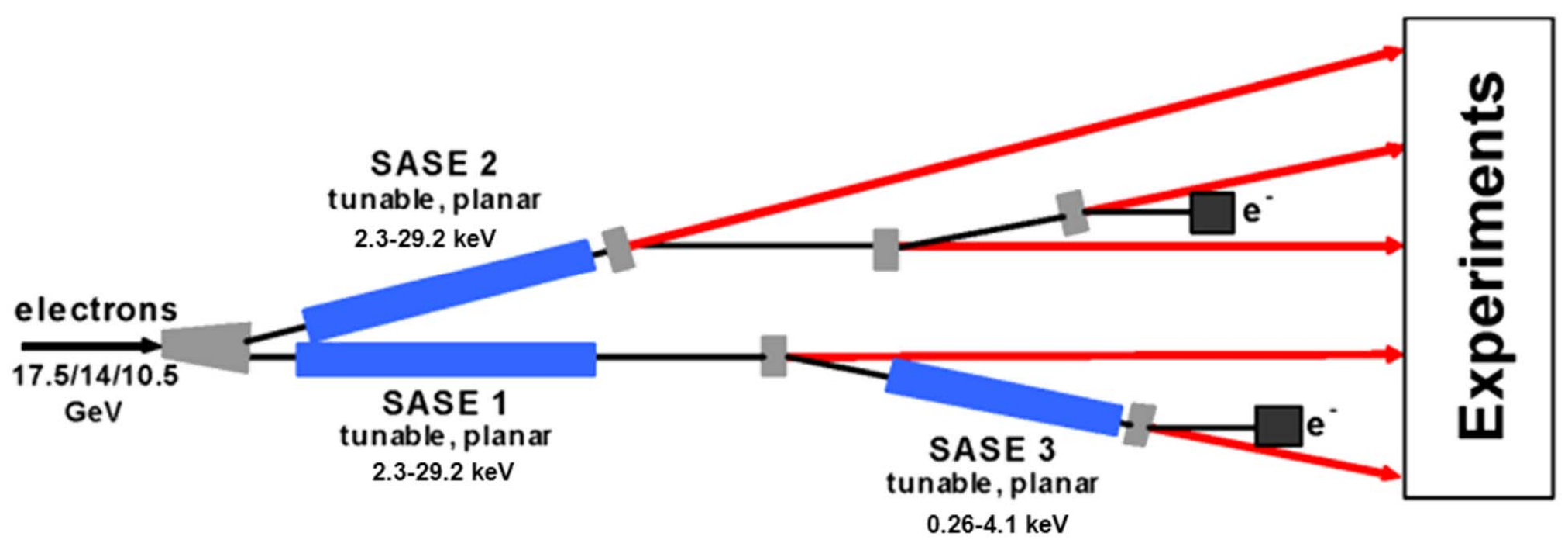
European XFEL

THE UNDULATOR CONTROL SYSTEM FOR THE EUROPEAN XFEL

S. Karabekyan, A. Beckmann, J. Pflüger — European XFEL GmbH, Hamburg, Germany
N. Burandt, J. Kuhn — Beckhoff Automation GmbH, Verl, Germany
A. Schöps — DESY, Hamburg, Germany

The European XFEL project is a 4th generation light source. The first beam will be delivered in the beginning of 2015 and will produce spatially coherent ≤80fs short photon pulses with a peak brilliance of 10^{32}-10^{34} photons/s/mm^2/mrad^2/0.1% BW in the energy range from 0.26 to 29.2 keV at electron beam energies 10.5 GeV, 14 GeV or 17.5 GeV. At the project start-up stage three undulator systems SASE1, SASE2 and SASE3 will be used to produce photon beams. The electron bunch train is distributed into two branches by a flattop kicker magnet into SASE1 and SASE2 beam lines, where hard X-ray beams are generated. After passing through SASE1 the electron bunches are used a second time by passing through the SASE3 undulator system to create additional soft X-ray beam. Each undulator system consists of an array of undulator cells installed in a row along the electron beam.



