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Advanced polarization and energy control for APPLE-II type undulator beamlines at MAX-IV

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MODG008

Outline

1. MAX IV introduction
2. MAX IV APPLE-II
3. Polarization Setup
4. Control System
5. Results
6. Conclusion and future development

MAX IV Introduction

3 accelerators:

- 3 GeV injector Linac with SPF
- 1.5 GeV storage ring
- 3 GeV storage ring
- 4 diagnostic beamlines

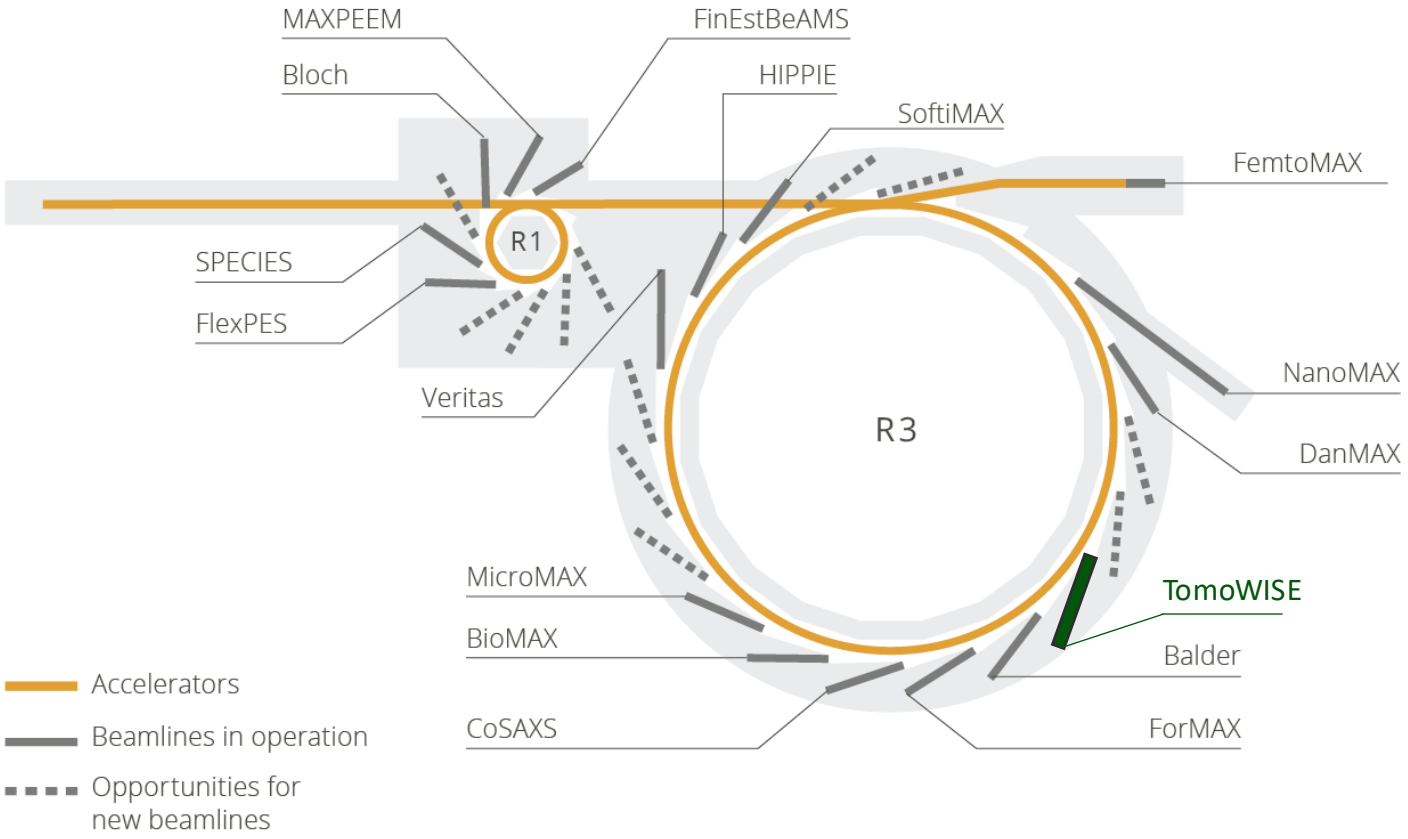
16 beamlines in operation:

- 24 branches
- 1 in construction – SinCrys at DanMAX

1 beamline in construction:

- TomoWISE – founded by WISE
- Full-field tomography, 20 to 65 keV
- >10^{12} ph/s and and 45 mm x 4.5 mm beam

