Gas Attenuator Instrument for SASE3 Soft X-Ray Beamline at the European XFEL

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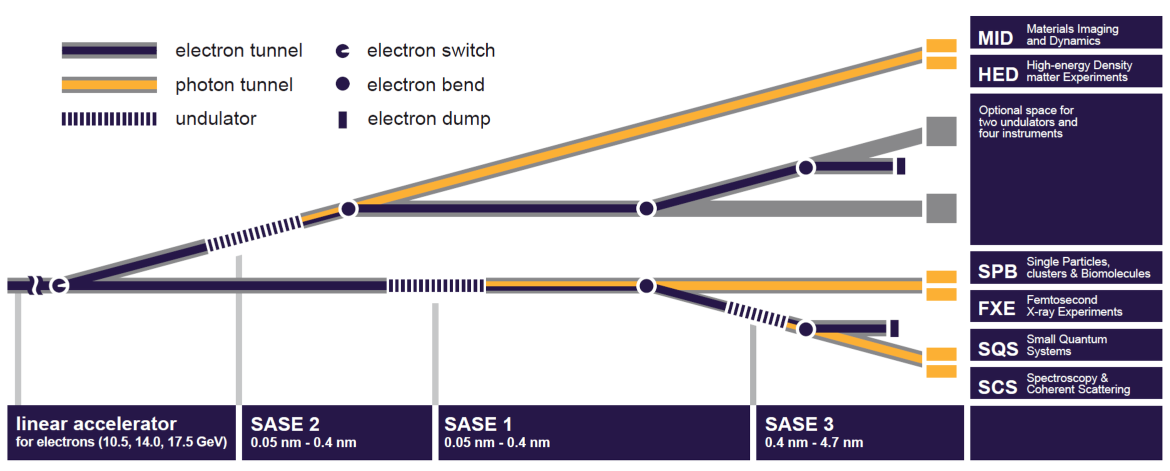
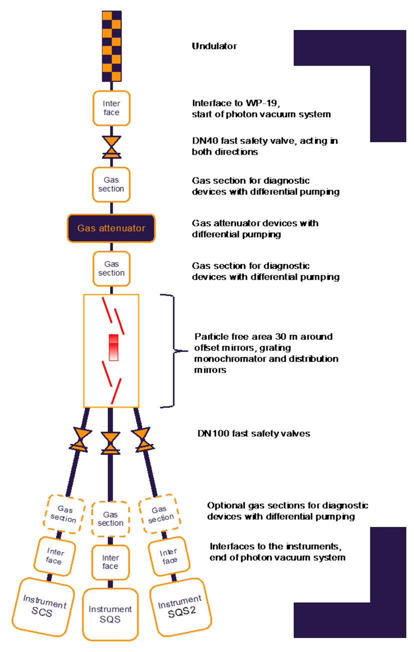
Soft X-ray beamline (SASE3) and the conceptual design requirements for the proposed device

The **SASE3** beamline at the European XFEL facility will offer outstanding X-ray beam properties in terms of brilliance and repetition rate [1, 5] in a range of energies that will cover from the machine's lower limit, 260 eV, to above 3 KeV. In the first operational phase, it will serve two of the six initially expected scientific instruments: the Small Quantum System (**SQS**) [2], and the Spectroscopy and Coherent Scattering (**SCS**) instruments [3]. In each case, the use of a tool that could enable a continuous and smooth modulation of the photon flux is definitely convenient. This purpose can be achieved by means of a gas-based device (so-called "*gas absorption cell*") where the attenuation level can be correlated with the actual gas density over a given interaction length and for a given gas species. In addition, the avoidance of solid separation interfaces is also highly desirable, eliminating in such case any optical interference with the beam that could lessen the initial beam quality. The latter condition suggests a windowless system that will have to deal not only with large optical apertures (up to 22 mm diameter) but with pressures up to 35 mbar (8 orders of magnitude higher than the average beamline base pressure). The proposed system has been designed considering not only these factors but others, such as control robustness, gas consumption minimization, gas type flexibility, integration with diagnostics devices [6], and an evident "user-friendly" orientation.

