A Modular Design For the Differential Pumping Modules at the European XFEL Photon Beamlines.

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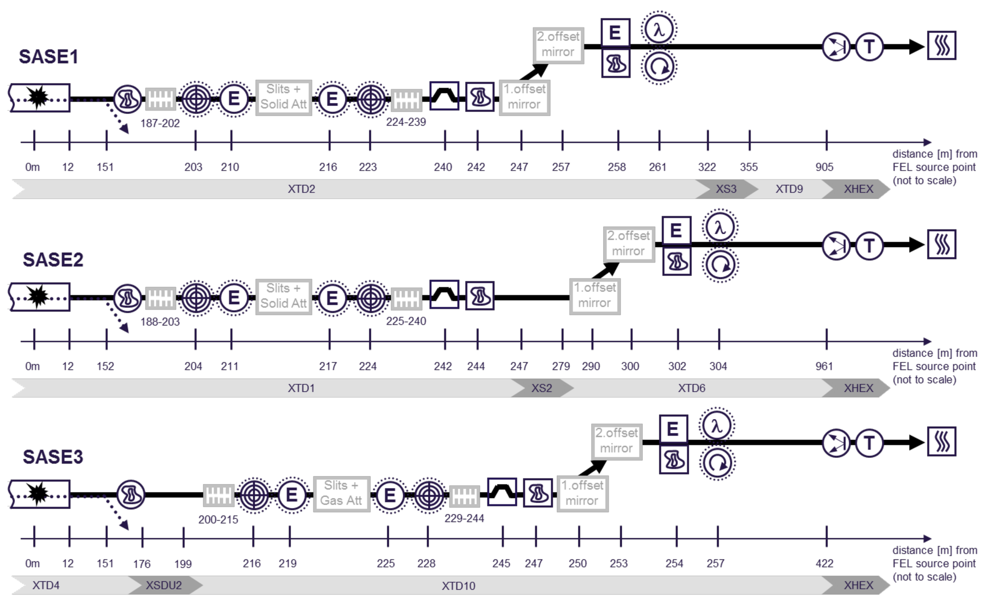
Windowless Gas-Based Diagnostics at the X-ray Beam Transport Systems [1].

Several kinds of gas-based diagnostics devices are developed by the X-ray diagnostics group (WP74) and placed in the beam transport system. These are in particular:

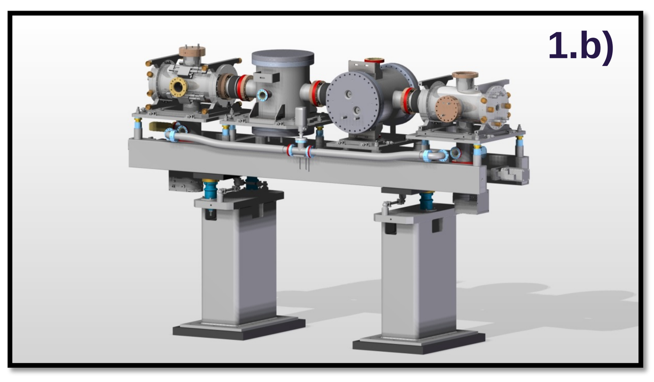
- Gas-based photo-emission spectrometers (**PES**) for spectral analysis [3].
- Gas-based beam intensity monitors (**XGMD**'s) [4].
- Gas-based beam position monitors (**XBPM**'s) [5].

Depending on different requirements, these devices can operate with different gases (Xe, Ne, Ar, Kr and even N_2), running within a pressure range that varies typically from $1{\cdot}10^{-6}$ mbar up to $5{\cdot}10^{-4}$ mbar (Currently R&D activities in WP74 are ongoing that explore the usable parameter space of these devices.) [2].

Since a windowless system is highly desirable, a differential pumping scheme is mandatory to **provide the required drop in pressure** down to the average beamline values (< $9{\cdot}10^{-8}$ mbar). This system should be able to **minimize** as much as possible the **flow** of the above mentioned noble gases to the rest of the X-Ray beam transport system, and being able at the same time to **maximize the optical clear aperture** between pumping stages. This document introduces a general overview about the design process and test procedures developed so far as part of the R&D activities of the WP-73 (X-Ray Optics & Beam Transport) Group.