Photon Beamline	Electron energy GeV	Photon energy keV	Wavelength Å	Undulator Gap mm	Magnetic period mm	Quantity of Undulators
SASE 1	10.5	2.3 – 14.9	5.4 – 0.83	10 – 24		
&	14	4.1 – 18.7	3.0 – 0.66	10 – 20	40	35
SASE 2	17.5	6.4 – 29.2	1.9 – 0.43	10 – 20		
	10.5	0.26 – 2.2	47.7 – 5.6	10 – 28		
SASE 3	14	0.47 – 2.6	26.6 – 4.8	10 – 24	68	21
	17.5	0.73 – 4.1	16.9 – 3.0	10 – 24		
						Total: 91

Requirements to the undulator control system

- Undulator gap control accuracy ±1 μm.
- Quadrupole mover positioning repeatability ±1 μm.
- Phase shifter gap control accuracy ± 10 μm.
- Maximal steering power for air coil correctors ±0.6 Tmm.
- Compensation of an ambient magnetic field of up to 150μT.
- Temperature measurement accuracy ± 0.03 K.

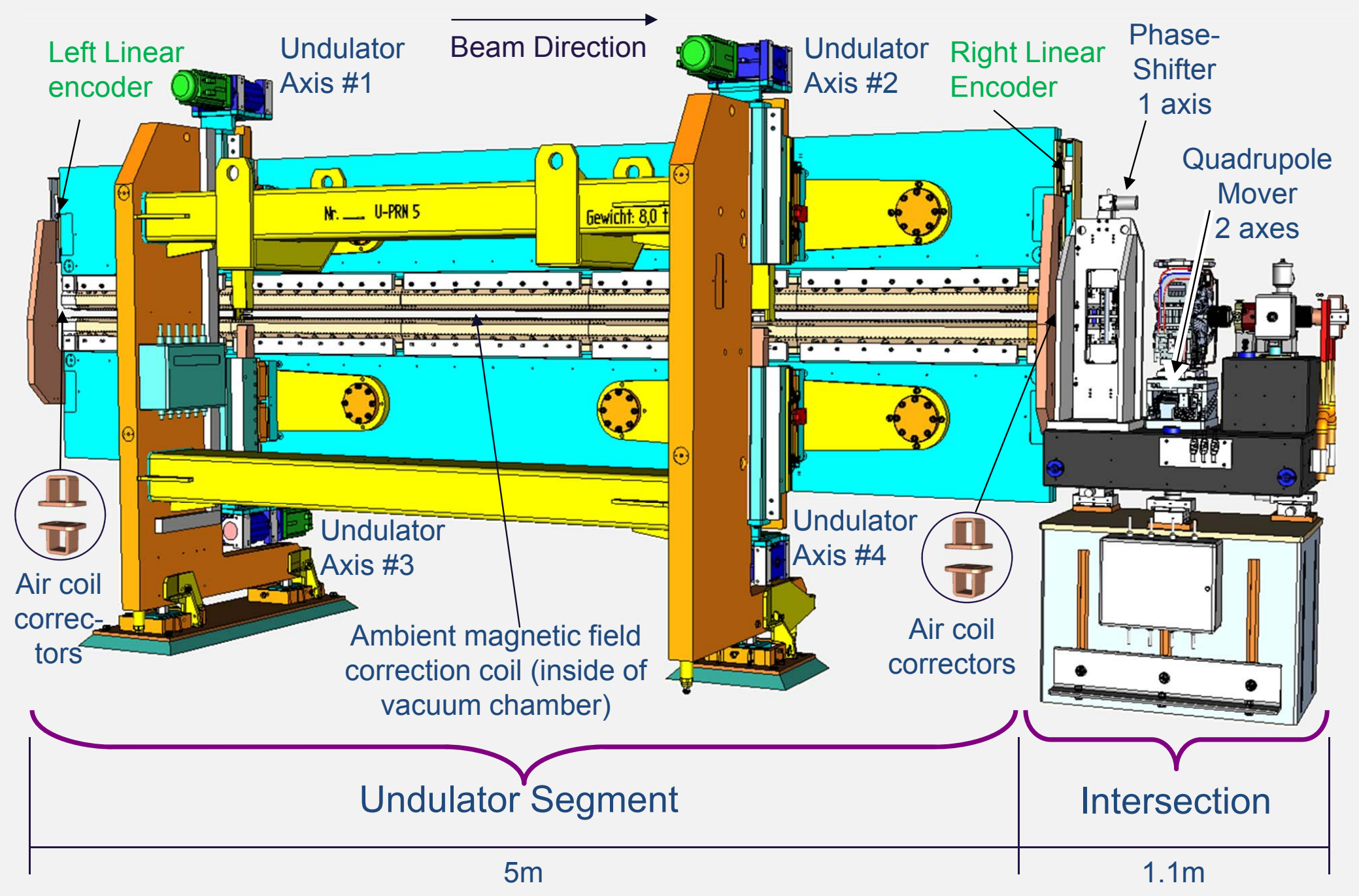
Objectives

Global Control System

- Highly reliable control of the whole undulator systems.
- Integration of the undulator system control into the accelerator or experiment control.
- Synchronous movement of all undulator cells inside of one undulator system.
- Possibility of the movement-synchronization with external devices.
- Different operational modes with complex movement-schemes (e.g. tapering of an undulator system, operation of a single or several undulator cells which could be necessary for diagnostic and maintenance).
- Flexibility for implementing additional controlled elements, e.g. a self-seeding mode.
- Handling of the slow control tasks (e.g. temperature monitoring, remote rebooting, handling the messages from firefighting system).
- Reliable error tracing and diagnostics.
- Simple and intuitive user interface.movement limitation, failure detection.

Local Control System

- Gap control with low following error between master and slave axes (<±10μm) in the full operational range (10mm÷220mm).
- Local temperature measurement and appropriate undulator gap correction.
- Undulator gap dependent air coil correction.
- Undulator gap dependent phase shifter control.
- Motion control for quadrupole movers.
- 3 way mixing valve control for the beam pipe temperature stability.
- Ambient magnetic field correction.
- Safe operation, damage prevention, proper and precise movement limitation, failure detection.



Control components of an undulator cell

Local Control of Undulator Cell

An undulator cell consists of a 5m long undulator segment and a 1.1m long intersection. Four servo motors are used on each undulator to control the gap between girders. One stepper motor is used for phase shifter control, and two other stepper motors control the position of the quadrupole magnet. The current of magnetic field correction coils as well as the gap of the phase shifter are adjustable as a function of the undulator gap. The control of the vacuum chamber temperature as well as correction of the ambient magnetic field is also in the scope of the local control system.

