Overview of tenders in the area of SCU development from European XFEL

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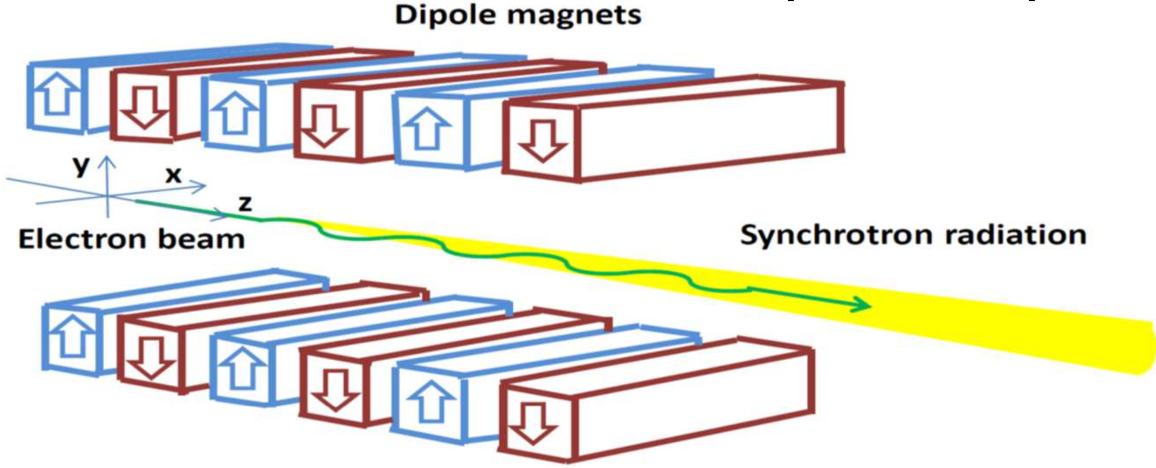
Outline

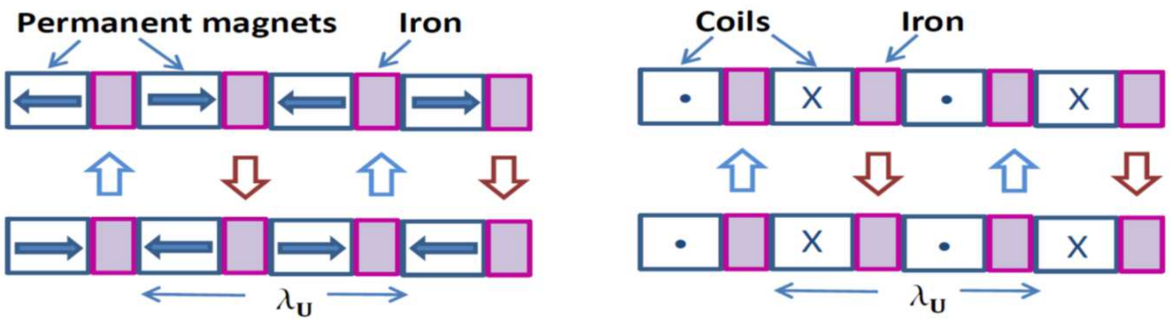
- Introduction
- EuXFEL undulator lines
  - Undulators
  - Intersections
- SCU developments

Introduction

- **Undulators are periodic structures made by sequences of dipole magnets and are used in synchrotron light sources and in free electron lasers to increase the photon flux produced in a narrow cone**



Permanent magnet undulator



Electromagnetic or Superconducting undulator

S. Casalbuoni, Supercond. Sci. Technol. 32 (2019) 023001

Introduction

- To increase the photon beam energy with the same electron beam energy it is necessary to reduce the period length λ_U ➡ short period undulators

$$\lambda = \frac{\lambda_U}{2\,n\,\gamma^2}\left(1 + \frac{K^2}{2} + \gamma^2\theta^2\right) \qquad K = \frac{e}{2\pi mc} B_0\,\lambda_U = 0.9336\, B_0[T]\,\lambda_U[cm]$$