1.a)



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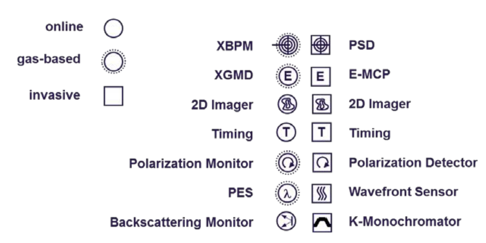


***Figure 1a)**: Schematic view of the spatial distribution along the Photon Beamlines of the different diagnostic devices. Notice the recurrence of gas-based devices (all of them windowless) that will require to be differentially pumped. **Figure 1b)**: 3D CAD View of a "XGM" (X-Ray Gas Monitor) basic unit including both, vertical and horizontal, XGMD's and XBPM´s modules [2]. (Pictures courtesy of Wolfgang Freund from WP-74):*

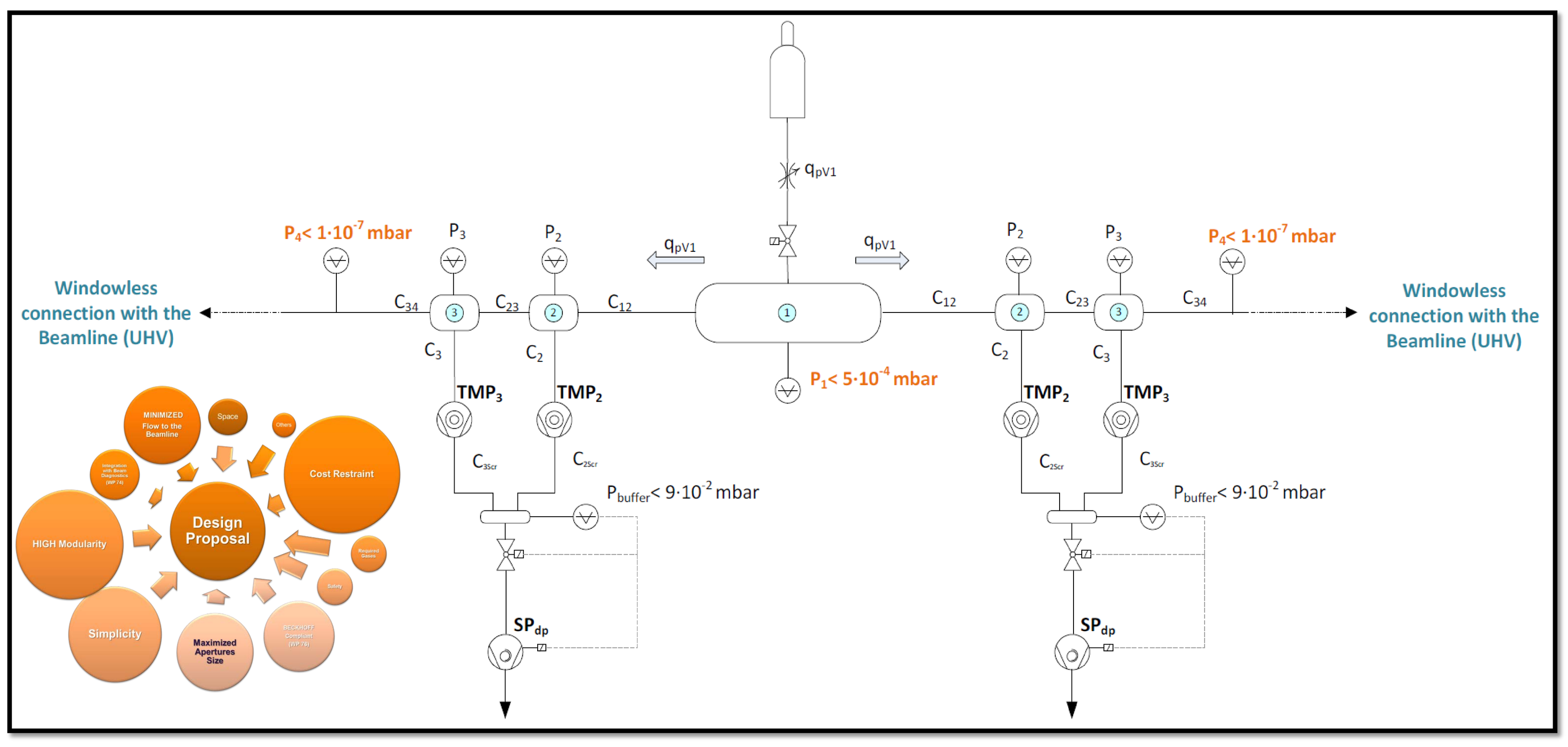
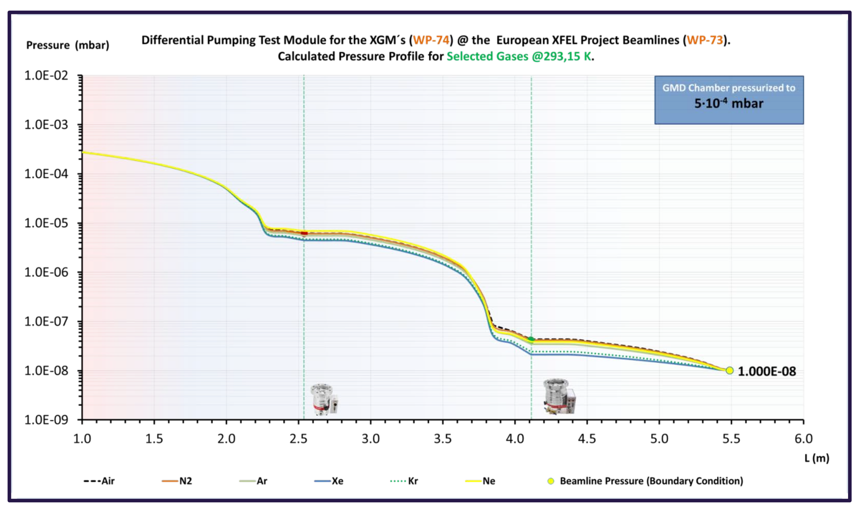
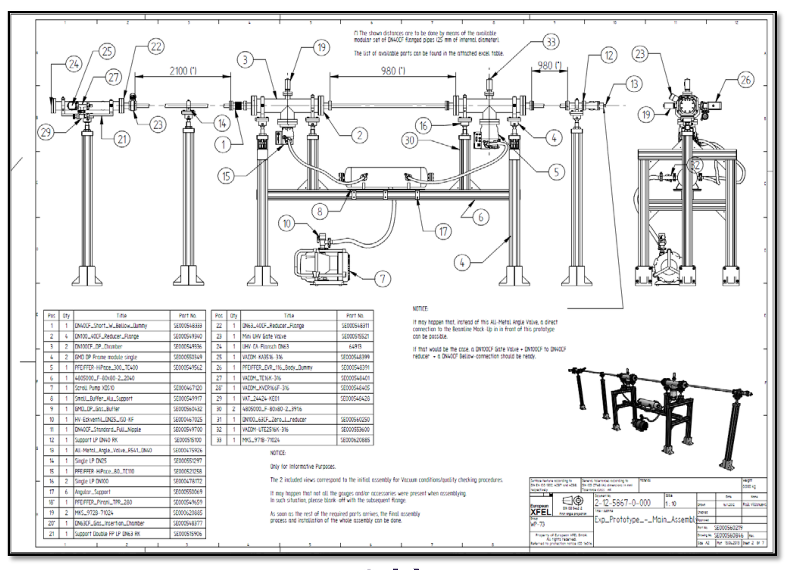