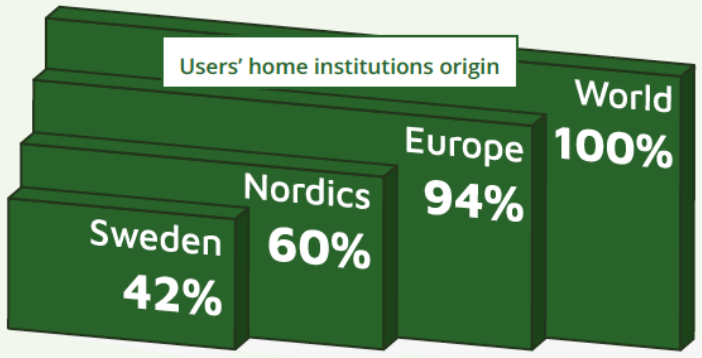
10 support labs and/or systems



2024 – the positive trend continues

USERS

1921 visiting users from **292** institutions across **35** countries



1 in 3 users is a female scientist

INDUSTRY

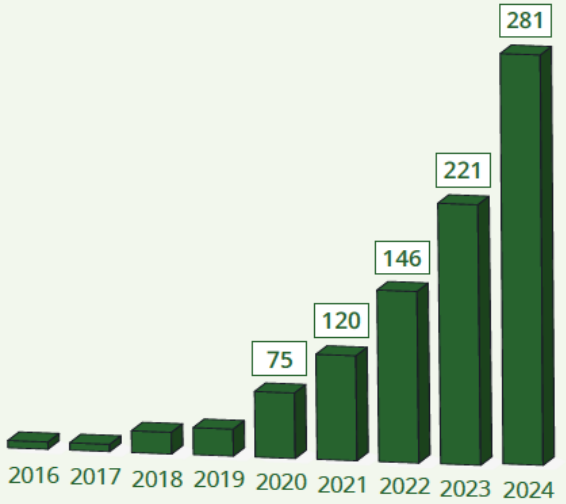
28 proprietary user groups including mediators

54% proprietary industry users from Sweden

4068 hours of beamtime for user scientific projects connected with industry

1143 hours paid proprietary beamtime

PUBLICATIONS



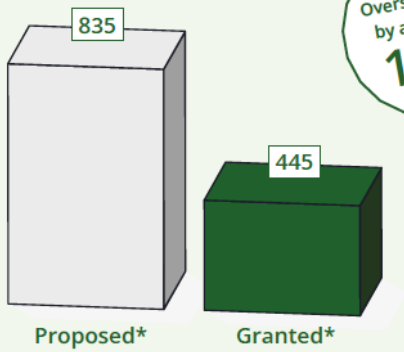
Publications per year*

*As of March 2025, correction rights reserved

+27% increase of publications compared to 2023

932 publications 2016–2024

USER SCIENTIFIC PROJECTS



Oversubscribed by a factor of **1,87**

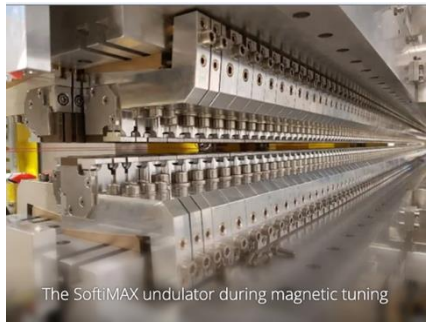
*2024 sum of Standard Access and BAG proposals, excluding Fast Access

43095 hours* of beamtime for user scientific projects

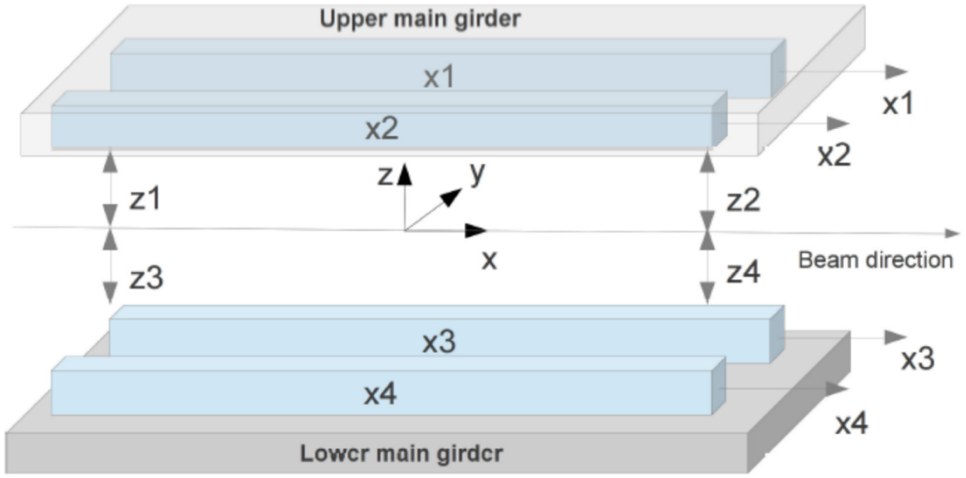
*Following the Swedish Research Council's definition of beamtime hours, based on cycles, including proprietary use.