- To increase the tunability range of the photon energy

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Developments to increase B_{max}

Permanent magnet undulator

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IVU= in-vacuum undulator

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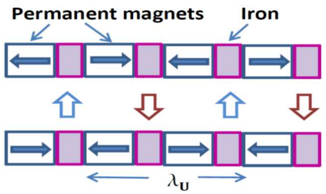
CPMU= cryogenic permanent magnet undulator



alternative technology to increase B_{max} further

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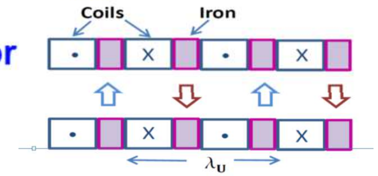
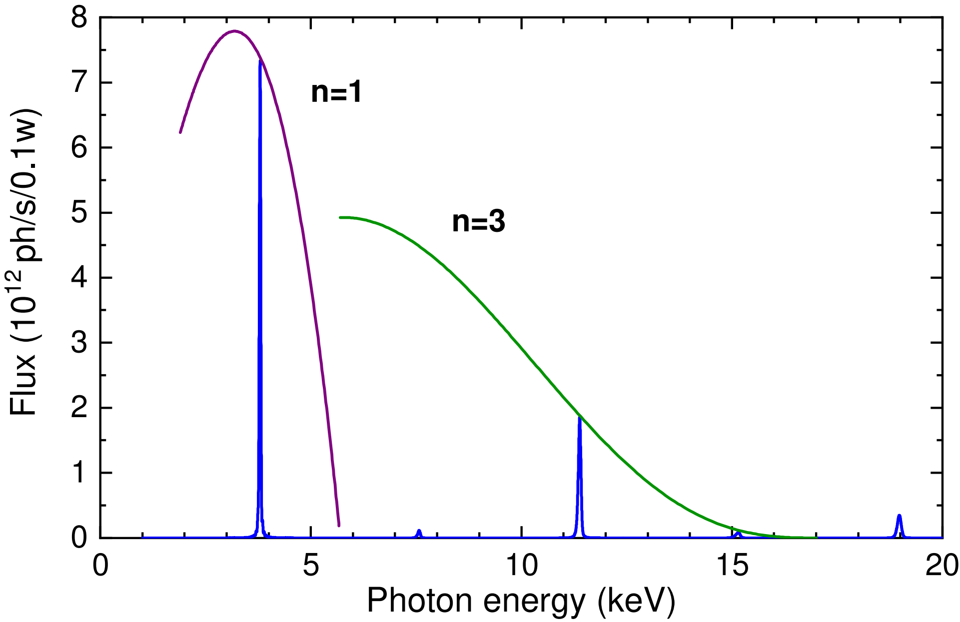
SCU=superconducting undulator





The position of the harmonics is shifted by changing the on axis peak magnetic field B_0

Introduction

- In a storage ring undulators are tipically 1-5 m long

- In FELs the total length required is much longer: about 100 m.

The dimension of the single units is similar as in storage rings: at European XFEL undulator length is 5 m.

There are mainly 3 reasons:

  - Easier to handle: manage support structures to keep the forces and magnetic field measurement setups
  - Space between undulators is needed for quadrupoles to periodically focus of the electron beam, keeping its dimensions small enough for the FEL process to occur
  - Space between undulators is also used to place electron beam diagnostics

