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The Vacuum System of the Photon Transport Beamlines at the European XFEL Facility

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European XFEL

EVC-15

The Facility

The European XFEL is a **3.4 km** long underground facility that generates **extremely intense X-ray flashes** to be used by researchers from all over the world. It officially began operation in September 2017. In full operation it produces **coherent femtosecond X-Ray pulses** with unprecedented brilliance in the **energy range from 250 eV to 25 keV** at MHz repetition rate (1).

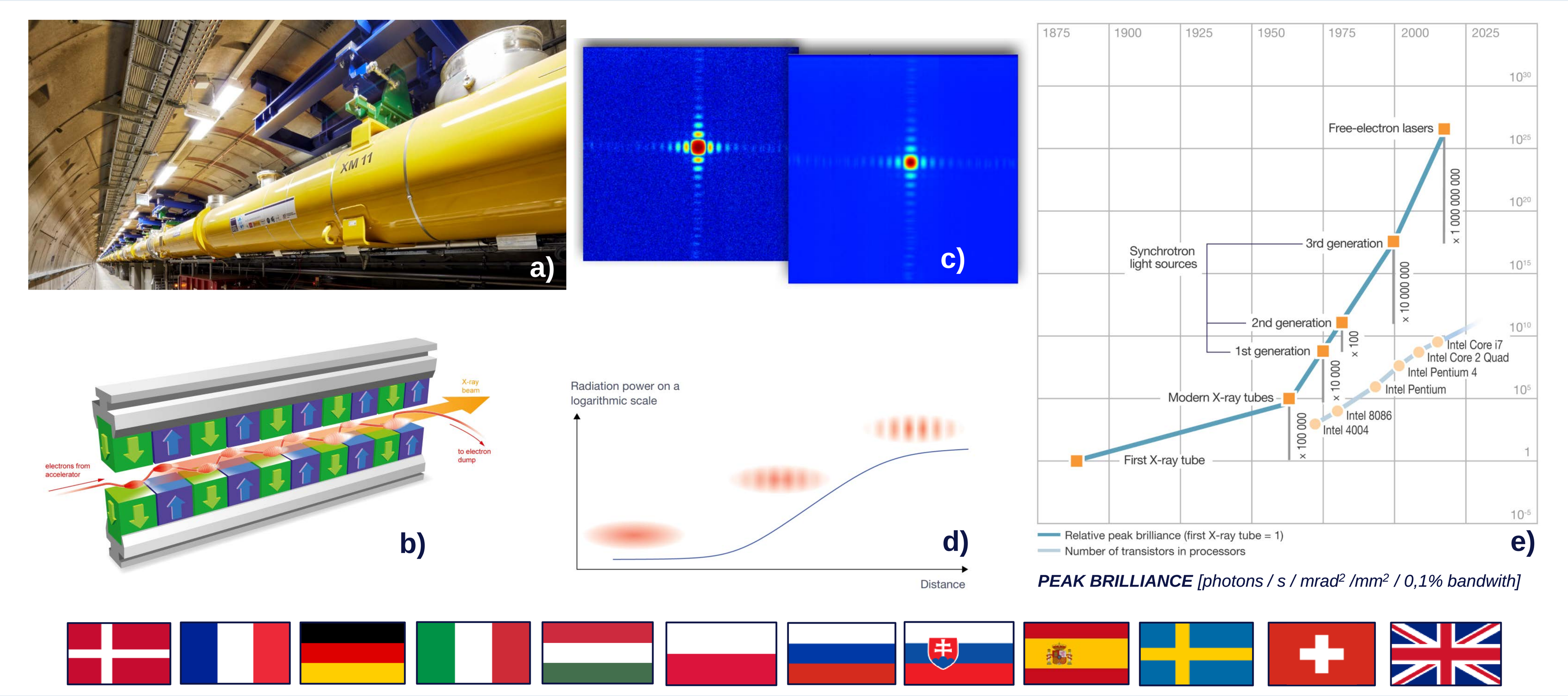

Figure 1. *a) Picture of the accelerator modules b) undulator light production c) first slit diffraction pattern at SPB instrument d) scheme of electron bunching phenomena e) comparative evolution of light source relative peak brilliance against Moore´s law.*

Photon Transport System Beamlines.