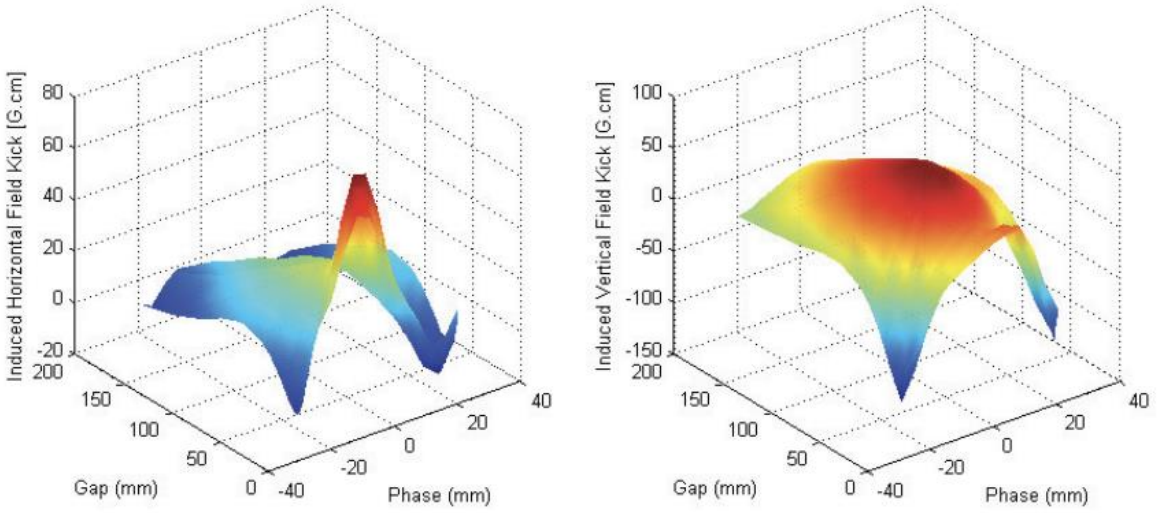
MAX IV APPLE-II

Beamline	ID Type	Period Length [mm]	Length [m]	K-eff value	Gap [mm]
Bloch	Q-APPLE II	84	2.6	8.65	14
FinEstBeAMS	APPLE II	95.2	2.6	10.4	14
SPECIES	APPLE II	61	2.6	4.85	16
MAXPEEM	APPLE II	58	2.6	4.89	14
HIPPIE	APPLE II	53	4	3.35	11
Veritas	APPLE II	48	4	3.35	11
SoftiMAX	APPLE II	48	4	3.35	11


The SoftiMAX undulator during magnetic tuning


The Quasi-APPLE II undulator for BLOCH beamline at the 1.5 GeV ring





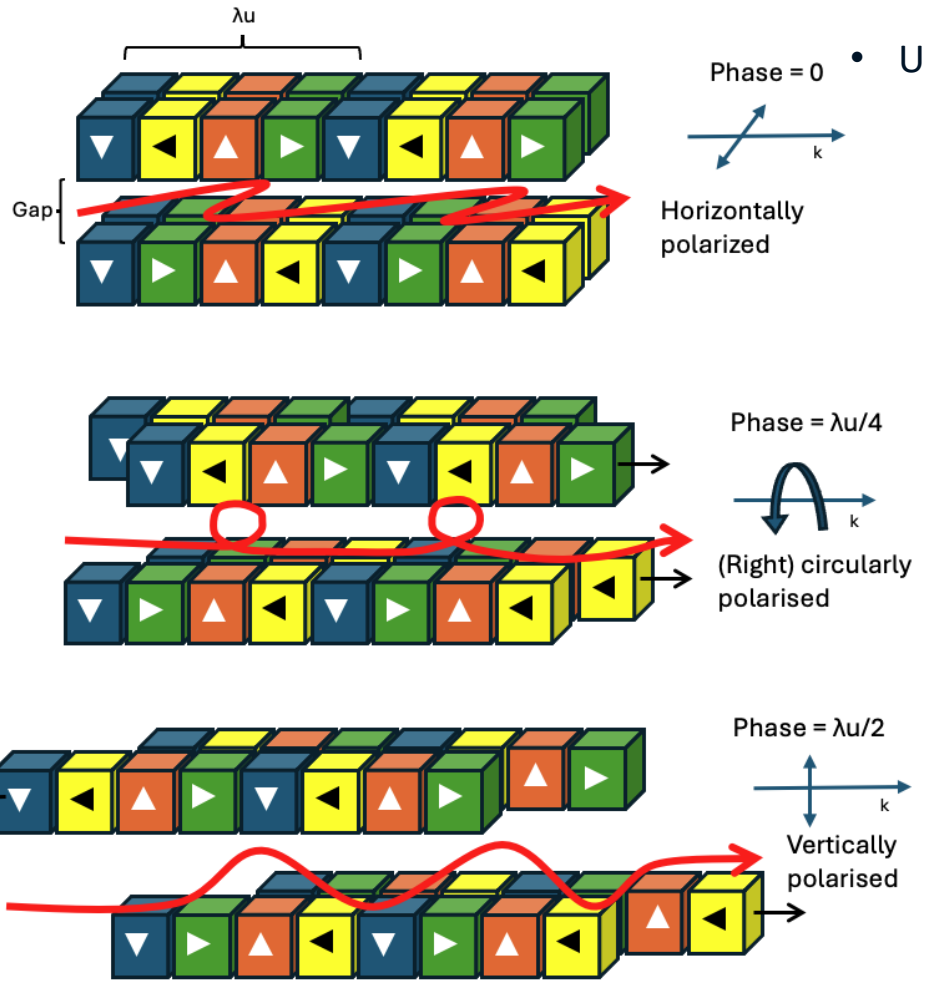
HIPPIE APPLE-II induced kick as function of gap and phase in helical mode

