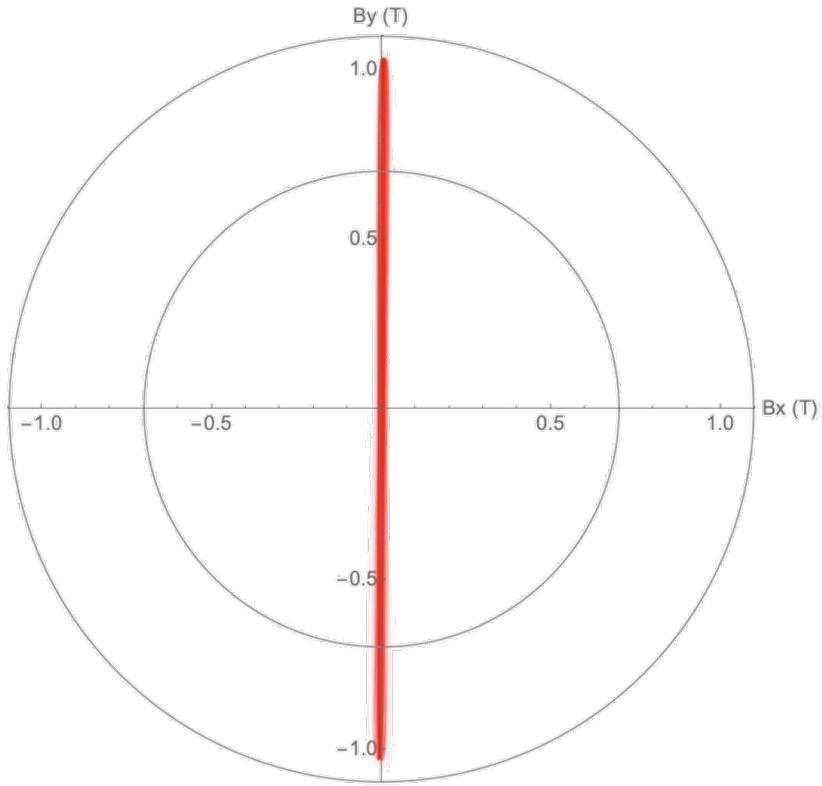
- APPLE - Advanced Planar Polarized Light Emitter
  - APPLE-X – is a „Delta“ type helical undulator, rotated by 45° around the magnetic axis.
  - It allows to vary not only the longitudinal but also the radial displacement of all 4 magnetic structures

APPLE-X undulators control – Polarization modes

- No Light mode corresponds to the minimum magnetic field or K value
  - Girder - Radial positions: Top Left (TL) = Top Right (TR) = Bottom Left (BL) = Bottom Right (BR) = 15.8mm
  - Girder Shift positions: TL = TR = 22.5 mm, BL = BR = -22.5 mm
- Mixed/Undefined mode
  - Not all undulators in the selected color are in the same polarization mode
- Linear Horizontal (LH) mode girder position
  - Radial: 6.25mm – 15.8mm
  - Shift
    - ► TL: 0 mm
    - ► TR: 0 mm
    - ► BL: 0 mm
    - ► BR: 0 mm



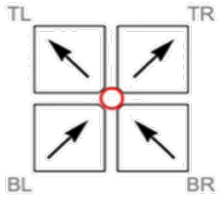
Visualization by M. Calvi (PSI)

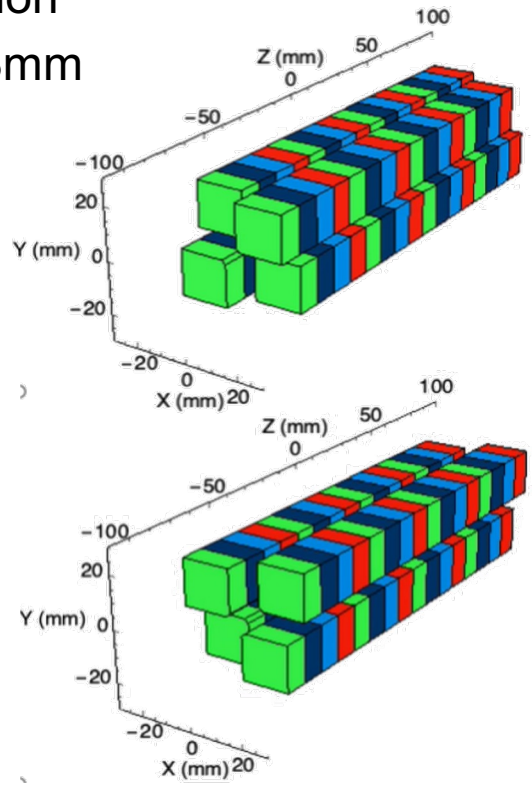


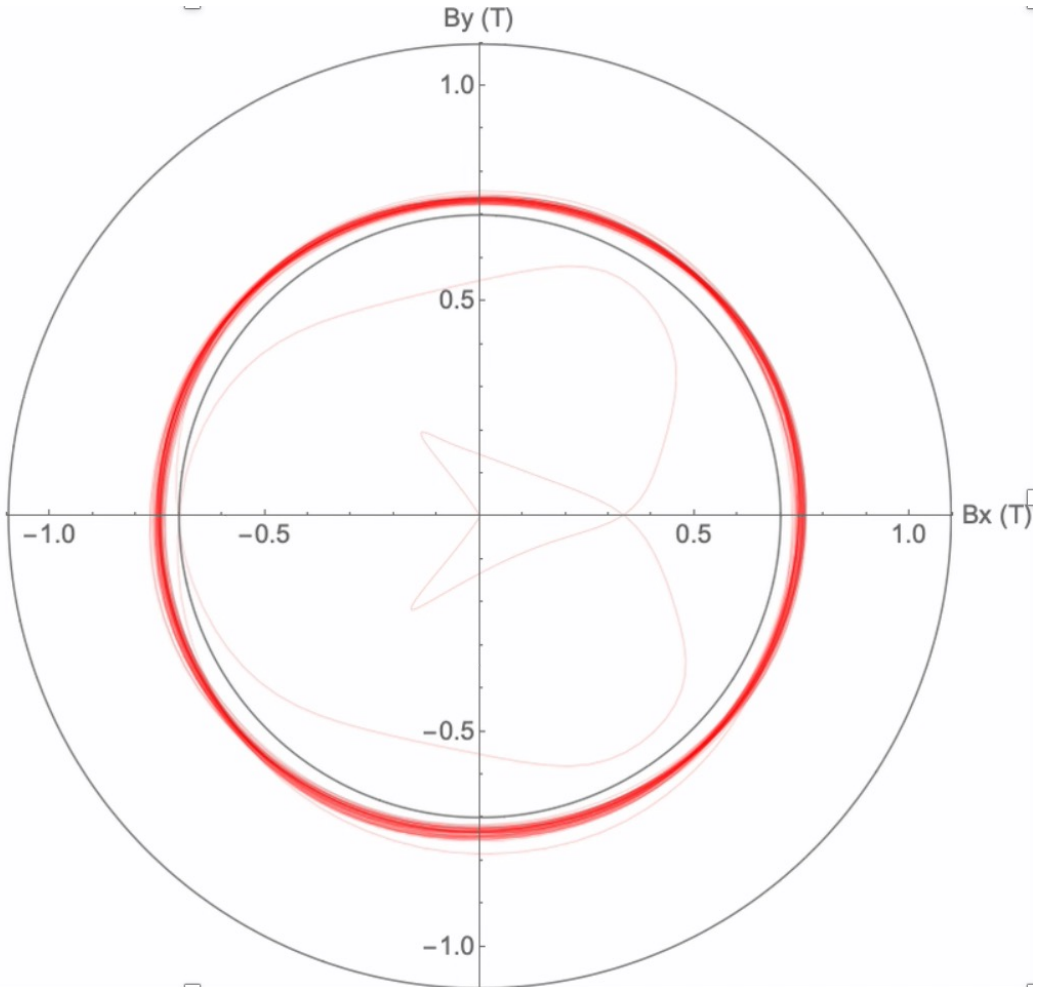
Polarization mode - Circular Clockwise (C+), Circular Anti-clockwise (C-)