The facility comprises a **superconducting LINAC** (**1.9 km long**; up to **17.5 GeV**) and initially three branched photon beamlines: SASE1 and SASE2 that operate in the hard X-ray regime, and SASE3 that covers the soft X-ray range up to 3,5 keV.

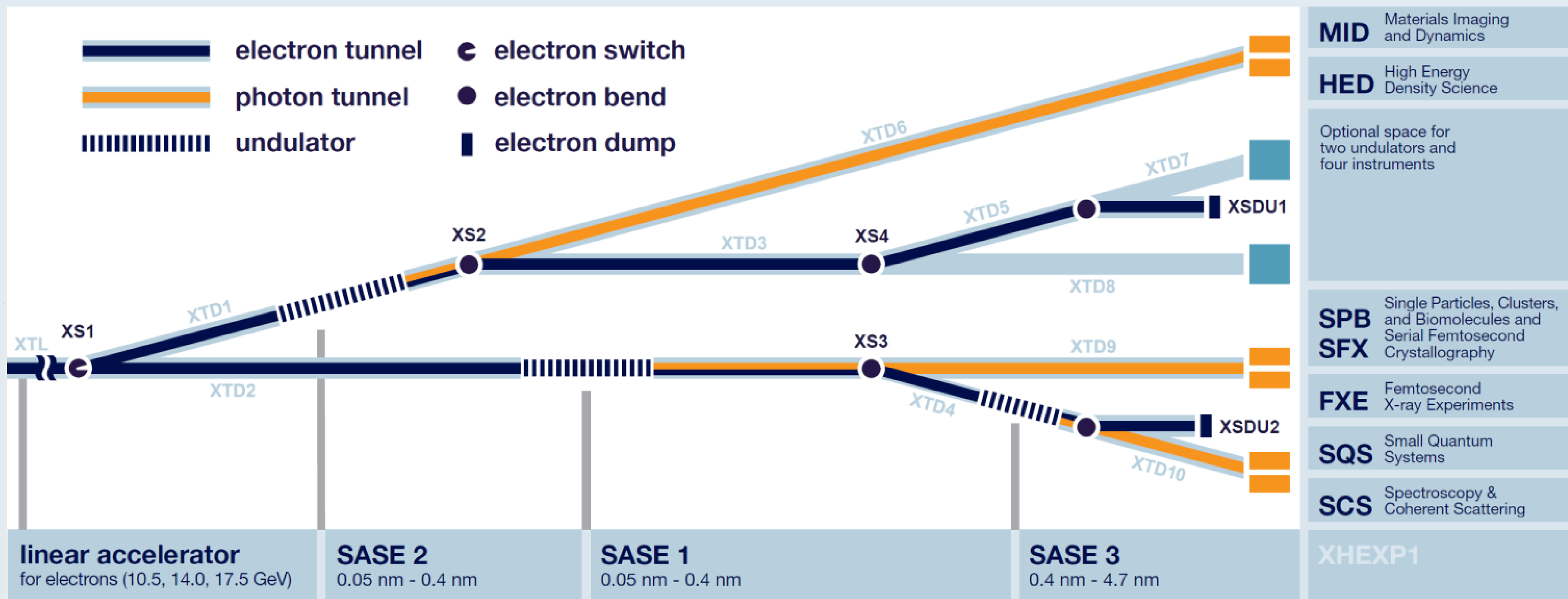

Figure 2. *Schematic outline of the facility tunnels structure.*

Materials, Manufacturing & Assembly.

- All the **beampipes** are exclusively manufactured out of **stainless steel (1.4306 or 1.4404)**
- Connections are done with **CF-flange system** using specifically **1.4429 ESU specifications**.
- The **production** of the almost **3 km of photon beampipes**, was outsourced to **industrial partners**, including the welding manufacturing and their ready-to-assemble delivery (anodic cleaning, drying and ISO class 5 packaging).
- In the particular case of the **long vacuum sectors** (aprox. 1,5 km) in between the distribution mirrors and the in-tunnel experimental instrumentation, **in-situ orbital welded 18m long pipes** were installed as the best compromise between reduced installation effort and layout versatility.
- **A UHV specifications and guidelines document** (3) was developed to harmonize the different contributions from the involved industry partners and/or the various in-kind component contributions from the rest of participating institutions.