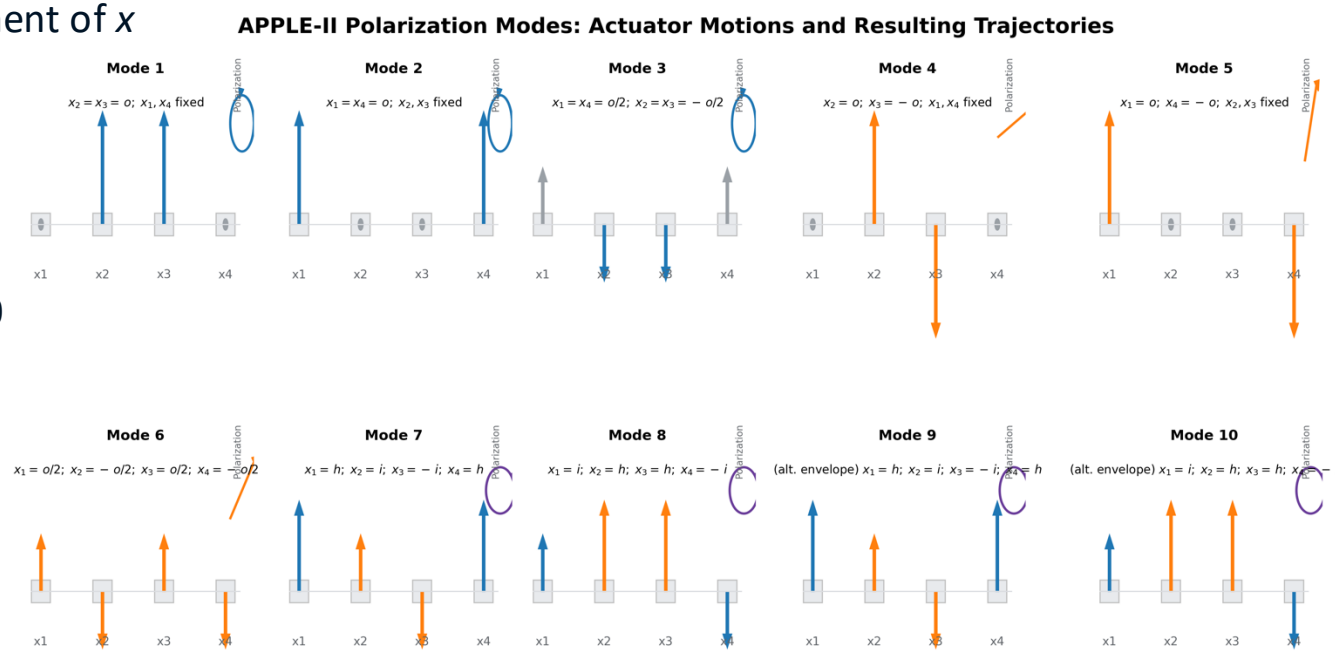
H. Tarawneh at al https://doi.org/10.1063/1.5084586

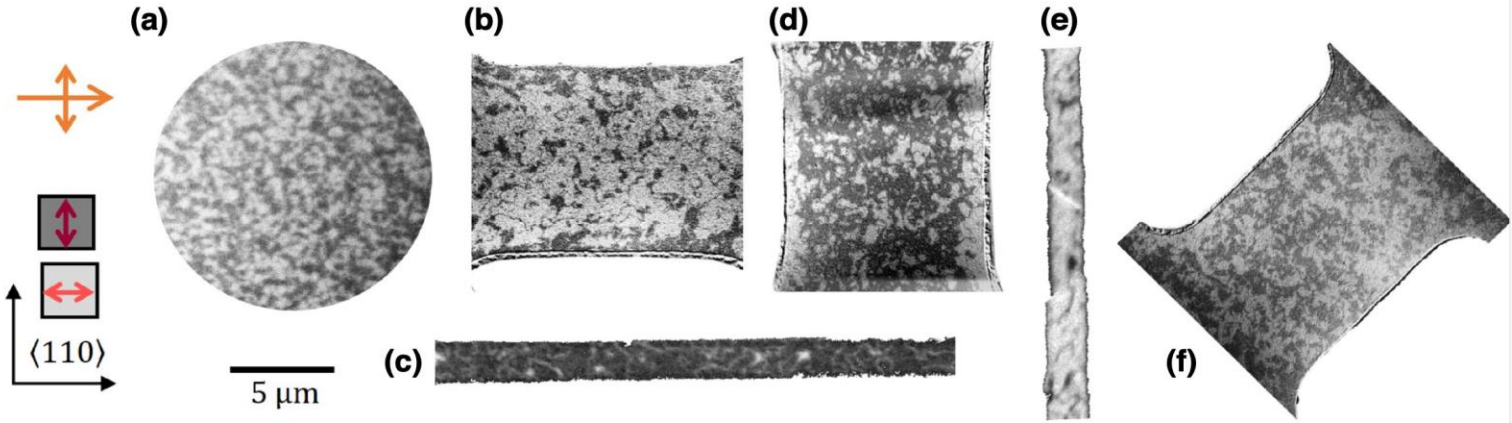
Polarization Setup

Modes: arrangement of *x* (phase motors):

