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

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(a)European X-Ray Free Electron Laser Facility.

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).

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.

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 14429 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 (approx. 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.

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 ISO 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, deoxygenated N₂ 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).

Pumping Systems.

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

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 5·10⁻⁴ 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 (2025 mm) windscreenless Differential Pumping Sectors to offer in all cases an interface pressure < 1·10⁻⁹ 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).

References.

(4) ISO 14644-1: “Classification of air cleanliness”.

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