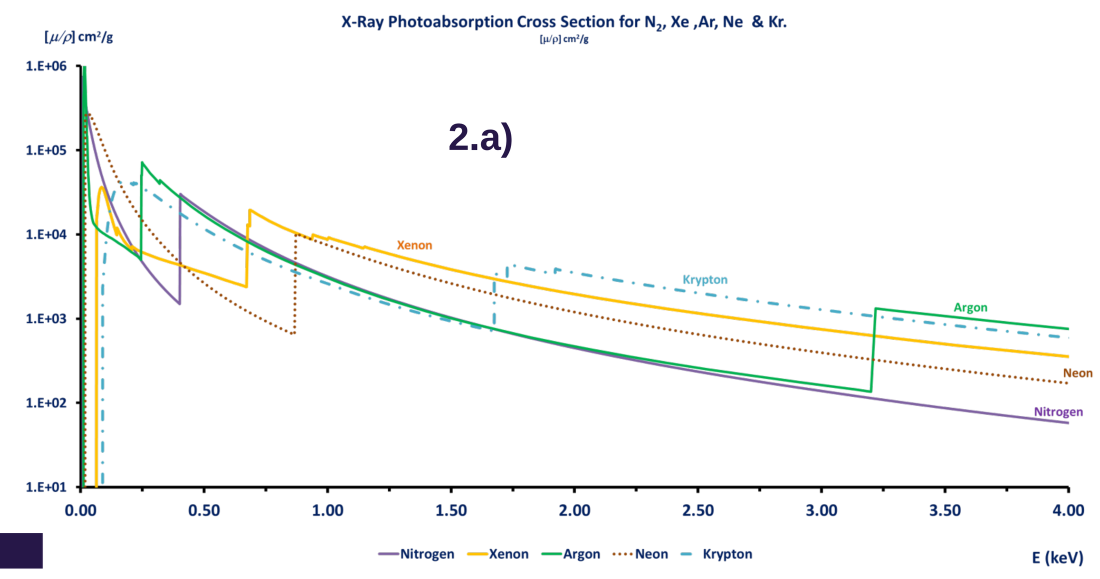


1.a)

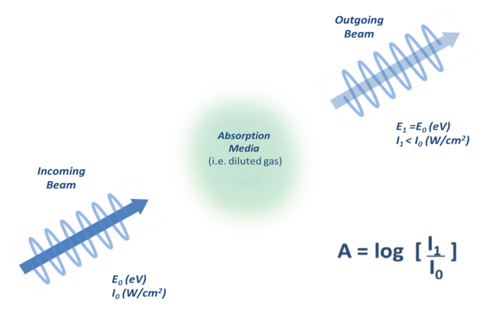


1.b)

***Figure 1a)**: Schematic view of the XFEL Project Photon Beamlines. **Figure 1b)**: Location view of the Gas Attenuator instrument in the SASE3 beamline. The instrument is located before any optical instrument and "surrounded" by two gas monitor devices (GMDs) [6], which will characterize the beam properties, including photon flux, before and after the interaction with the gas cell. As one can see, those additional instrument are also gas-based. However, they are gas type–independent from the Gas Attenuator (i.e. they are provided with their own differential pumping system).*