Hybrid permanent magnet undulators at European XFEL

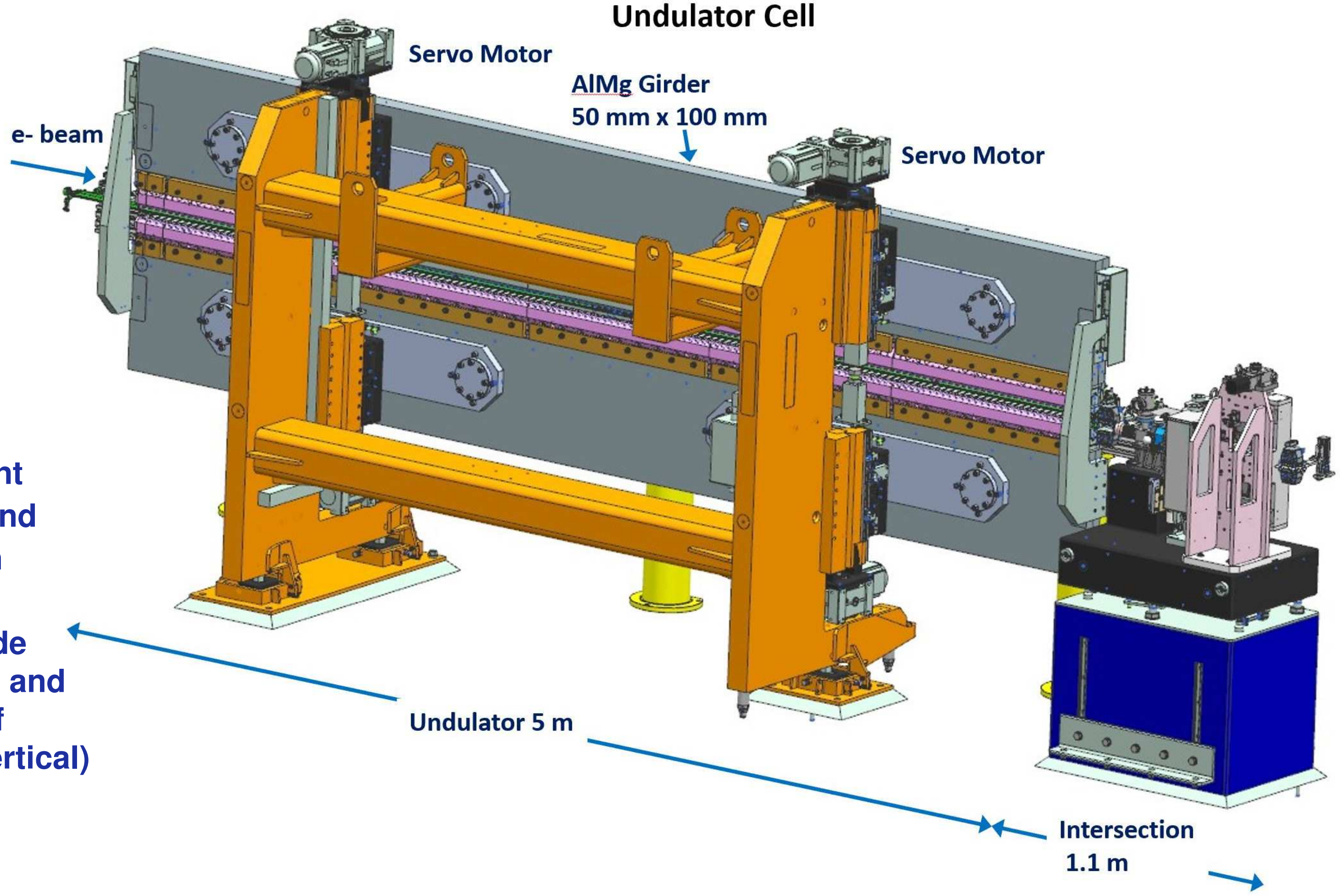
Table 1
Specifications for the undulator segments of the EuXFEL.

The operational ranges for gap and K parameter match user requirements (Altarelli *et al.*, 2006). Only inside are all specifications strictly fulfilled. Magnetic tuning was always performed at the tuning gap to limit gap dependence of magnetic properties, see discussion of Fig. 4.