Figure 3. *Orbital welding of UHV transport beampipes.*

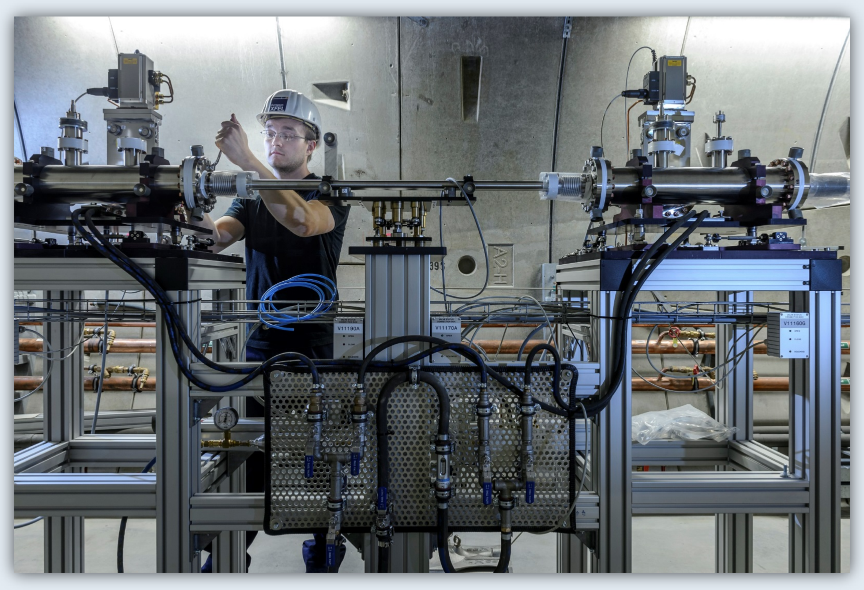

Figure 4. *SASE1 Beamline XTD9 - tunnel works.*

Particle "Free" UHV Sectors.

One of the main **challenges** faced during the installation has been the fact that a large proportion of the almost 3 km long photon **vacuum system** had to be **assembled under ISO5** (4) **cleanroom class** to **guard the optical properties of the high quality X-Ray mirrors** (2).

Specific assembly procedures (**segmentation**, use of **portable clean tents**, **deonized N_2** blowing, etc.) has been thoroughly used during the last 3 years installation period. First results with beam indicate no issues (i.e. diffraction patterns due to in-beam-path micrometric particles).