***Figure 2**: Simplified overview of the proposed differential pumping design scheme. The graphic shows the use of two pumping stages at each side of the gas based beam diagnostic module. Each of those includes a turbomolecular pump (TMP) and a common forevacuum line ("Buffer") design to safely provide the required compression ratio for each turbo but just using a single Scroll-type pump ("SP") per side. Gas flow directions and interstage conductances are shown as q_{pV_i} and C_{ij} respectively.*



3.a)



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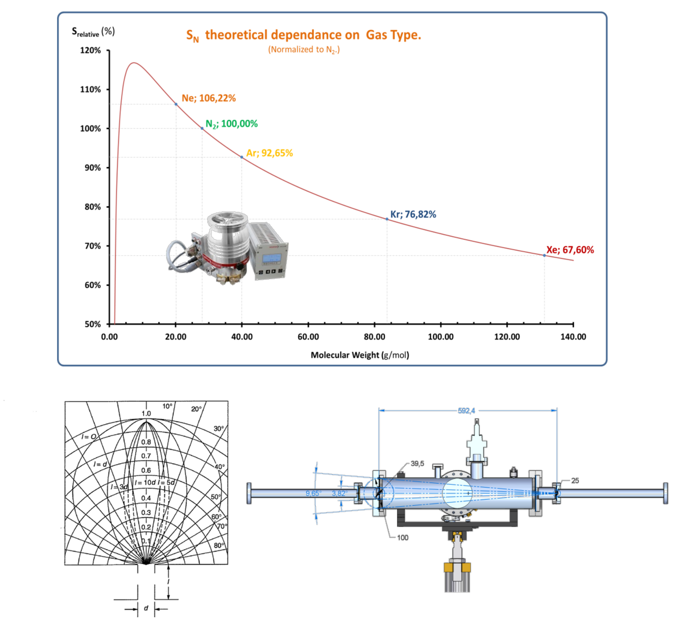
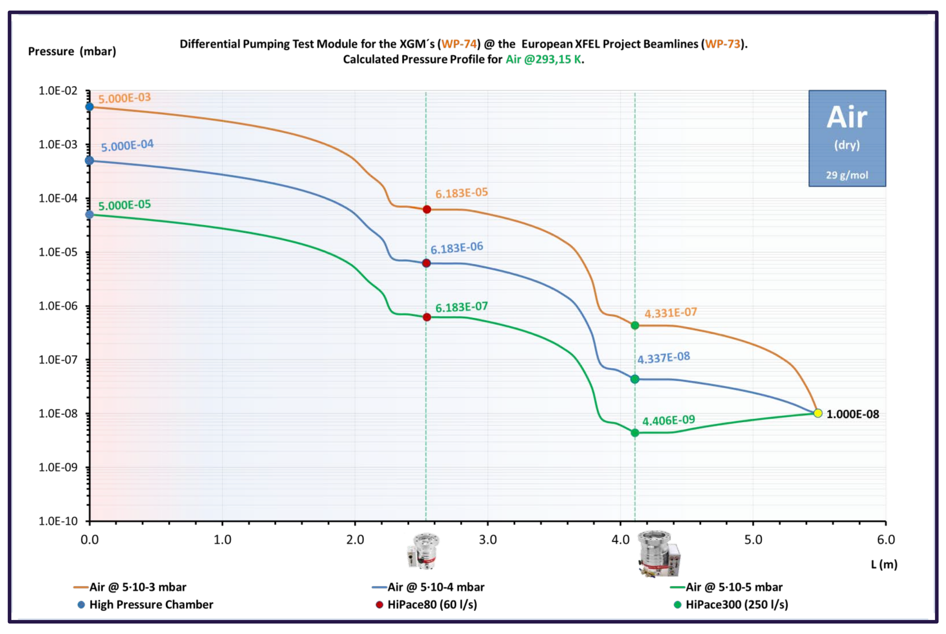


3.c)



3.d)

***Figure 3a**: Pressure drop profile, calculated by the "Matrix-Transfer" Method, showing the expected performance differences depending on the gas type. **Figure 3b**: General CAD drawing showing the main components of the test setup to be used. **Figure 3c**: TMP's theoretical S_{eff} dependence with the gas type at a given temperature (i.e. most probable thermodynamic molecular velocity). In this figure is also shown the expected beaming effect due to the geometrical configuration of the system. **Figure 3d**. Comparison of calculated pressure drop profiles provided by the system for dry air when then pressure in the gas chambers varies from $5{\cdot}10^{-5}$ up to $5{\cdot}10^{-3}$ (stress-test conditions).*

System Description and First Tests Results.

Considering the total number of gas-based diagnostic devices along the European XFEL Photon Beamlines (up to 10 assemblies), the diverse installation features of some of them (i.e. beam axis is 2.6 m. above XTD2 tunnel floor level), as well as a clear cost-efficiency orientation of the proposed system, the development of a modular, flexible and adaptive solution, mostly based in "off-the-shelf" UHV components has been considered as the most suitable approach.