	SASE1 / SASE2	SASE3
Undulator type	U40	U68
Period length (mm)	40	68
Segment length (m)	5	5
Total number of poles	248	146
Magnetically active poles	246	144
Number of ending poles	3	3
Operational gap range (mm)	10–20	10–25
Operational K-parameter range	1.65–3.9	4–9
Maximum peak field @ 10 mm (T)	1.11	1.66
Tuning gap (mm)	14	16
Maximum gap (mm)	200	200
Maximum phase jitter (°)	≤8	≤8
Maximum 1st B_y field integral (T mm)	±0.15	±0.15
Maximum 1st B_x field integral (T mm)	±0.15	±0.15
RMS of 2nd B_y integral (T mm^2)	<100	<210
RMS of 2nd B_x integral (T mm^2)	<100	<100
Radiation wavelength range (nm)	0.05–0.4	0.4–5.2
Number of segments in system	35	21
System length (m)	205	121

S. Abeghyan et al., J. Synchrotron Rad. (2019). 26, 302–310

Typical undulator cell at European XFEL



European XFEL planar undulators for SASE1/2/3 are hybrid permanent magnet undulators using NdFeB and soft iron poles made of cobalt iron

The beam vacuum chamber is made of extruded aluminum-magnesium and has an elliptical beam stay clear of 15 mm (horizontal) and 8.6 mm (vertical)

Intersection at European XFEL

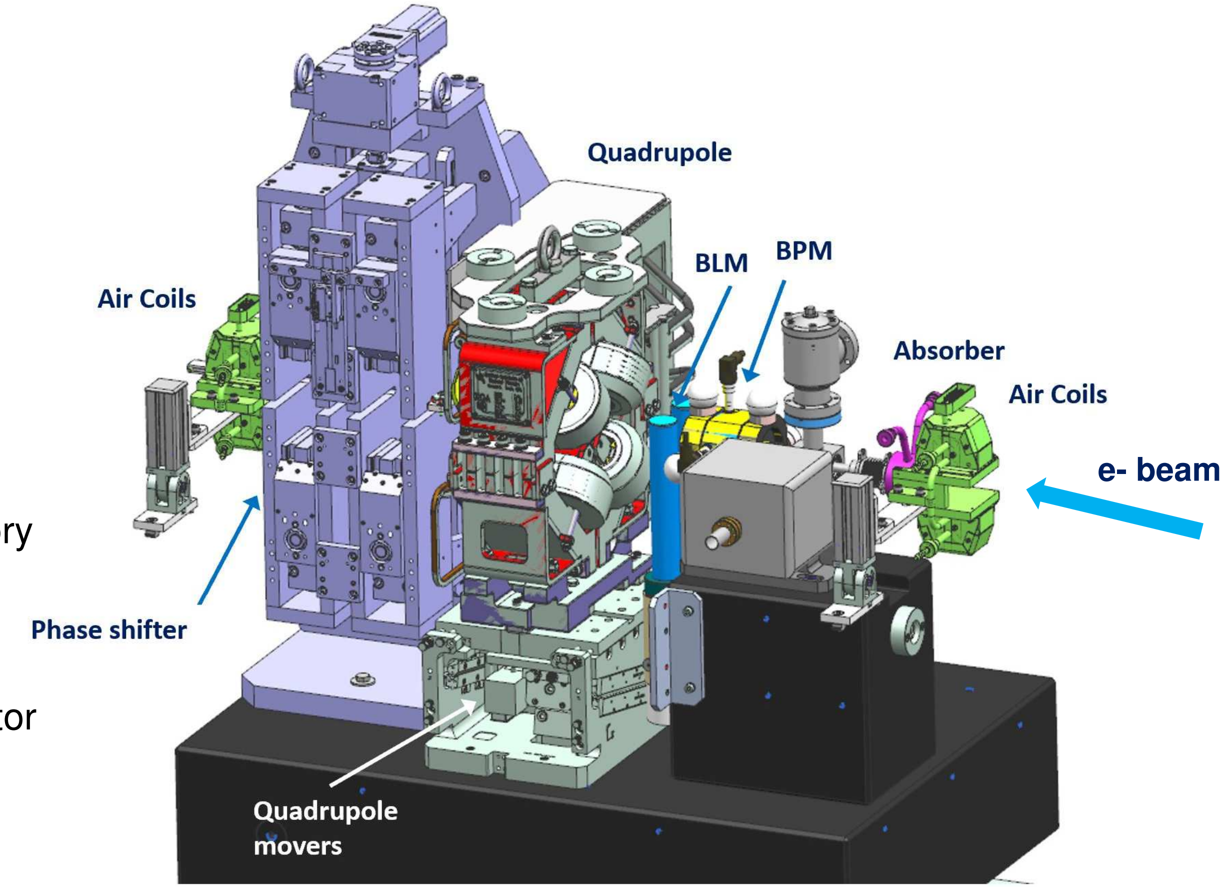
- Air coils: compensate vertical and horizontal field integrals to specified values