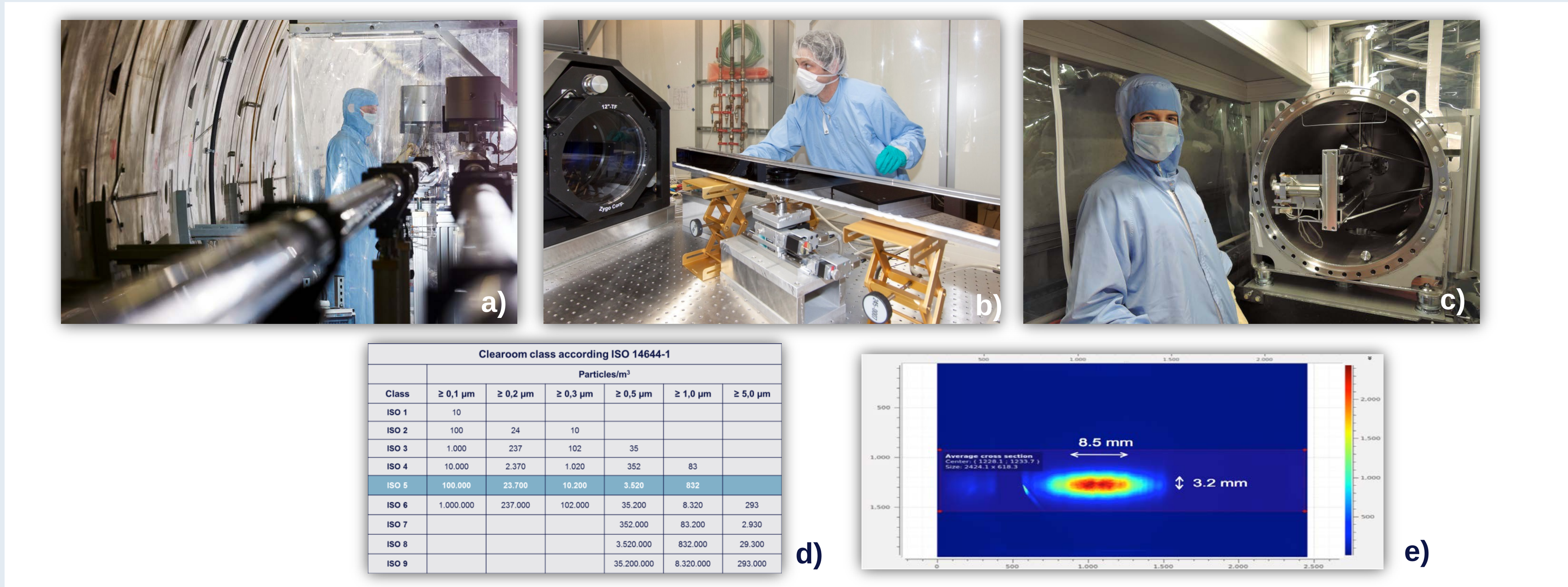

Figure 5. *a) Assembly of beamline components in the tunnels. b) optical metrology lab. c) first mirror installed in its final UHV chamber . d) ISO 14644-1 class table. e) Beam profile after mirrors reflections.*

Pumping Systems.

In general, the **overall static pressure is in the 10^{-9} mbar range**. Since most of the system is **unbaked**, this is achieved using a combination of proper **cleaning processes**, **surface treatments** and a **lumped distribution** of **triode ion pumps** with additional specific configurations at critical components (mirrors, gratings, etc.) where NEG cartridges are also used.

Figure 6. *Examples of Triode Ion Getter Pumps installed in both branches of SASE2 Beamline.*

- There are installed more than **300 Ion pumps**, **35 Turbomolecular pumps** of sizes ranging from 80 to 1200 l/s, **12 NEG cartridges**, several large capacity multistage **Roots pumps**, and more than **16 scroll dry pumps**.
- Special attention was placed in the so-called **"gas sectors"** where noble gases **(Ar, Kr, Ne, Xe)** are injected in the beamline for **beam diagnostic purposes (up to $5\cdot10^{-4}$ mbar)** or **to reduce the photon flux (up to 35 mbar)**. In both cases the Vacuum Group has designed, tested, and installed the necessary **large clear aperture (20/25 mm) windowless Differential Pumping** Sectors to offer in all cases an **interface pressure < $1\cdot10^{-8}$ mbar**.

Vacuum Control System.

The control system is based on a **redundant PLC loop** with a base latency of **10 ms**. For **faster signals**, specific μ-TCA based crate equipped with **FPGA e-boards** are set where needed (i.e. MPS loop)