- C+ and C- modes are from the experiments point of view (from downstream to upstream)

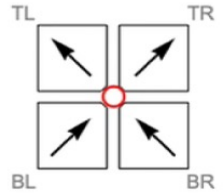
- Circular mode girder position
  - Radial: 6.25mm – 15.8mm
  - Shift for C+
    - ▶ TL: 11.25 mm
    - ▶ TR: -11.25 mm
    - ▶ BL: -11.25 mm
    - ▶ BR: 11.25 mm
  - Shift for C-
    - ▶ TL: -11.25 mm
    - ▶ TR: 11.25 mm
    - ▶ BL: 11.25 mm
    - ▶ BR: -11.25 mm





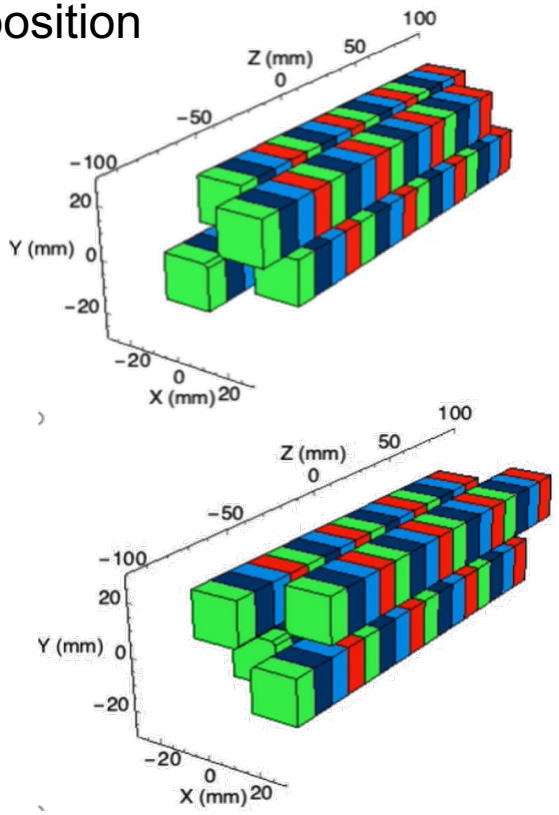


APPLE-X undulators control – Polarization mode Linear Vertical (LV)

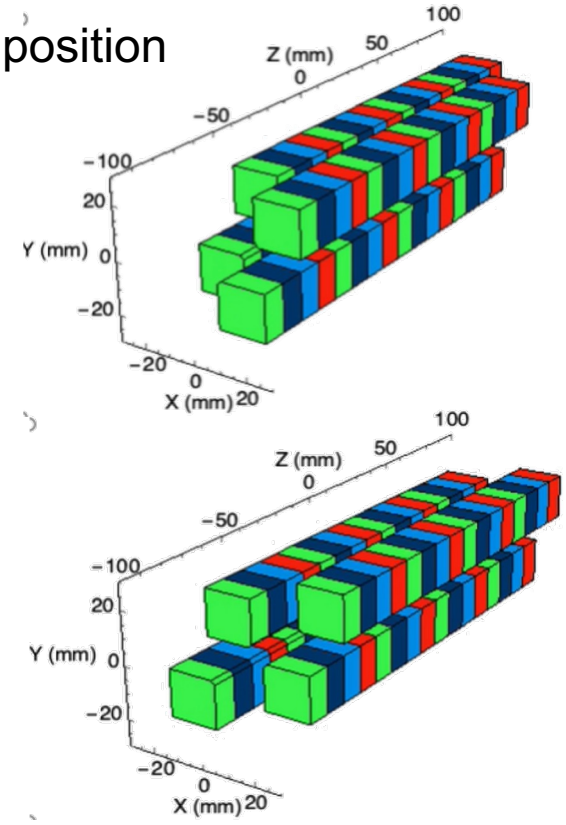


- Linear Vertical girder position
  - Radial: 6.25mm – 15.8mm

- Linear Vertical girder position
  - Shift for LV1
    - ▶ TL: 22.5 mm
    - ▶ TR: - 22.5 mm
    - ▶ BL: - 22.5 mm
    - ▶ BR: 22.5 mm
  - Shift for LV2
    - ▶ TL: - 22.5 mm
    - ▶ TR: 22.5 mm
    - ▶ BL: 22.5 mm
    - ▶ BR: - 22.5 mm