- BPM: cavity based BPM with sub-µm resolution

- Quadrupoles: periodically focus the electron beam, keeping its dimensions small enough for the FEL process to occur. The quadrupoles can be steered (quadrupole movers) vertically and horizontally by ±1.5 mm with an accuracy of ±1 µm
BPMs + quadrupoles: BBA to define a straight trajectory within the electron beam dimensions of about 30 µm along the undulator line of about 200 m

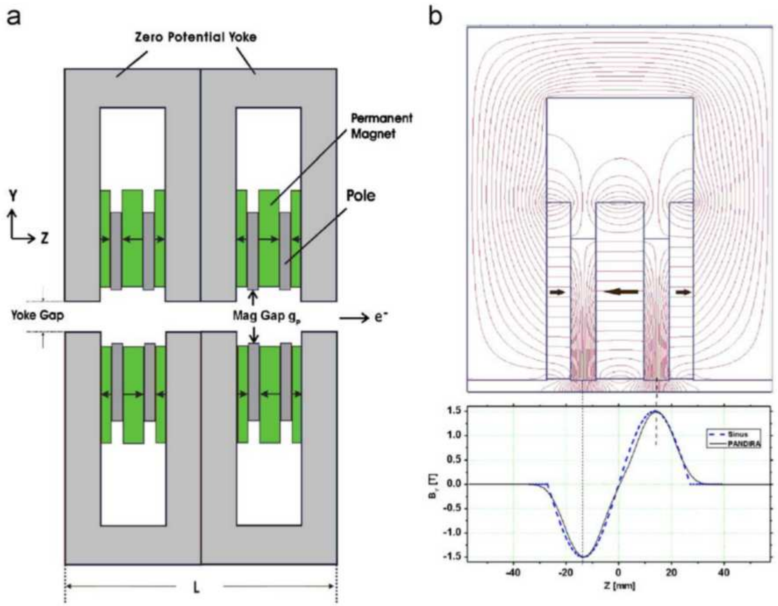
- BLM: to reduce the radioactivation of the accelerator components

- Absorber: protect downstream undulators from synchrotron radiation of upstream ones



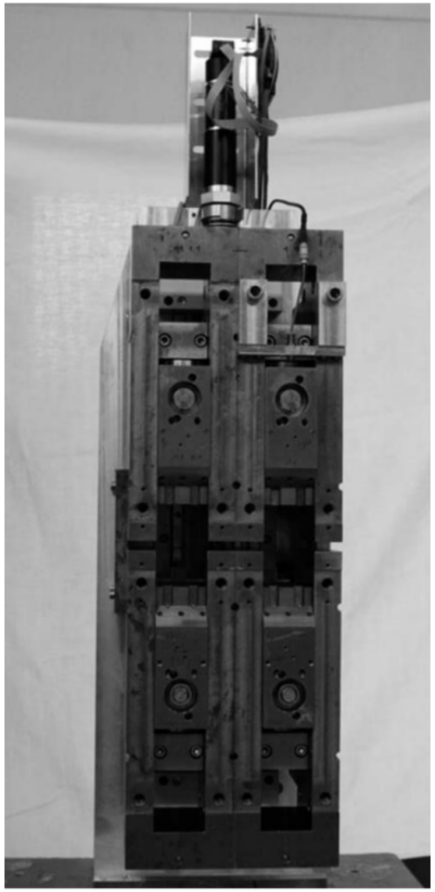
Phase shifter

The phase shifter must compensate the phase advance of the emitted photons with respect to the electrons in the intersection of length L_S at all undulator K values.