- Helical: 1-3
- Inclined: 4-6
- Universal: 7-10







S. Reimers at al https://doi.org/10.1103/PhysRevApplied.21.064030

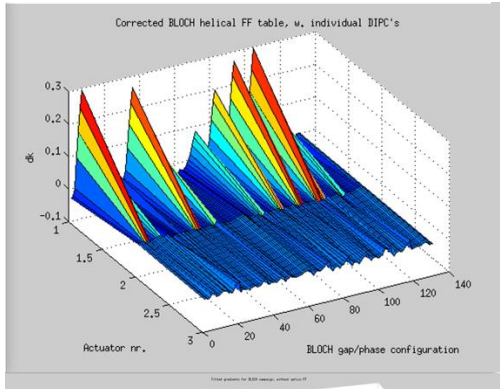
Control System

Z1
Z2
Z3
Z4
SERVO DRIVER
X1
X2
X3
X4
SERVO DRIVER
PLC encoders
PLC
IcePAP
Orbit
Corrector 1
Corrector 2
Corrector 3
Corrector 4
PS 1
PS 2
PS 3
PS 4
Accelerator Control System
PLC device
IcePAP Controller
GAP
Phase Helical
Phase Inclined
TAPER
Trajectory
Power Supply device
Feedforward Loop
Beamline Control System
Parameters
ID Energy
Harmonic
Mode
Polarization
Trajectory
Range
Velocity
Power supplies
Optics

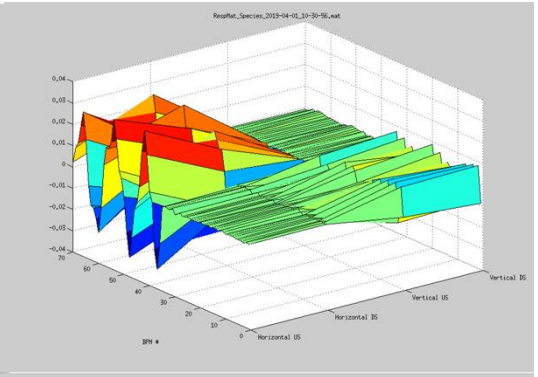
Control System - Correction

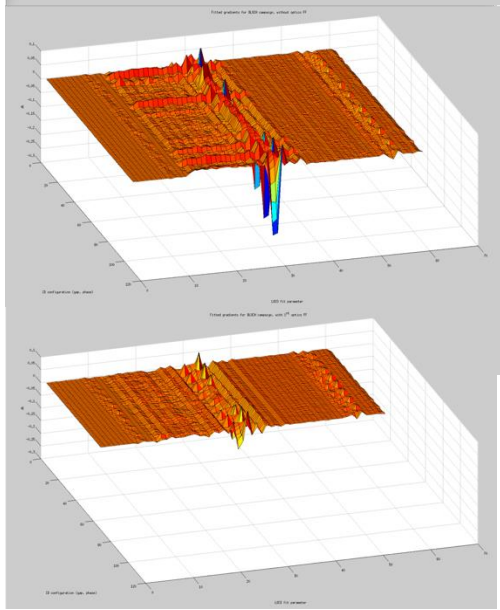
Multi-dimensional Feedfoward controller in Tango 10Hz for optics and orbit compensation.

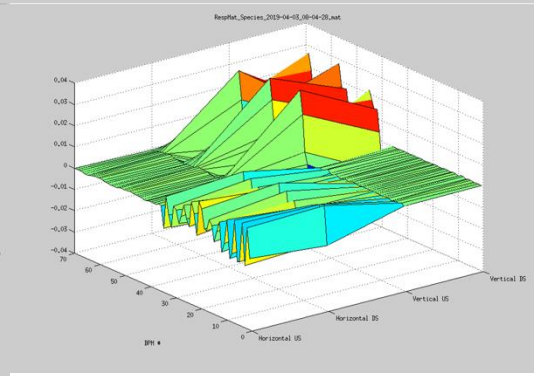
Optics BLOCH APPLE-II:



Orbit SPECIES APPLE-II:



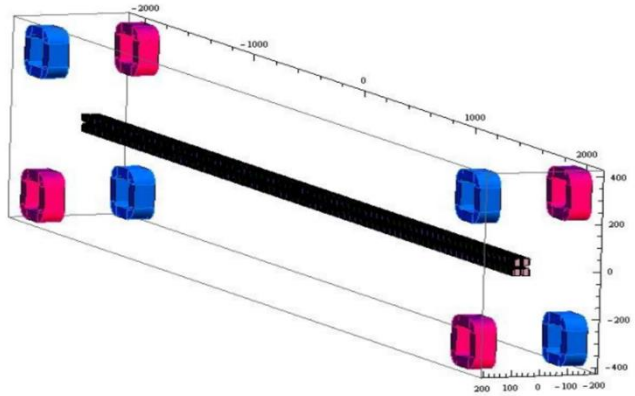




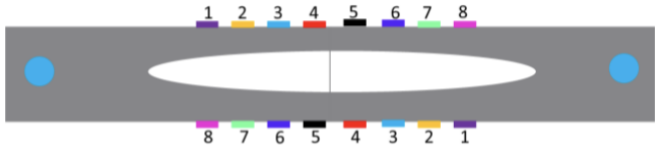
C. Takahashi at al

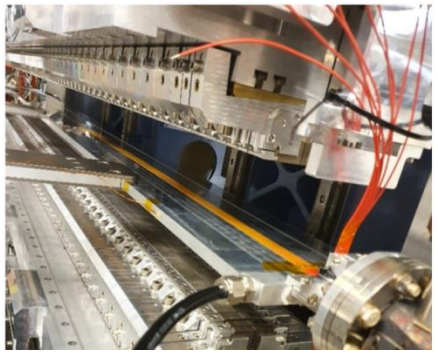
doi.org/10.18429/JACoW-IBIC2022-TUP41

Orbit correctors:



Optics correctors:





ML approach underway for replacing FF

C. Takahashi at al to appear in [IPAC'25 proceedings]

For trajectory control details see:

Advancing position-based continuous energy scans at MAX IV: expanded beamline coverage and enhanced control integration

THAG006
25 Sept 2025, 10:15
15m
Grand Ballroom (Palmer House Hilton Chicago)

Contributed Oral Prese...
MC09: Experiment C...
THAG MC09 Experime...