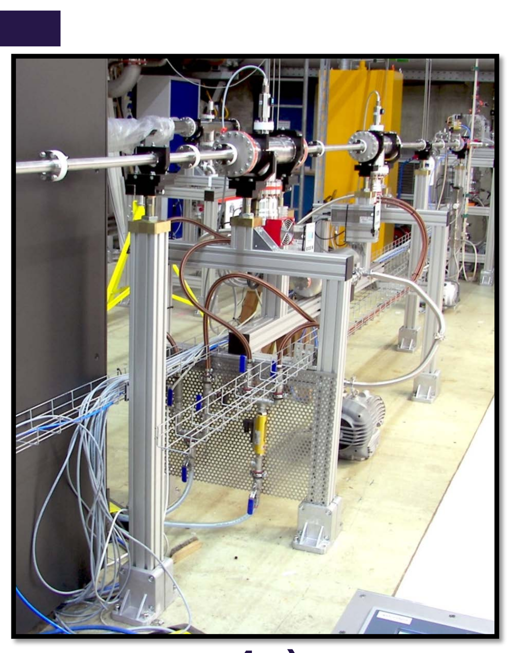
Following this purpose, the developed differential pumping system is based on a reduced number of "*building blocks*": (single-type, all-orientation-enabled pumping chamber design, standard TMP's, common forevacuum system, long-tubes with reduced diameter as conductance limiters between pumping stages, etc., *see figure 2*). In addition, probably one of the most challenging restrictions was the high value of the required optical clear aperture for most of cases (up to a diameter of 25 mm).

On the other hand, installation available space is not a special issue for the majority of those situations. Therefore a narrow, long-pipe solution has been adopted as flow limiting element between pumping stages.

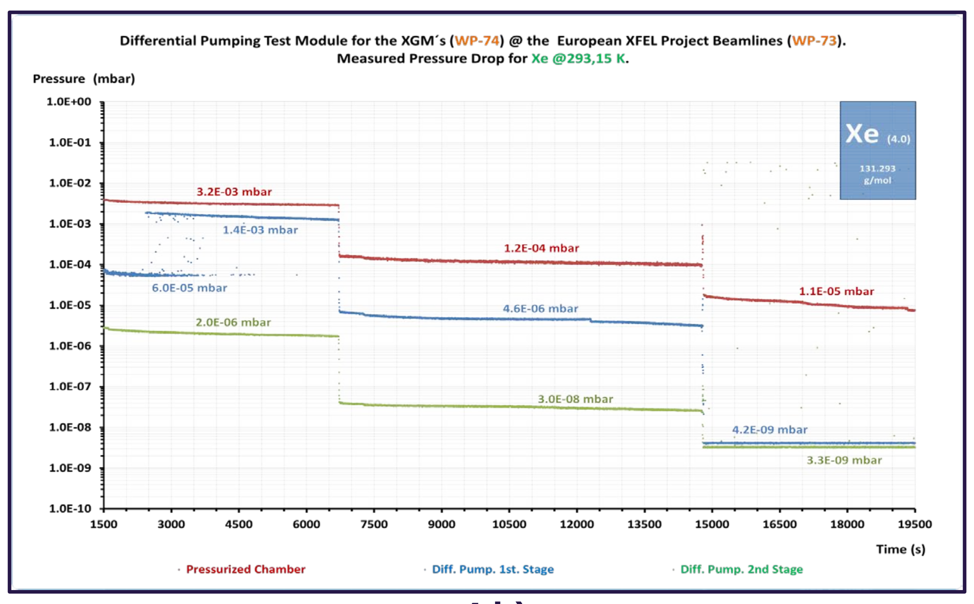
After calculating (*See figures 3.a and 3.d*) the respective pressure profiles for the different gas candidates (Xe, Ne, Kr, N_2 and also dry-air) with the theoretical corrected values for both conductances and effective pumping speed in each case, a test-setup has been built to explore the design real perfomance space. This setup includes not only the D-P basic design (*See figure 3.b*) but also a gas injection chamber with the respective gas manifolds for the above mentioned gases (*See figure 4.a and 4.c*).

A first round of so-called "*initial acceptance tests*" has been already performed with dry air, N_2 and Xe showing a succesful agreement between experimental results and calculated values when comparing both pressure profiles (*See figures 4.b and 4.c*). After those, a second test phase is foreseen. In this phase a complete deployment of the project PLC control scheme layout is one of the major targets, together with the gathering of additional long-term stability tests data (i.e. TMP's working parameters shall be monitored to confirm the temporal reliability of the proposed design).