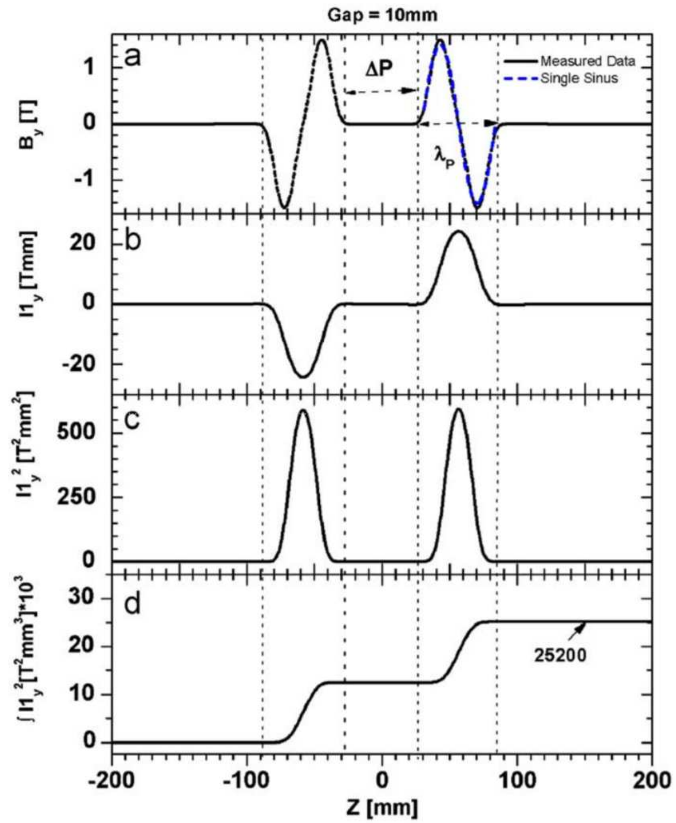
H. H. Lu, Y. Li, J. Pflueger, NIMA 605 (2009) 399–408