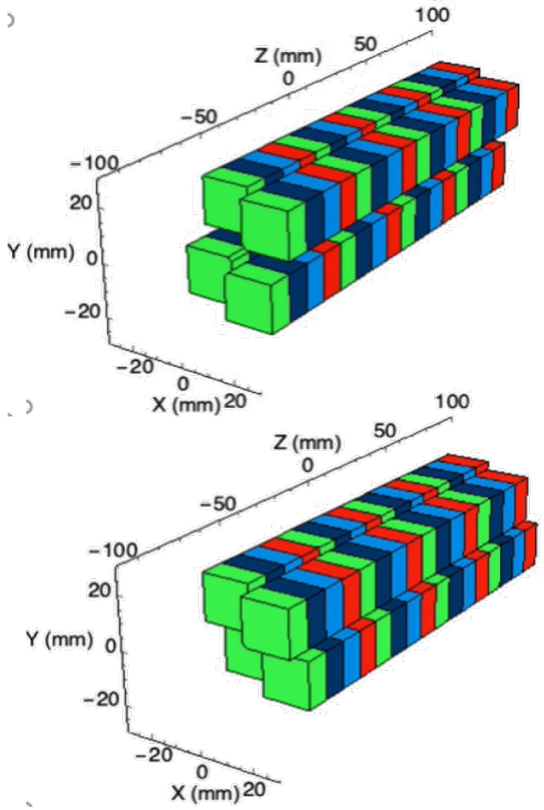
- Linear Vertical girder position
  - Shift for LV3
    - ▶ TL: 45 mm
    - ▶ TR: 0 mm
    - ▶ BL: 0 mm
    - ▶ BR: -45 mm
  - Shift for LV4
    - ▶ TL: 0mm
    - ▶ TR: 45 mm
    - ▶ BL: -45 mm
    - ▶ BR: 0 mm



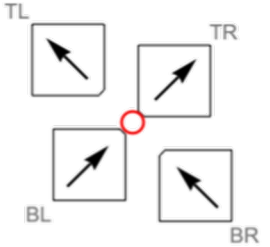
APPLE-X undulators control – Polarization mode 45°, 135°, New 45°, New 135°

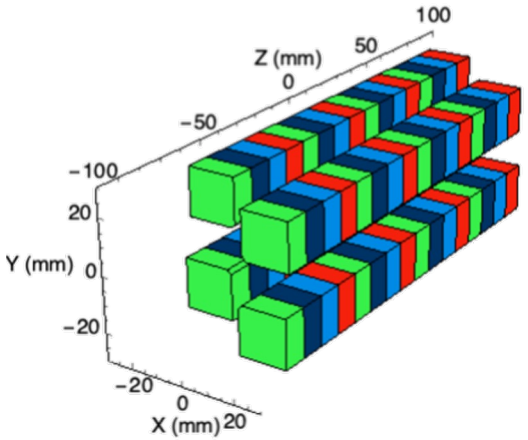
- 45°, 135° girder position
  - Radial symmetric: 6.25mm – 15.8mm

- 45°, 135° girder position
  - Shift for 45°
    - ▶ TL: 22.5 mm
    - ▶ TR: 0mm
    - ▶ BL: 0 mm
    - ▶ BR: -22.5 mm
  - Shift for 135°
    - ▶ TL: 0 mm
    - ▶ TR: 22.5 mm
    - ▶ BL: -22.5 mm
    - ▶ BR: 0 mm



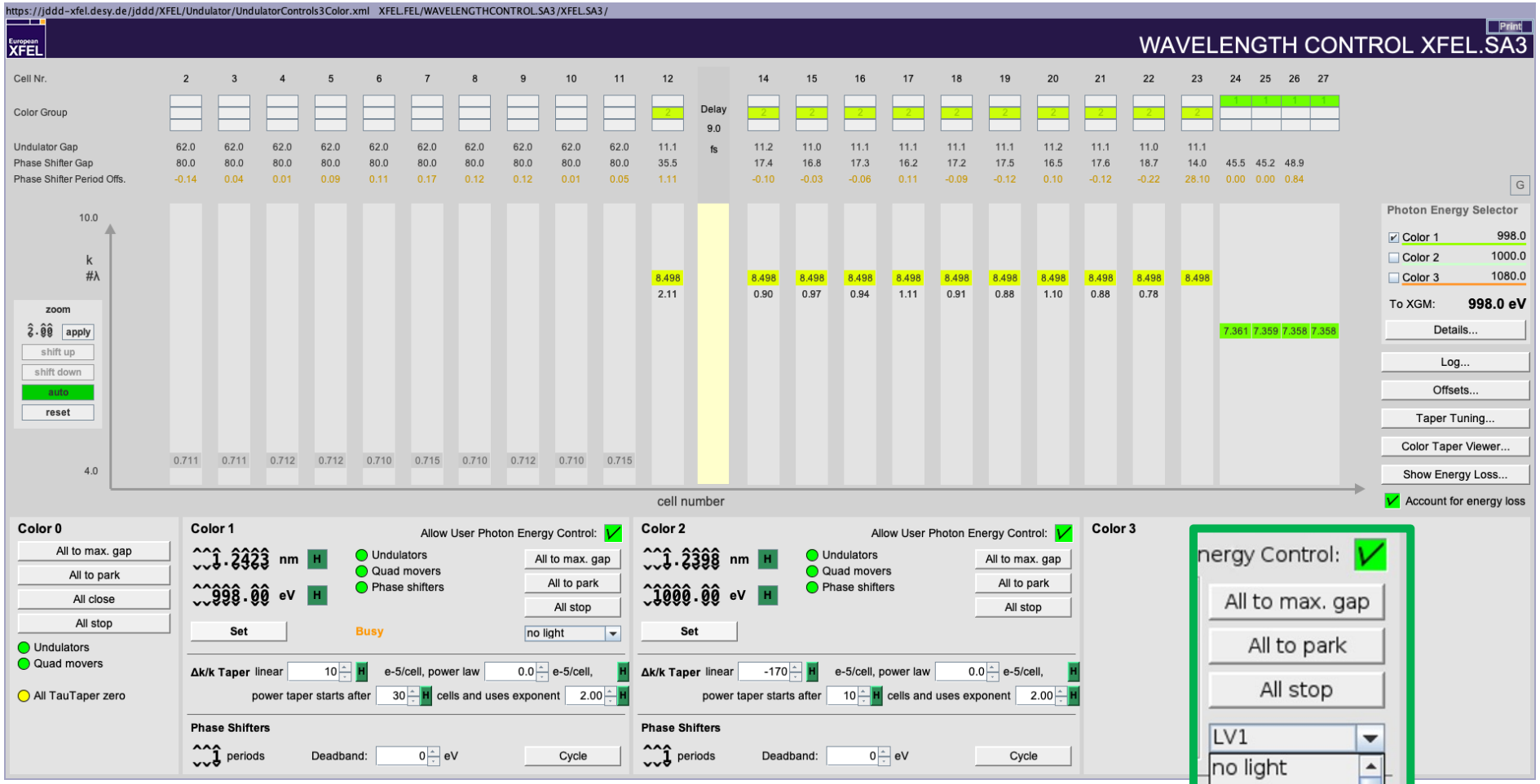
- New 45°:
  - Radial TL and BR = 15.8 mm
  - Radial: TR and BL: 6.25 mm – 15.8 mm
- New 135°:
  - Radial TR and BL = 15.8 mm
  - Radial: TL and BR: 6.25 mm – 15.8 mm
- New 45°, New 135° girder position
  - Shift for New 45°
    - ▶ TL: 22.5 mm
    - ▶ TR: 0mm
    - ▶ BL: 0 mm
    - ▶ BR: -22.5 mm
  - Shift for New 135°
    - ▶ TL: 0 mm
    - ▶ TR: 22.5 mm
    - ▶ BL: -22.5 mm
    - ▶ BR: 0 mm