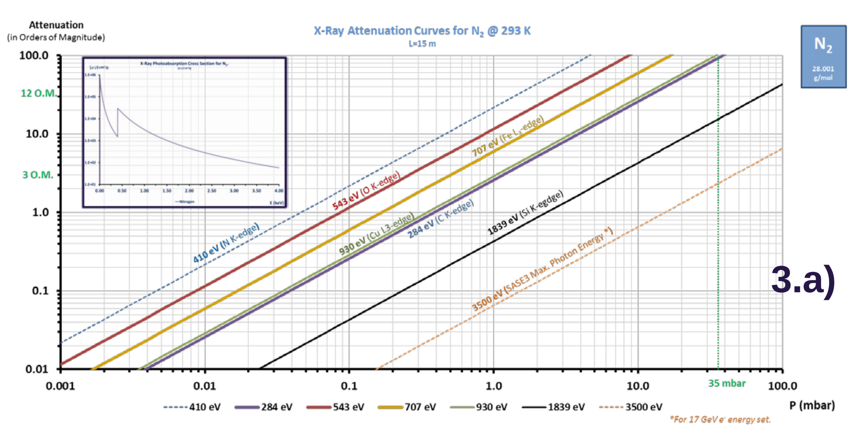


2.a)

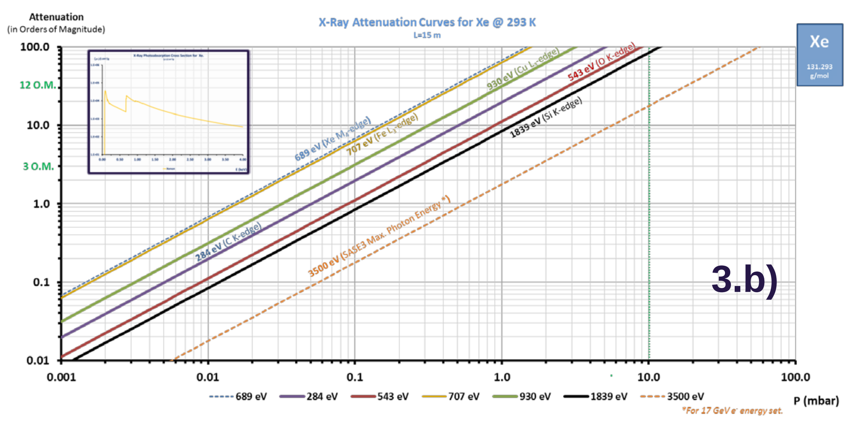


2.b)

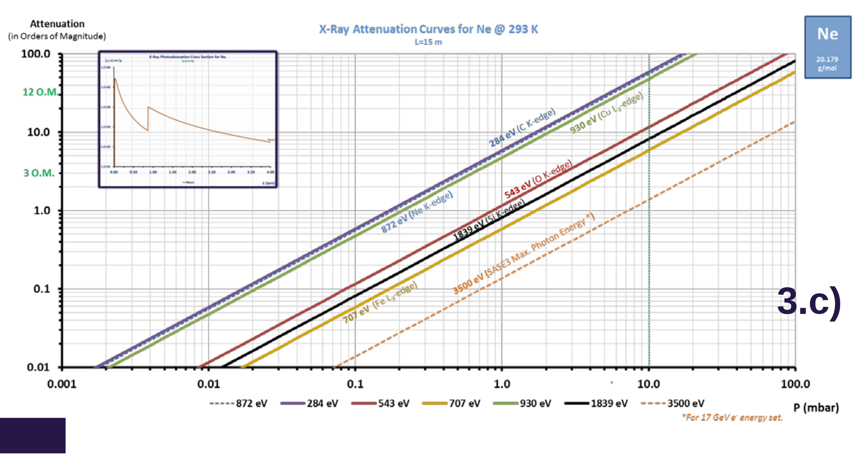
***Figure 2a)**: X-ray mass absorption coefficient for selected gases (N_2, Xe, Ne, Ar, and Kr). Horizontal axis shows photon energies ranging up to 4000 eV. **Figure 2b)**: Pictorial view of the interaction process and the basic reduction effect ("photon absorption") of the gaseous media on the outgoing photon beam flux [4].*