magnets NdFeB
poles iron cobalt

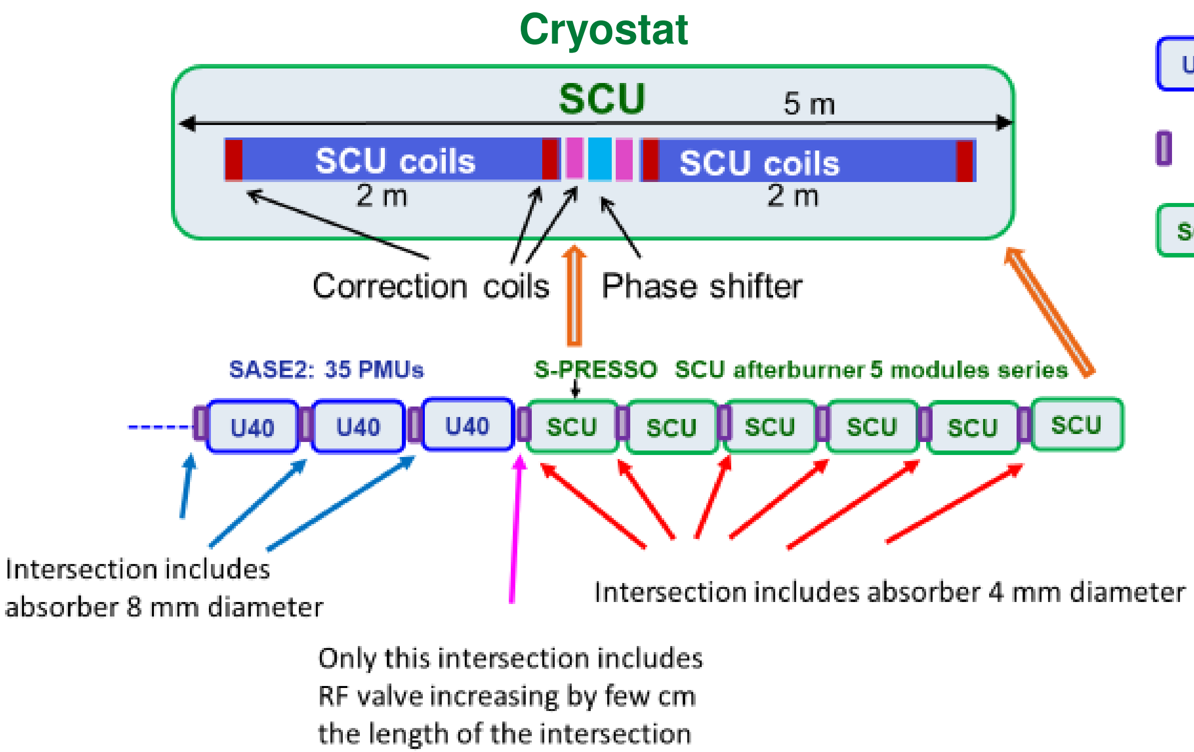


Phase shifter of European XFEL

Measured values



SCU afterburner planned at EuXFEL

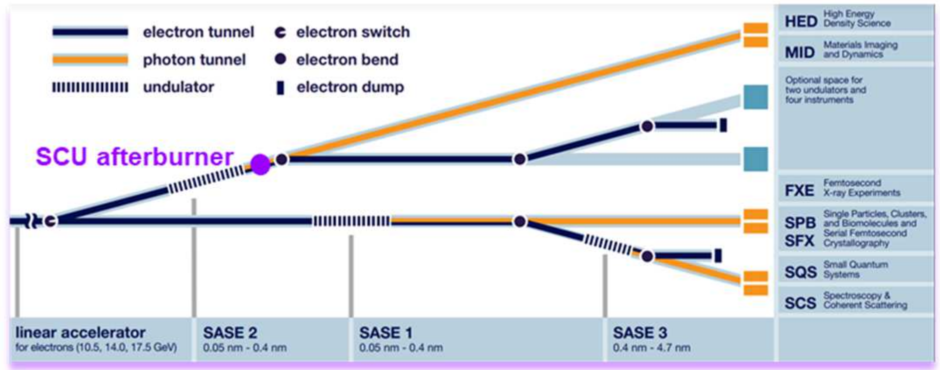


S-PRESSO: **S**uperconducting undulator **PRE-S**erie**S** m**O**dule to be produced before the five modules of the SCU afterburner.
Specified and contract assigned to Noell GmbH

U40 5 m

Intersection 1.1 m
same between PMUs and SCUs

SCU 5 m



The cooling scheme of S-PRESSO and of the afterburner modules will be based on **cryocoolers** as from the KIT/Noell design

S. Casalbuoni et al., SRI2021

Components for SCU afterburner at EuXFEL

- Part of the SCU module:
  - Cryocoolers
  - Power supplies
    - ► Correctors and phase shifter: ±10 A, 10 V
    - ► Main coils: 400-1000 A, 10-20 V

    as small as possible to fit in the tunnel
  - Vacuum pumps
  - CAM movers

- Elements for intersections:
  - Quadrupoles
  - Quadrupole movers
  - Air coils (correctors)
  - Granite stone, alignment mechanism
  - Absorbers
  - BPMs
  - BLMs
  - Phase shifters
  - RF bellows
  - RF valve

Thank you for your attention!