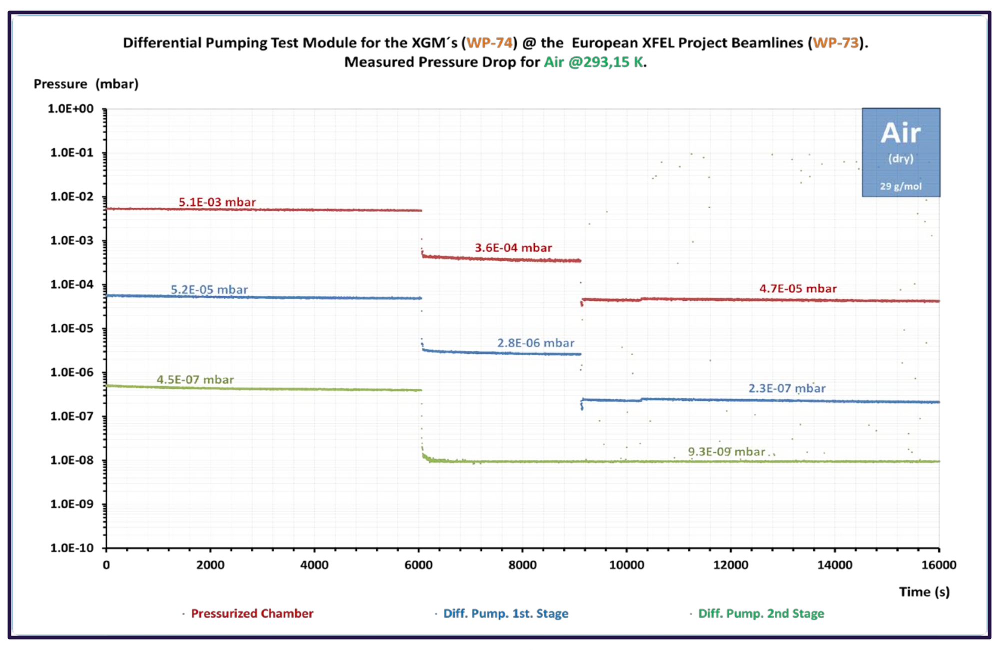
Finally, if the so-called "*long-term stability tests*" result succesful, the project will be moving towards the "*serial production stage*" with shall include the manufacturing, preassembly and vacuum conditioning of the complete pumping modules, enabling its final installation in the European XFEL project beamlines and its commisioning together with the actual gas-based photon beam diagnostic devices.



4.a)



4.b)



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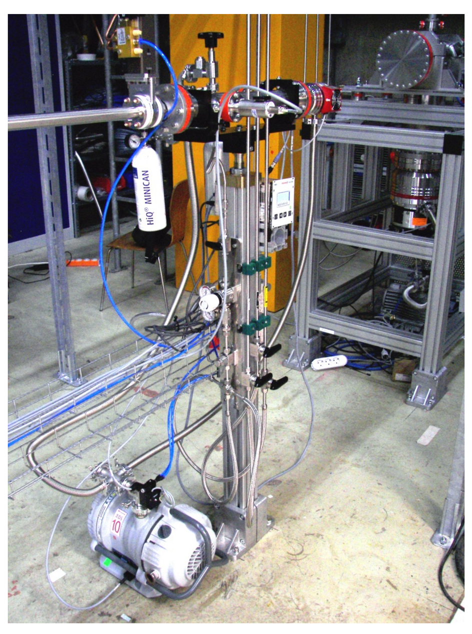

4.d)

***Figure 4a**: Photograph of the installed test setup. **Figure 4b**: Measured pressure drop profile at different inlet pressures when Xenon is injected in the system (notice instability issue with the pressure gauge of the 1st D-P stage). **Figure 4c**: Measured pressure drop profile at different inlet pressures when dry air is injected in the system. **Figure 4d:** Photograph of the gas injection chamber at the test setup.*

References.

[1] Harald Sinn et al., XFEL Technical Design Report, TR-2012-006: "*X-Ray Optics and Beam Transport*".

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[5] J. Mießner, et al., Nucl. Instr. and Meth. A (2010), doi:10.1016/j.nima.2010.10.155

Acknowledgments

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