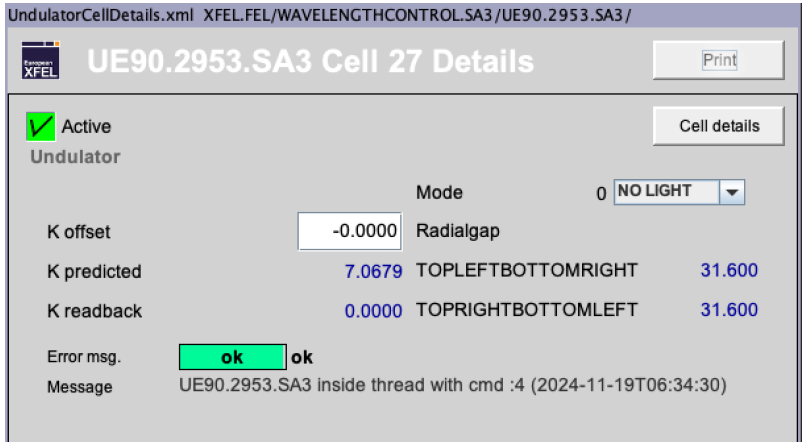
APPLE-X undulators control - SASE3 wavelength control panel

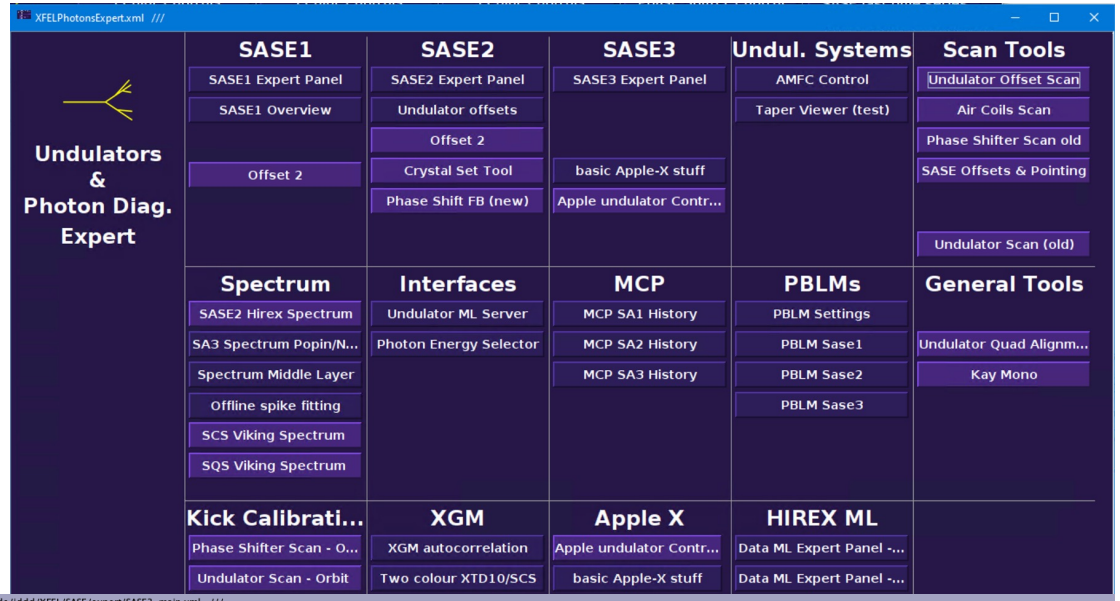
- SASE3 wavelength control panel offers the following selection options
  - Color group
  - Polarization mode
  - Photon energy
  - Phase Shifter Period selection
  - Taper type and parameters selection

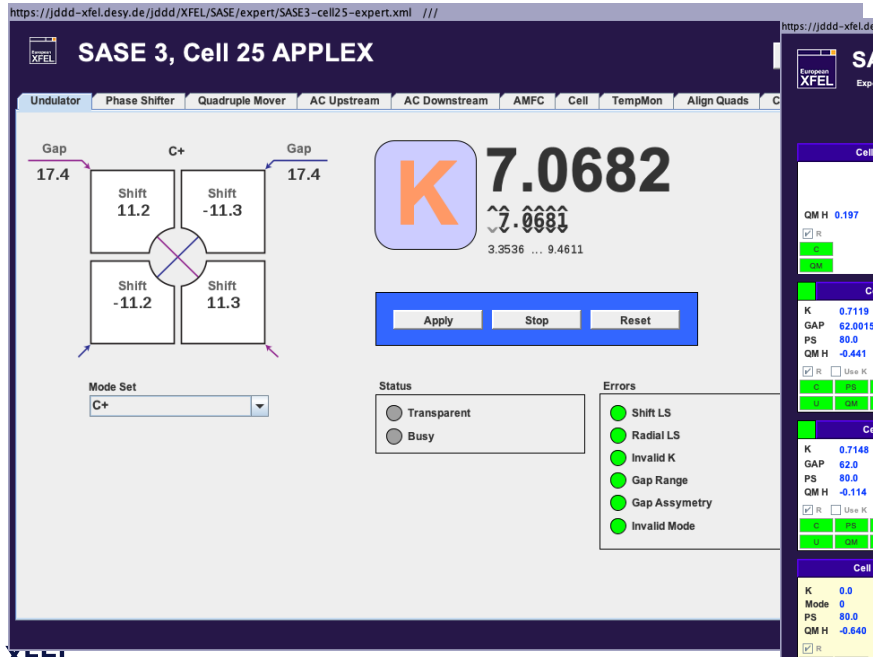


APPLE-X undulators control – Expert panels

- APPLE-X expert panels are available from 3 color panel, or from the XFEL main panel:
  - Photons Expert Panels
  - SASE3 Expert Panels
  - Cells 24 - 27