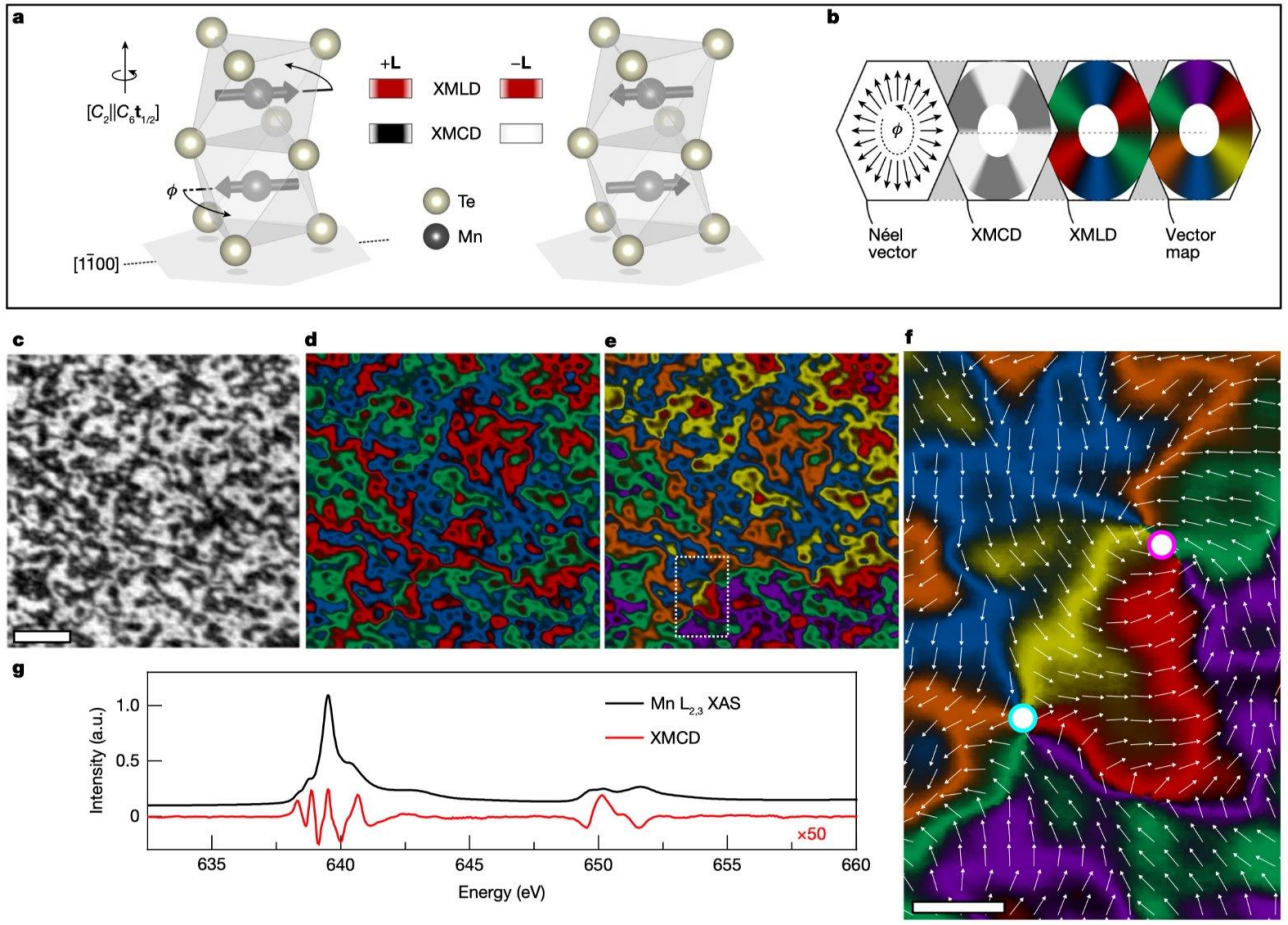
Speaker

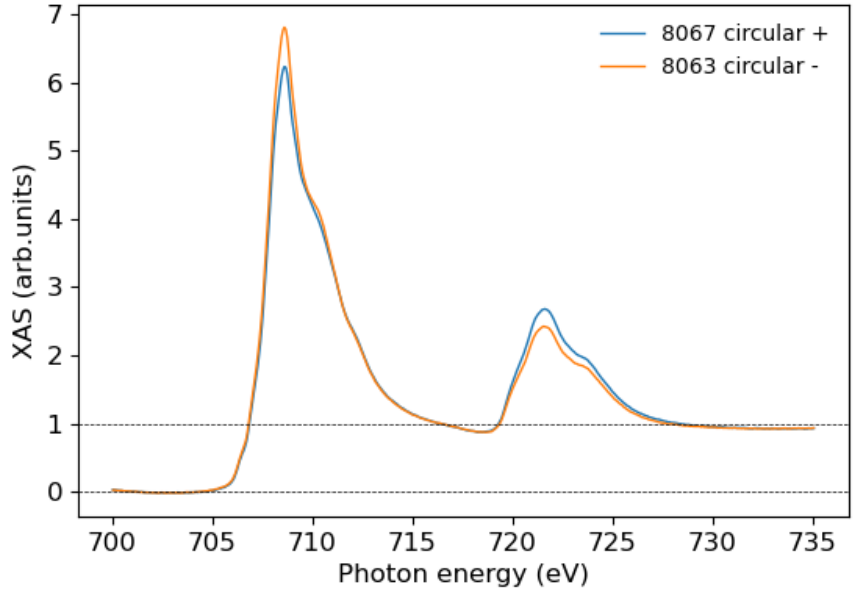
Lin Zhu (MAX IV Laboratory)

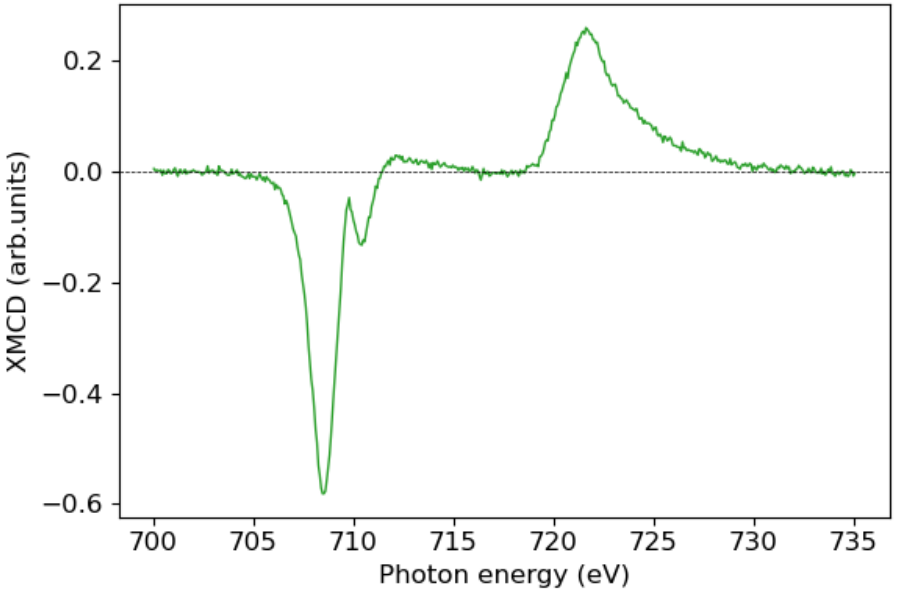
Recent commissioned circular polarization control at HIPPIE:

Results

XMCD PEEM at MAXPEEM:







O. J. Amin at al [doi.org/10.1038/s41586-024-08234-x](doi.org/10.1038/s41586-024-08234-x)

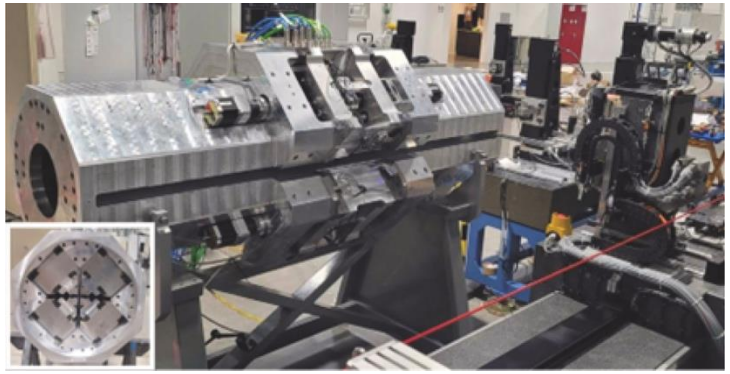
Conclusion and future development

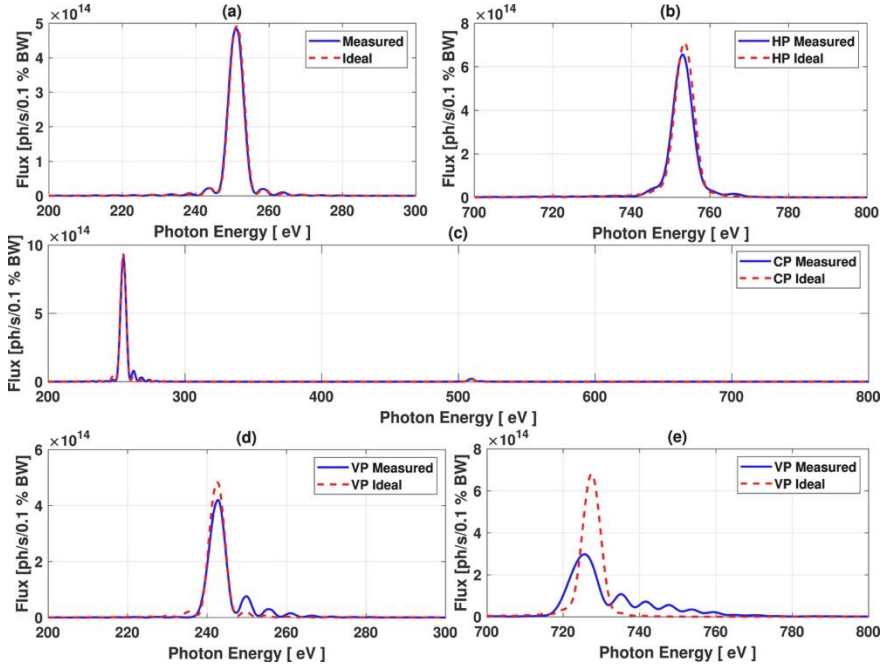
Apply same Control System for the in-house developed APPLE X

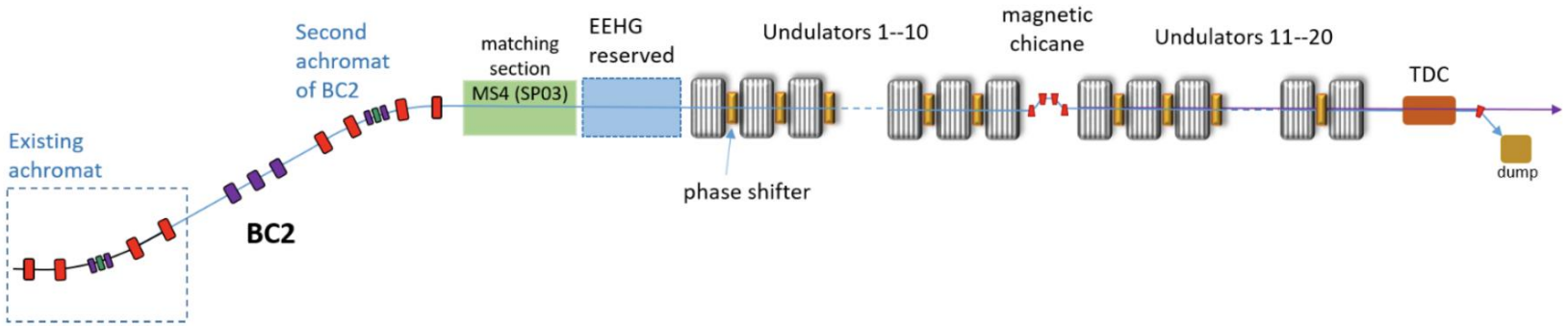
Possible installation at MAX IV SXL and/or

3 GeV storage ring

Parameter	Value
Magnet material	SmCo
Period length	40 mm
Number of periods	48
Number of full poles	96 Hor. + 97 Vert.
Magnetic gap range	7 mm–26 mm
Design effective K-range	3.885–1.508
Achieved max. K_{eff} (HP/CP/VP modes)	3.87/4.01/4.14 @ 7.6 mm 3.70/3.84/3.95 @ 8 mm







F. Curbis at al [The Soft X-ray Laser @ MAX IV : Conceptual Design Report]

H. Tarawneh at al [doi.org/10.1016/j.nima.2024.170162]

Thank you!

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