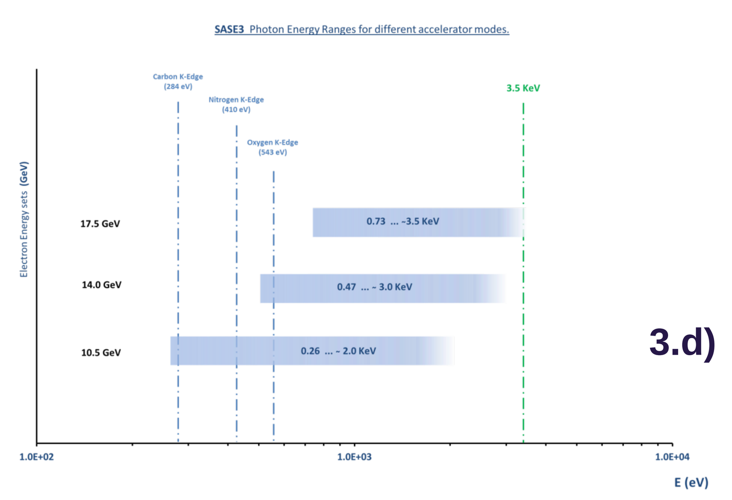
3.a)



3.b)



3.c)



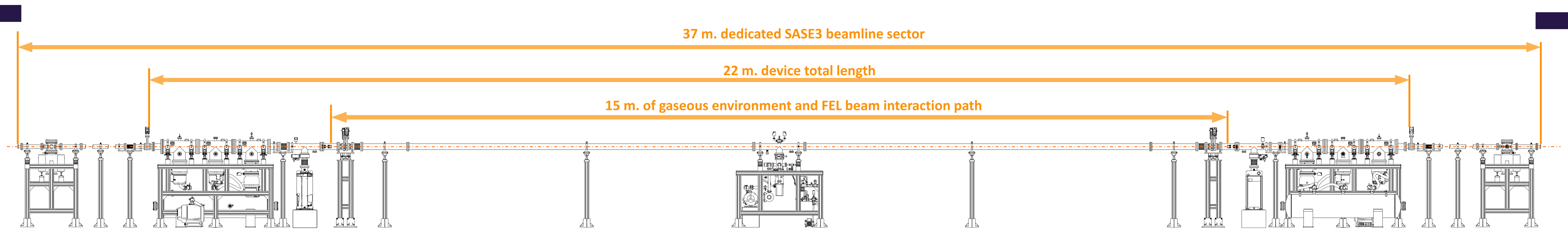
3.d)

Initial set of specifications

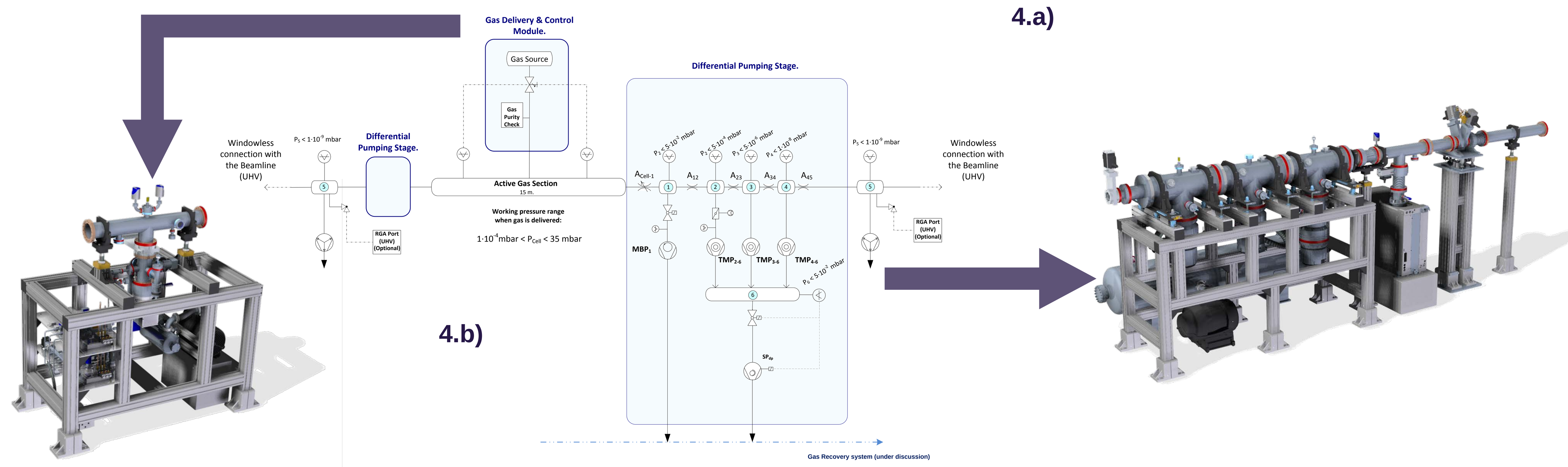
During the first operational phase of the European XFEL facility, the gas attenuator device will provide the following perfomances figures and capabilities.