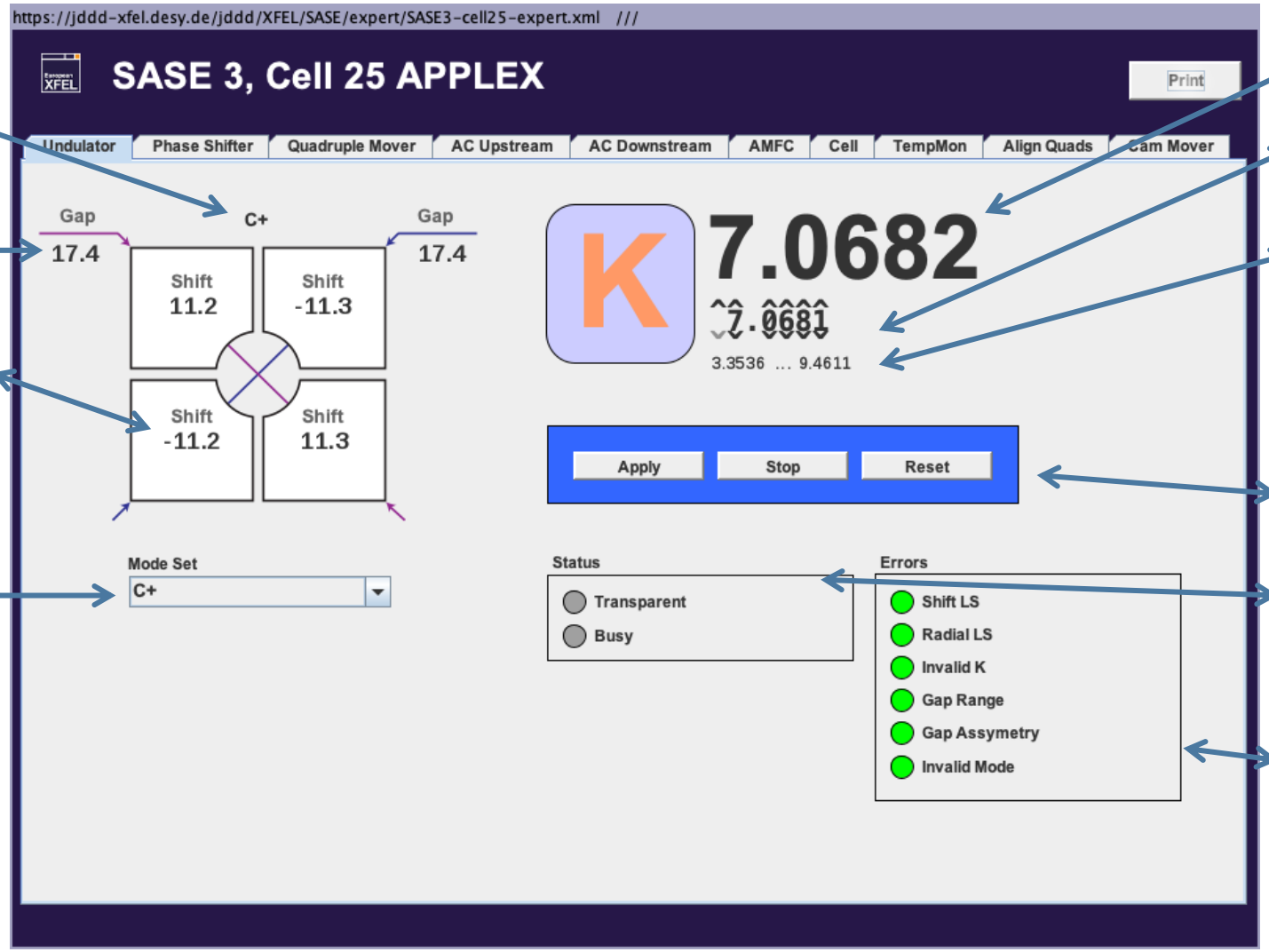






APPLE-X undulators control – Expert panel for a cell: Undulator tab

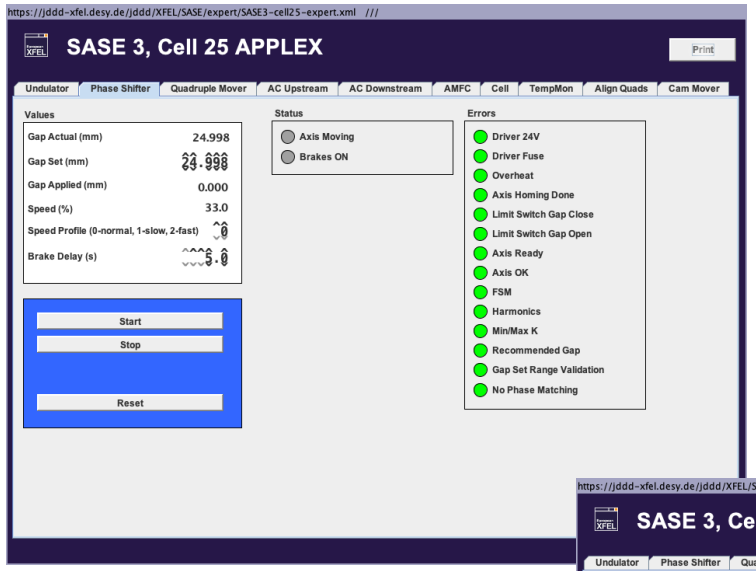
- Actual polarization mode
- Actual gap value
- Actual shift position of the magnet girder
- Polarization selection mode