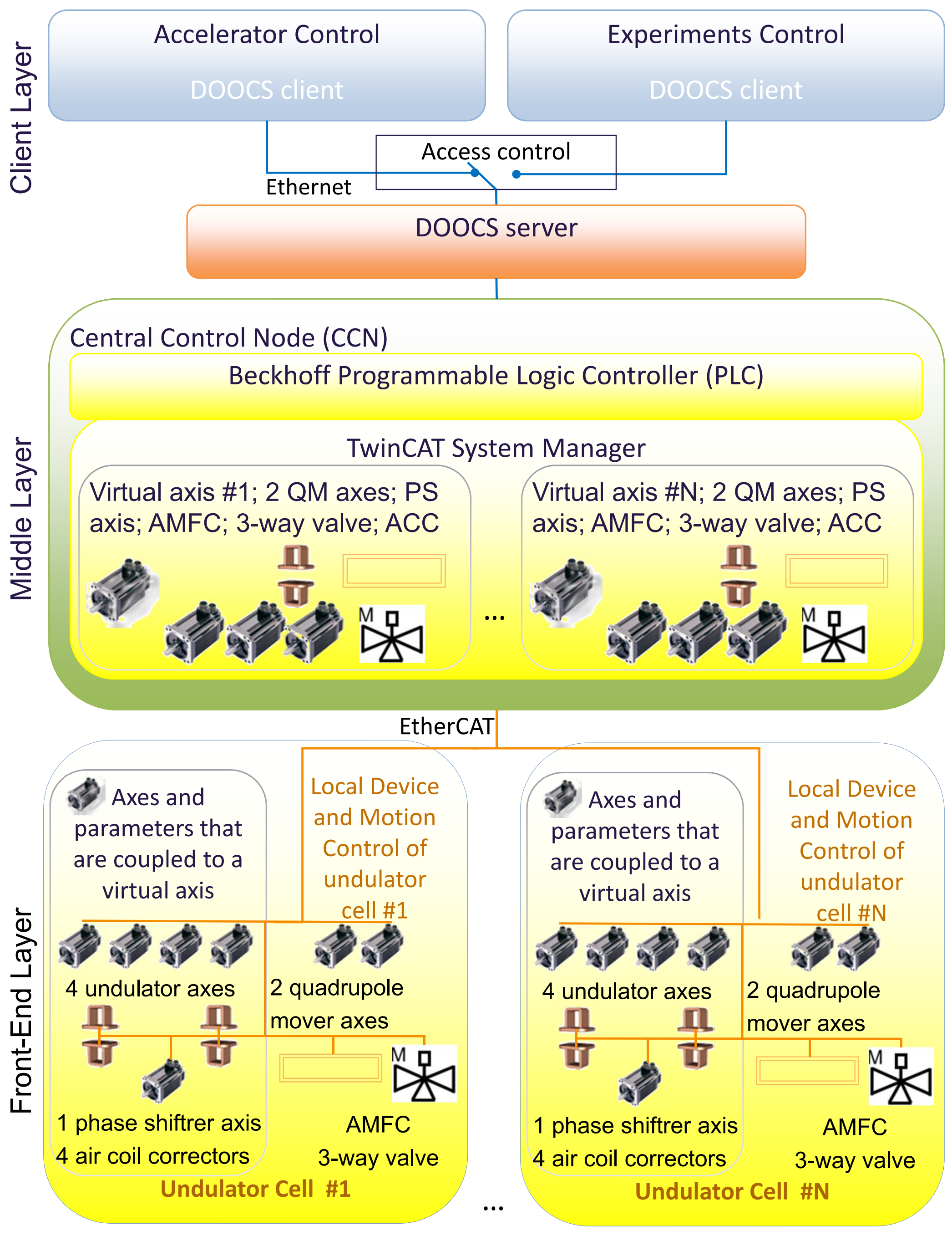
The local control system is based on industrial components produced by Beckhoff Automation GmbH and a Programmable Logic Controller (PLC) implemented in the TwinCAT system.