Capabilities	Status
Operative photon energy range	From 260 to 3500 eV *(acc. to SASE3 specifications)*
Min. controllable attenuation factor	0.01 O.M.
Min. attainable attenuation factor	From 3 O.M. *(independently from gas type or photon beam energy)* to 10 O.M. *(for specific experimental conditions).*
Available gases	Nitrogen and Xenon *(Ar, Ne, or Kr still under discussion)*
Max allowable pressure in the gas cell	35 mbar *(for N_2).*
Gas purity check and RGA systems	Yes
Configurable gas manifold system *(i.e. gas mixtures)*	Yes
Variable aperture system for the 1st D-P stage	Yes
Integration with photon beam diagnostics	Yes

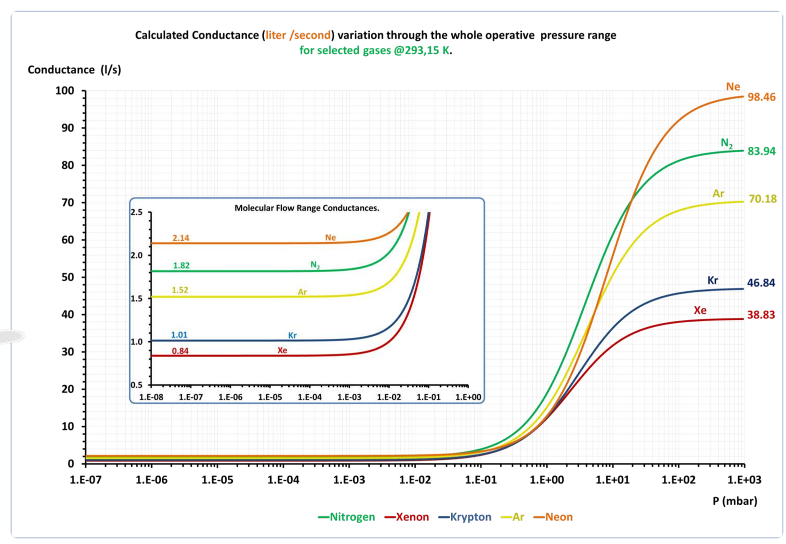
***Figures 3a) to 3c)**: Attenuation perfomance of the instrument for selected photon beam energies with scientific interest. The vertical axis shows the attenuation in orders of magnitude (OM). The horizontal axis shows the required gas pressure to achieve a given attenuation level for the specific gas type and photon beam energy. The vertical green line establish an initial technical upper boundary in terms of gas pressure. **Figure 3d)**: SASE3 expected photon energy ranges for different LINAC operation modes [1].*



4.a)



4.b)



4.c)

***Figure 4a)**: 2D CAD view of the Gas Attenuator instrument. **Figure 4b)**: Simplified process diagram of the device showing the different subcomponent integrations and the different gas pressure zones. A 3D CAD view is also shown for the "gas delivery and control module" (left) and the basic differential pumping module (right). **Figure 4c)**: Dependency of the gas flow conductance for selected gases with the discharge pressure for an orifice (5mm diameter, 10 mm long). The example poses one of the bigger challenge for the designed system: combining large apertures (up to 20 mm diameter) with a constraint gas consumption and an expanded and seamless range of operation for the differential pumping system .*

References

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