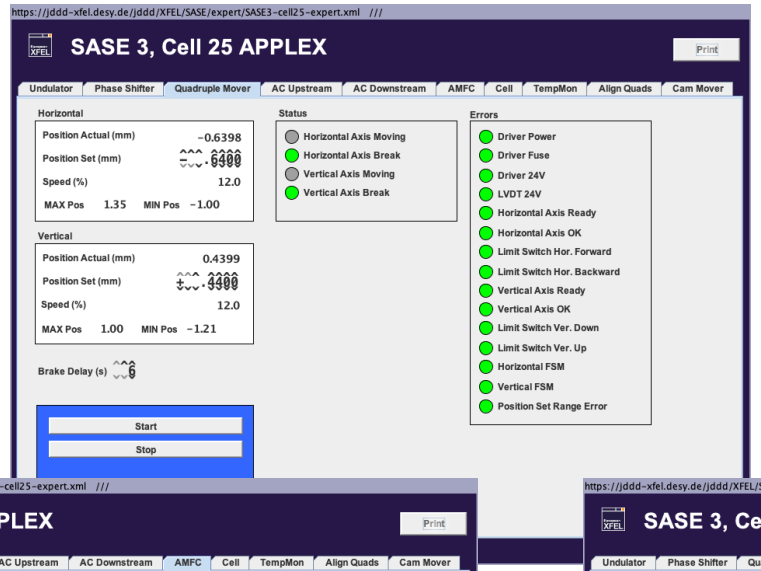


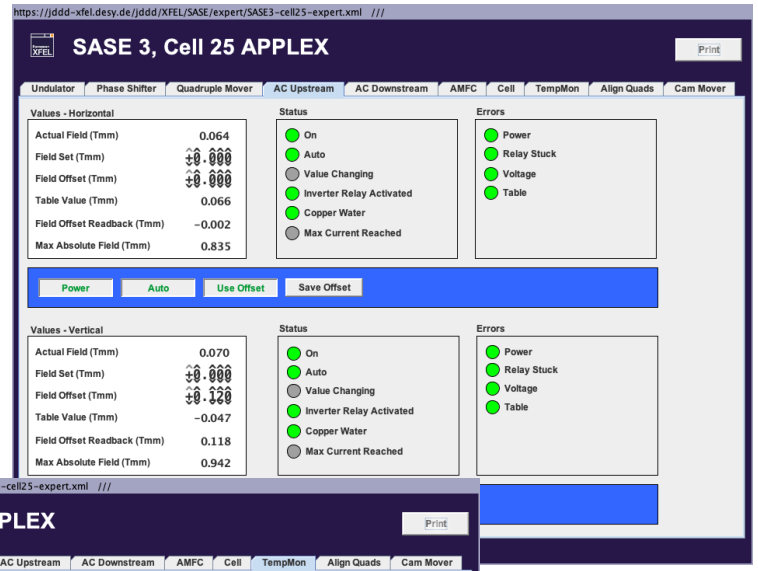
- K Actual
- K Set
- K range for selected polarization mode
- Control buttons
- Status indicators
- Error indicators

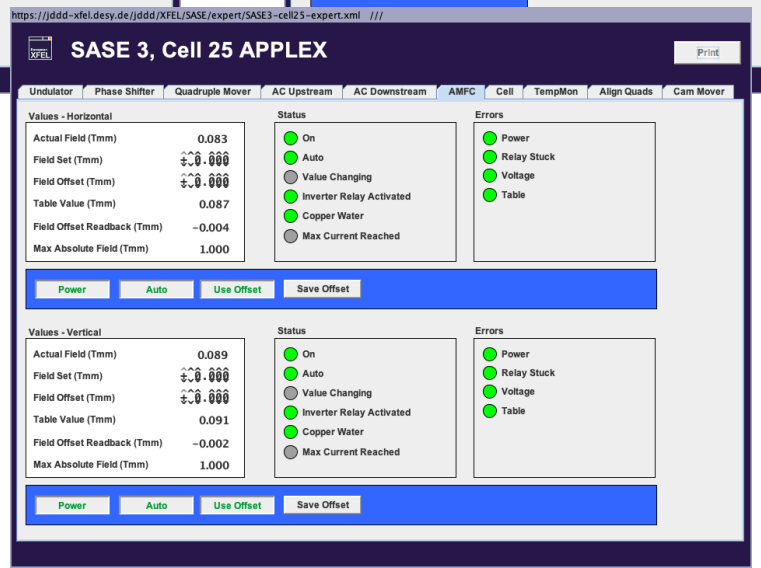
APPLE-X undulators control – Expert panel for a cell

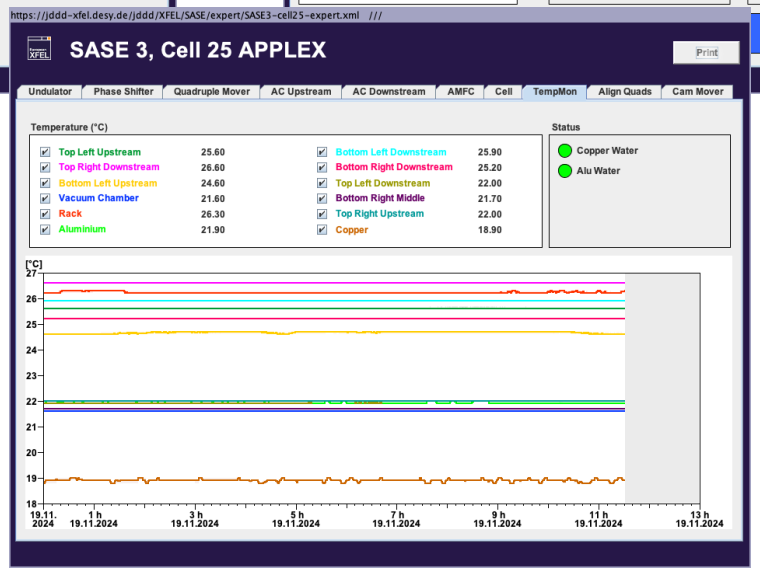
- The tabs: Phase Shifter, Quadrupole Mover, Air Coils Upstream/Downstream, Ambient Magnetic Field Corrector, Cell and Temperature are like in case of the planar undulator controls