Global Control of Undulator System

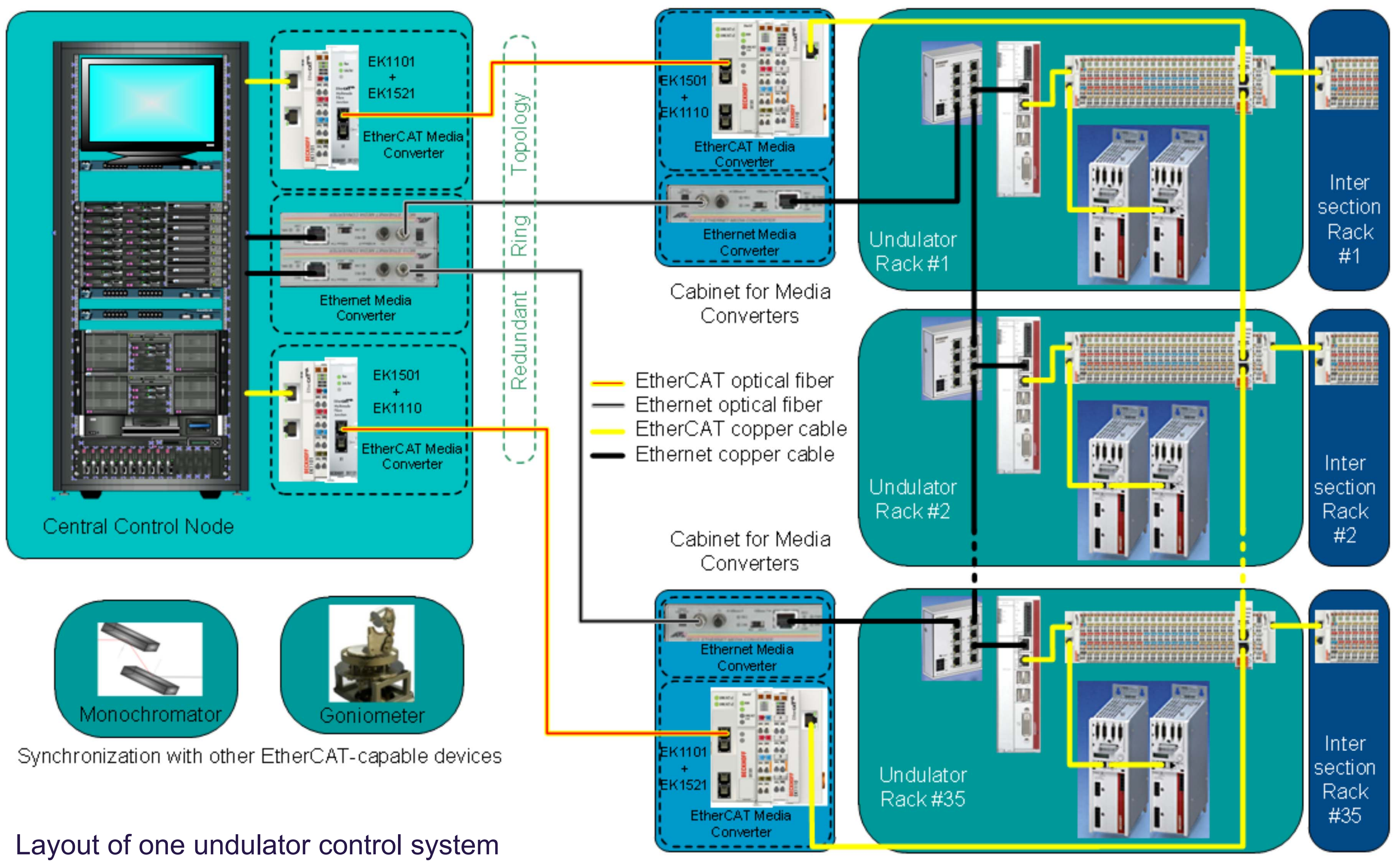
One virtual axis represents the undulator for the global control. Inside of the local control system all axes and parameters depending on the undulator gap, are coupled to this one virtual axis. The implementation of this scheme will allow for synchronizing the movements of all undulator cells inside of one undulator system. The starting time for the movements of the individual undulator cells could be precisely synchronized (<< 1us) by implementation of the EtherCAT fieldbus system in the local control as well as between the Central Control Node (CCN) and Local Device and Motion Control (LDMC).

Four undulator axes, one phase shifter axis and four air coil correctors are the components which can be controlled locally and coupled to the virtual axis. Nevertheless the LDMC also contains components like a quadrupole mover, an ambient magnetic field correction coil or 3-way valve which are not directly depending from the undulator gap. So these components are not coupled to the virtual axis.