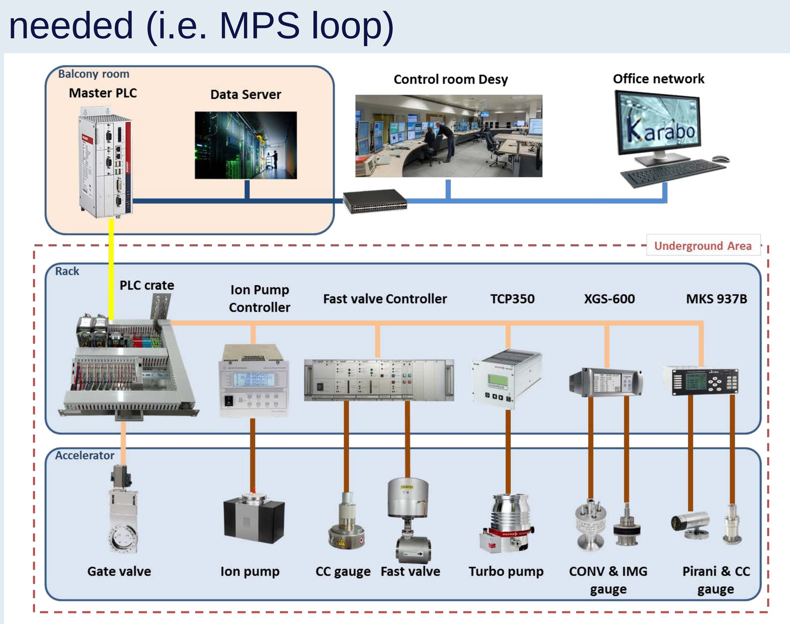

Figure 8. *Control System simplified schematic.*

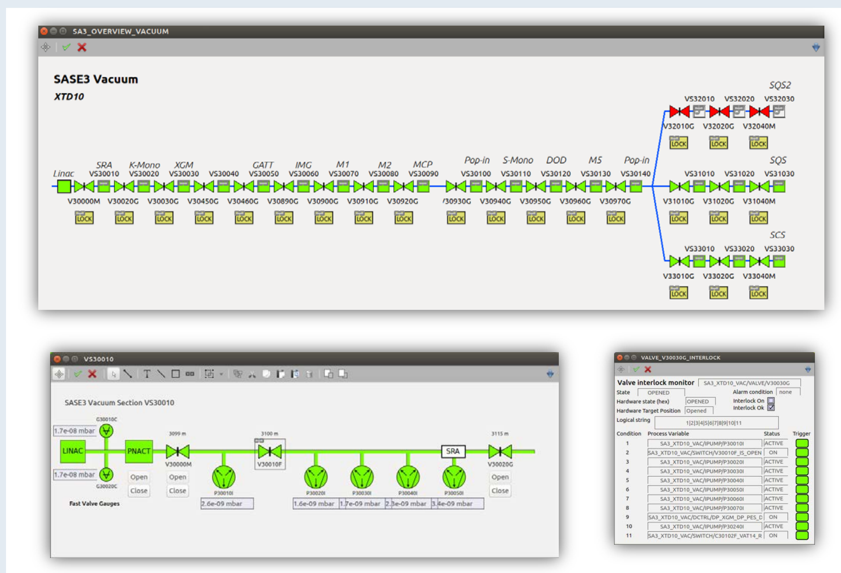

Figure 7. *Karabo GUI.*

The SCADA system ("**XFEL-Karabo**") is entirely designed by the Control and data Analysis Software Group and provides the necessary **GUI** features for the remote commissioning, operation and supervision of every single **80 vacuum sectors present** in the facility tunnels.

References.

(1) Altarelli et al. "*XFEL: The European X-Ray Free-Electron Laser - Technical Design Report*". 10.3204/DESY_06-097 (2006)
(2) Sinn et a. "*Technical Design Report: X-Ray Optics and Beam Transport*". 10.3204/XFEL.EU/TR-2012-006
(3) Dommach "*Technical Specification: UHV Guidelines for X-Ray Beam Transport Systems*". XFEL.EU TN-2011-001
(4) ISO 14644-1: "*Classification of air cleanliness*".

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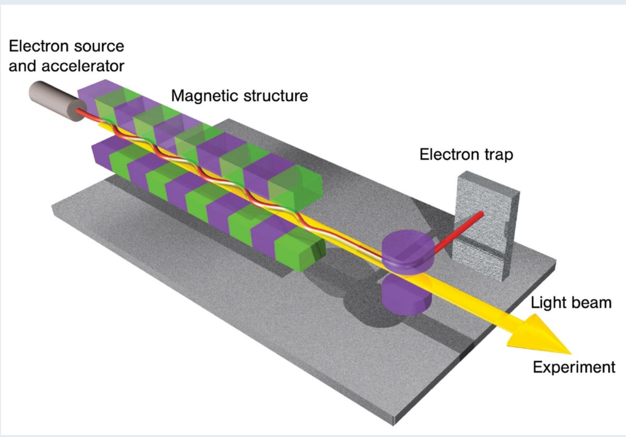

peak brilliance [photons / s / mrad² / mm² / 0.1% bandwidth]

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