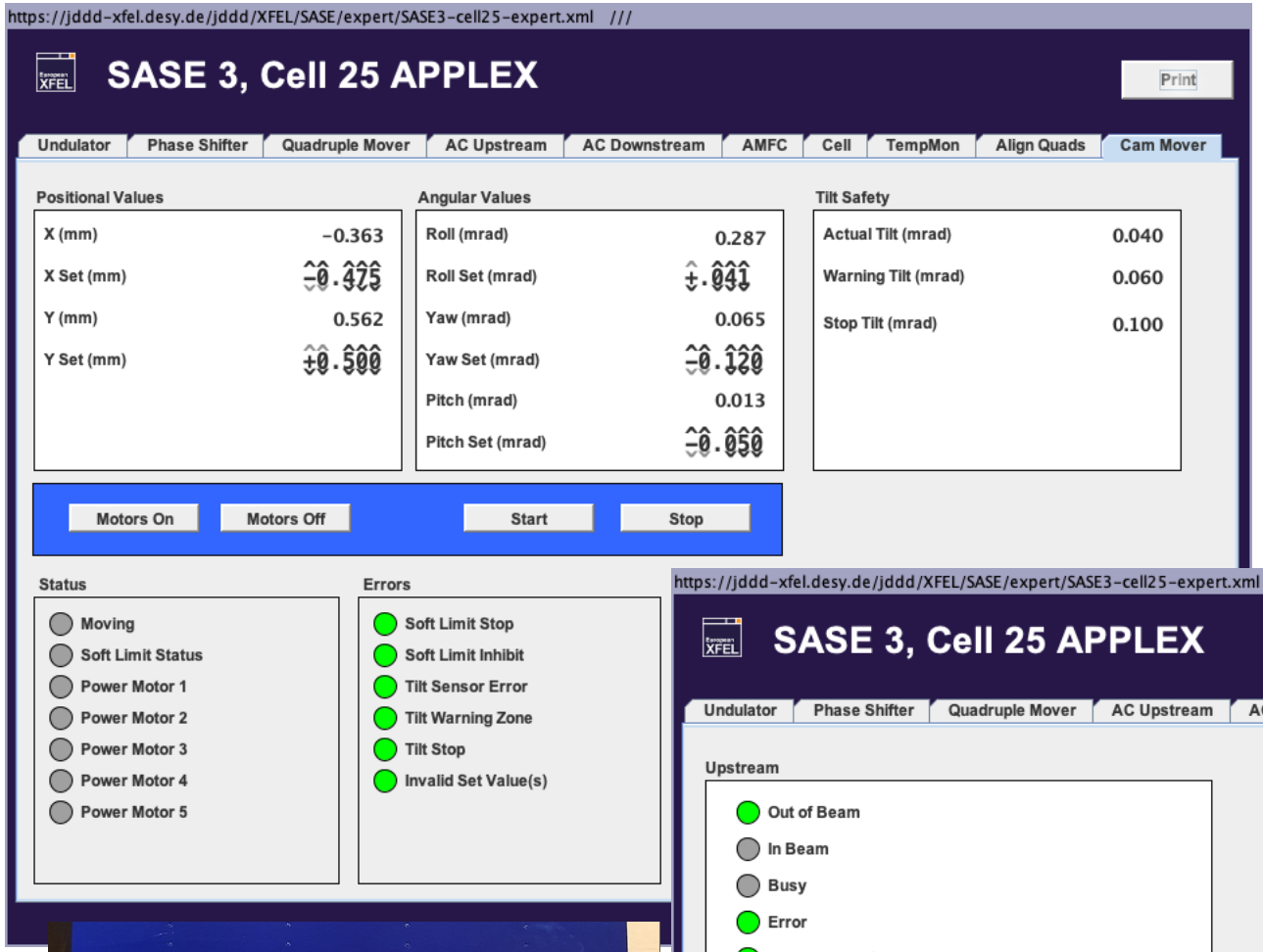




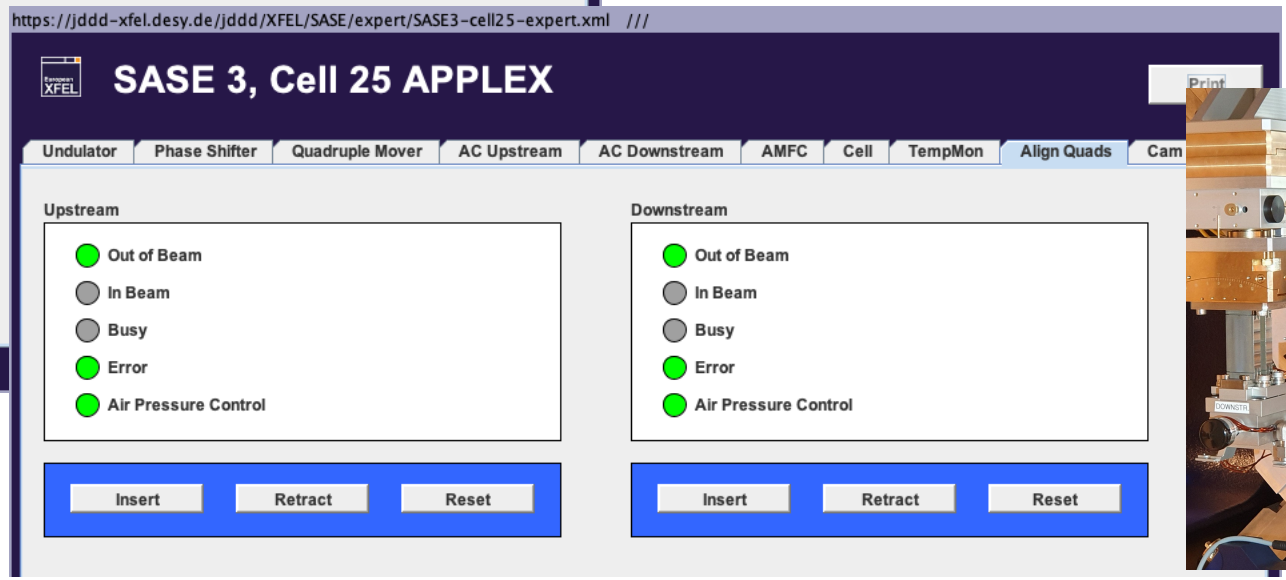


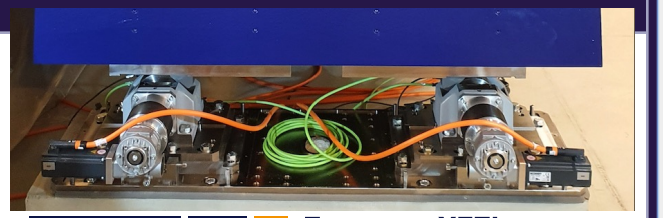


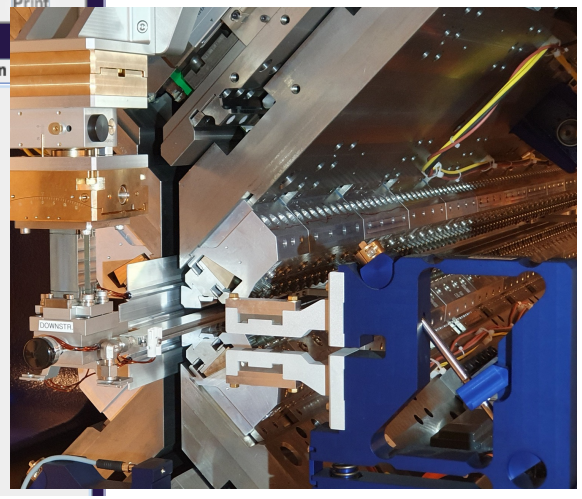
APPLE-X undulators control – New panels: Alignment Quadrupole, Cam Mover



- The purpose of the system is to adjust the magnetic axis of the undulator relative to the orbit of the e-beam.
  - Alignment quadrupoles only need to be inserted when aligning the undulator.
  - Operation of the cam movers is deactivated for global control to prevent possible damage to the vacuum system.