The Central Control Node is a separated Windows PC which is connected to each LDMC over the EtherCAT network. The global control program is also implemented in a Beckhoff PLC and TwinCAT System Manager. The PLC program running on this computer has two main tasks. The first task is to control all undulator cells which belong to one undulator system. The second task is to provide the interface to the accelerator or experiment control. This interface can be used for instance by a DOOCS (Distributed Object Oriented Control System) server or any other server that has access to the undulator control system. It will ensure communication between the global control PLC and the remote control clients.



Schematic overview of the undulator control system

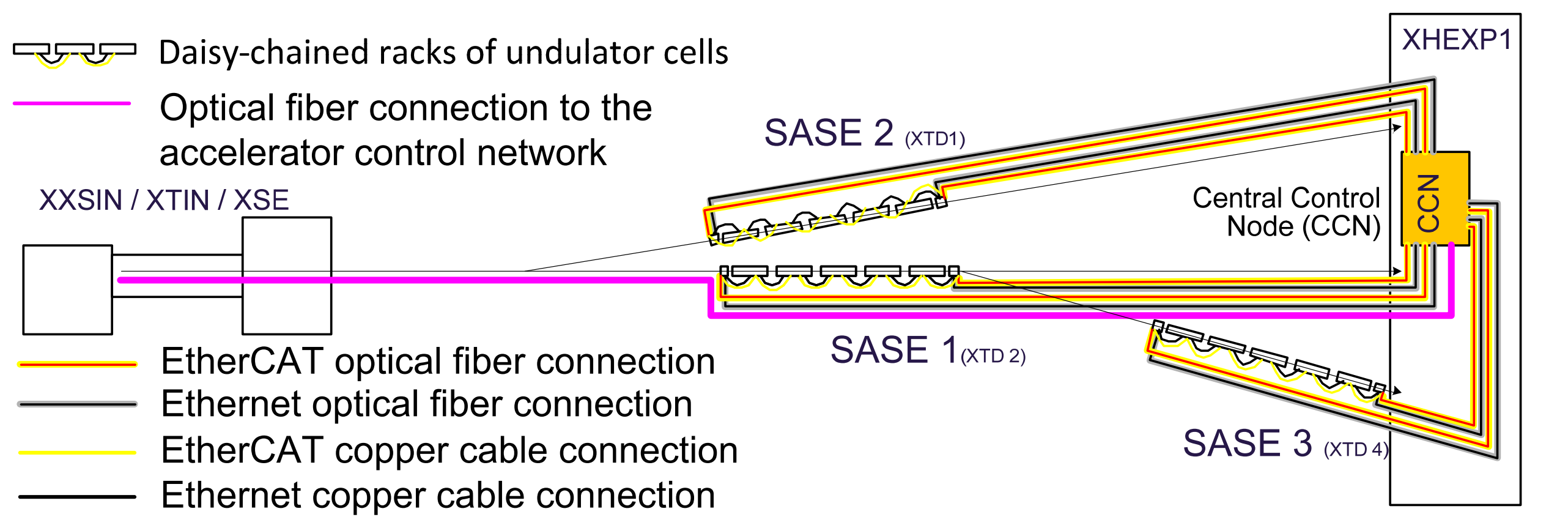


Layout of one undulator control system

Network Topology

One CCN will serve one undulator system. The CCN connects to its undulator system through the nearest tunnel by means of optical fibers. The undulator cells are daisy-chained by copper cable.

“Redundant Ring Topology” will be used, which allows to build a ring topology that can tolerate a single point failure. Each SASE string will have two redundant rings; Ethernet and EtherCAT. The EtherCAT network is used for real-time device and motion control, while the Ethernet is used for monitoring and remote access to the individual undulator PCs. The CCN will also have a dedicated optical fiber connection to the accelerator control system.



Control Parameters for Undulator System

The user experiments will be able to control the photon beam energy by changing the undulator system gap, optimize the photon beam intensity by applying a taper to the system gap and synchronize the system gap with external devices.

The accelerator control will have full access over the all undulator system parameters.

suren.karabekyan@xfel.eu

www.xfel.eu

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DESY HELMHOLTZ ASSOCIATION