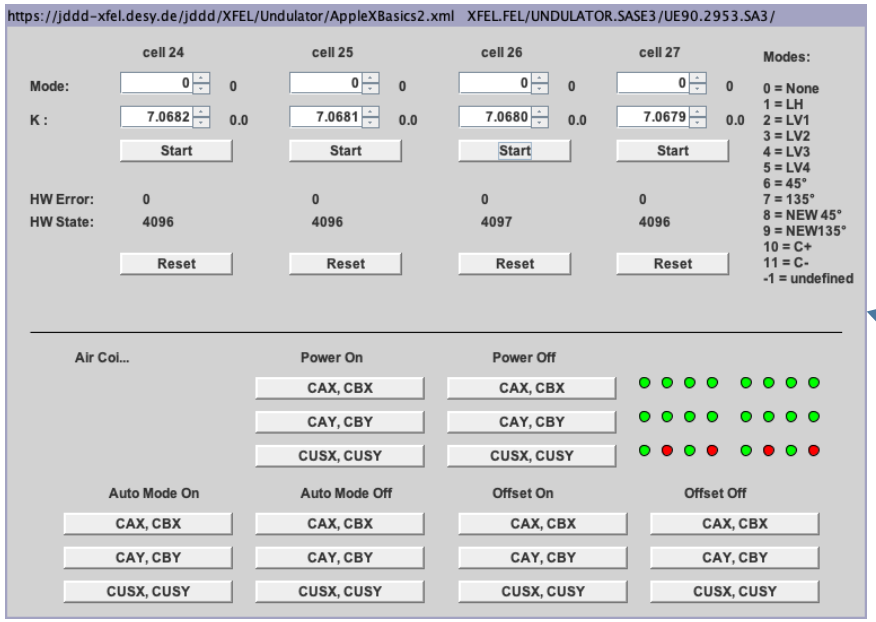


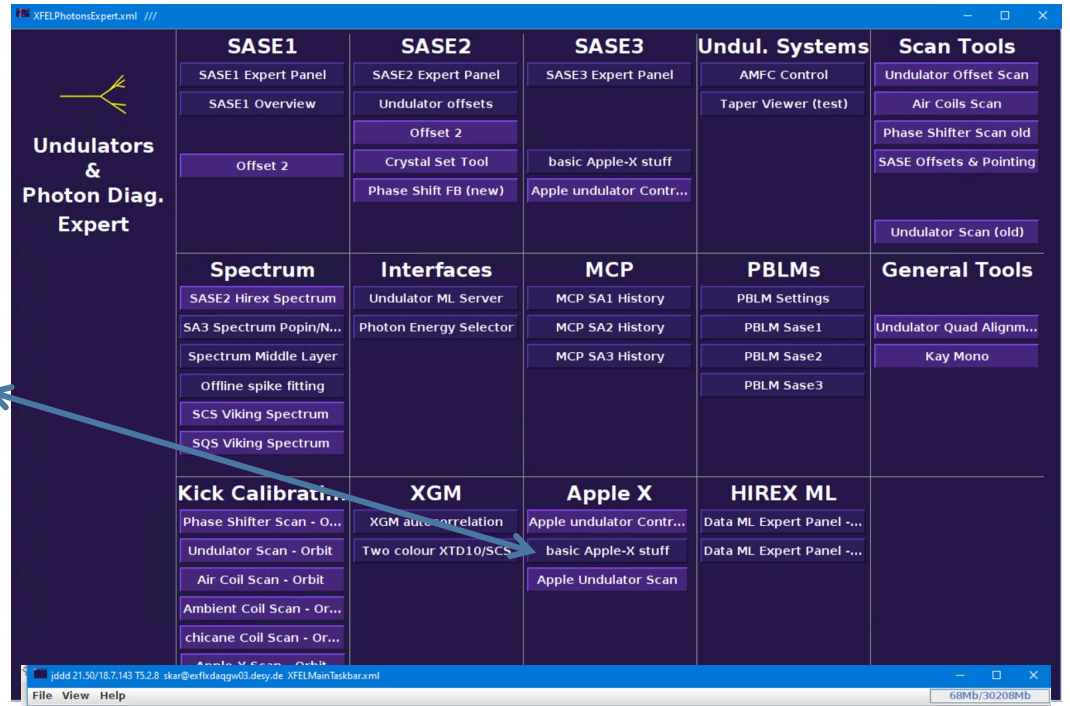


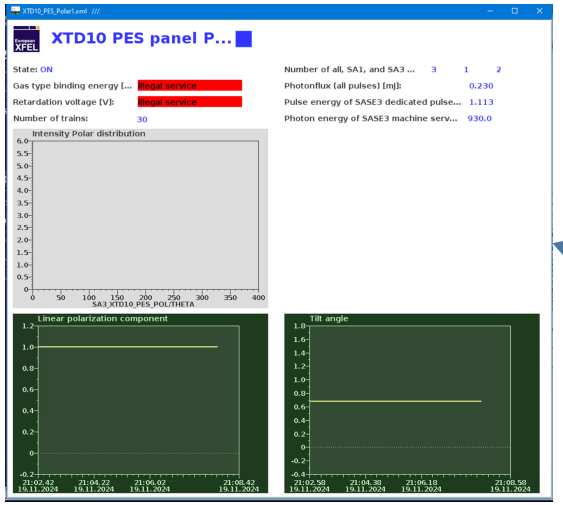


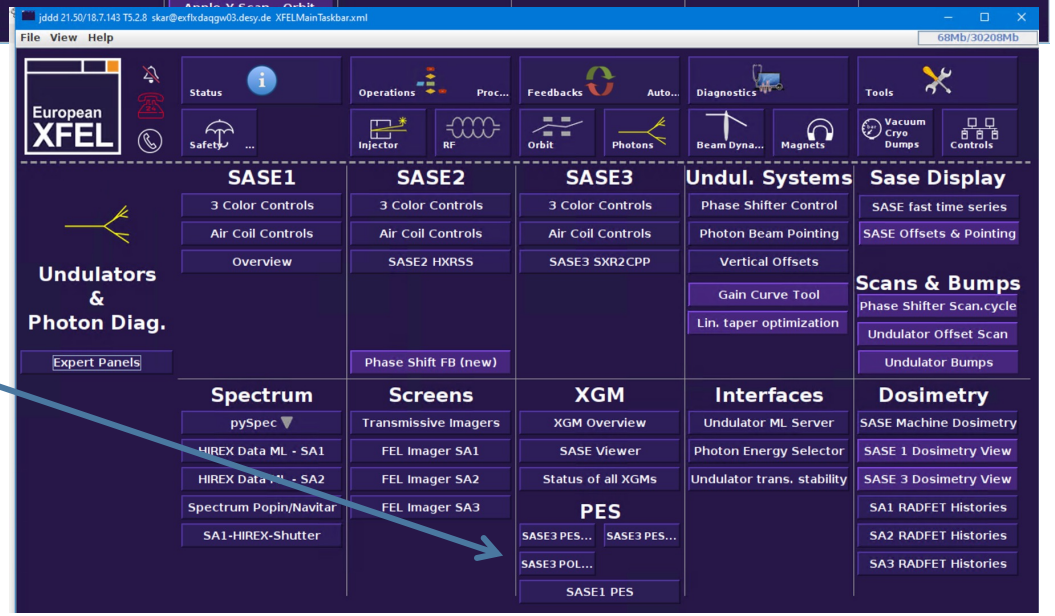
APPLE-X undulators – Useful panels

- Expert Panel - Basic Apple-X stuff
  - Correction coils control and status overview
- Photons panel– PES – SASE3 Pol.
  - Polarization online diagnostic









Thank you for your attention!