

# The Gas Attenuator of FLASH

*K. Tiedtke, N. von Bargen, M. Hesse, U. Jastrow, U. Hahn*

## INTRODUCTION

The experimental hall of the FLASH user facility is located approximately 30m behind the last dipole magnet which separates the electron and the photon beam. The photon beam transport system delivers the FEL radiation under ultra high vacuum conditions to five different end stations, which can be used alternatively.

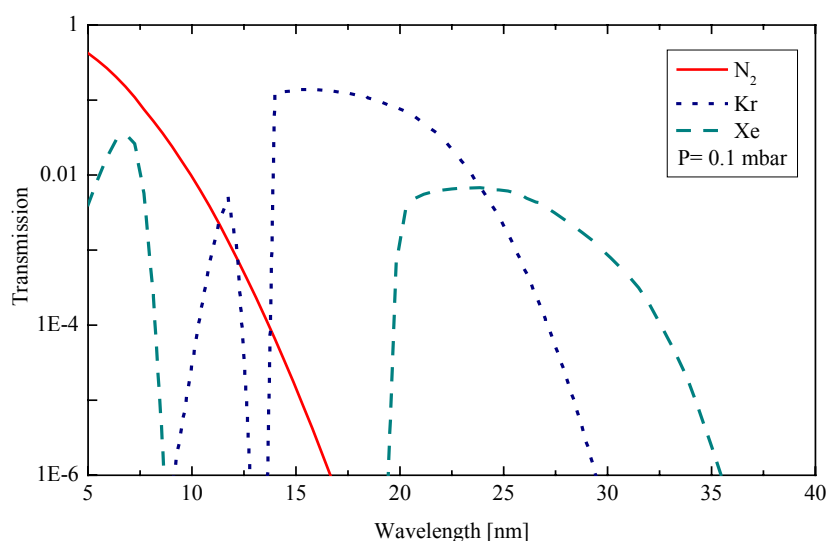


Figure 1: Calculated transmission of a 15m long gas cell at a pressure of 0.1 mbar for different gases.

At FLASH a gas attenuator system based on single photon absorption in a gas is in routine operation to attenuate the photon pulse energy (in average 10 $\mu$ J) on user demand. Common examples are the alignment of samples at moderate pulse energies, or the stepwise reduction of photon intensities without changing the focusing geometry in experiments investigating strong field phenomena. The principle of attenuation by photon absorption in a dilute gas combines several advantages such as:

- i) Reduction of pulse energy without altering the photon beam characteristics
- ii) Fast and flexible variation of the attenuation due to simple pumping schemes.

The attenuator consists of a windowless 15m long gas cell in combination with two differential pumping units at both ends. The maximum gas pressure is  $\sim$ 0.1 mbar resulting in an attenuation range of at least 5 orders of magnitude. Figure 1 shows the calculated transmission of the gas cell at a pressure of 0.1mbar for N<sub>2</sub>, Kr, and Xe.

## BASIC LAYOUT OF THE GAS ATTENUATOR

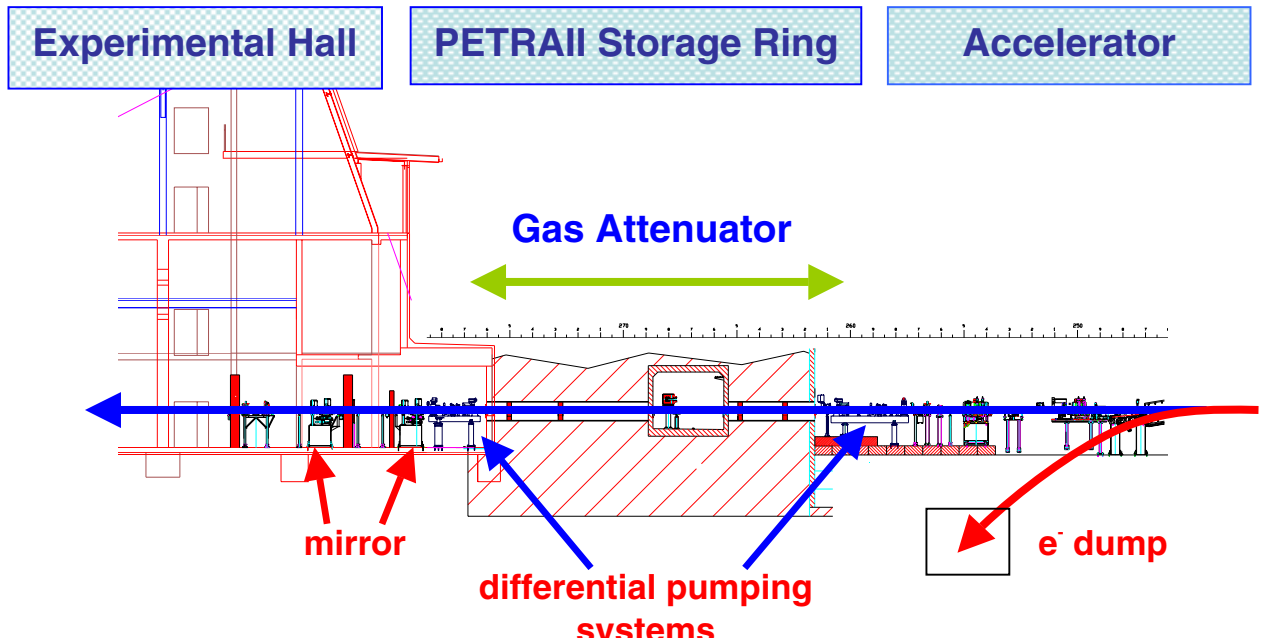


Figure 2: The layout of the gas attenuator at the crossing of the storage ring PETRA II and FLASH

Figure 2 shows the layout of the FLASH gas attenuator. On the right, the electron and photon beams are separated with the help of a dipole magnet. The FEL photons leave the accelerator tunnel and pass the storage ring PETRAII to attain the experimental hall. The 15m long drift section through PETRAII is an ideal place to install a gas attenuator system, since this section is located in front of the photon beam distribution optics.

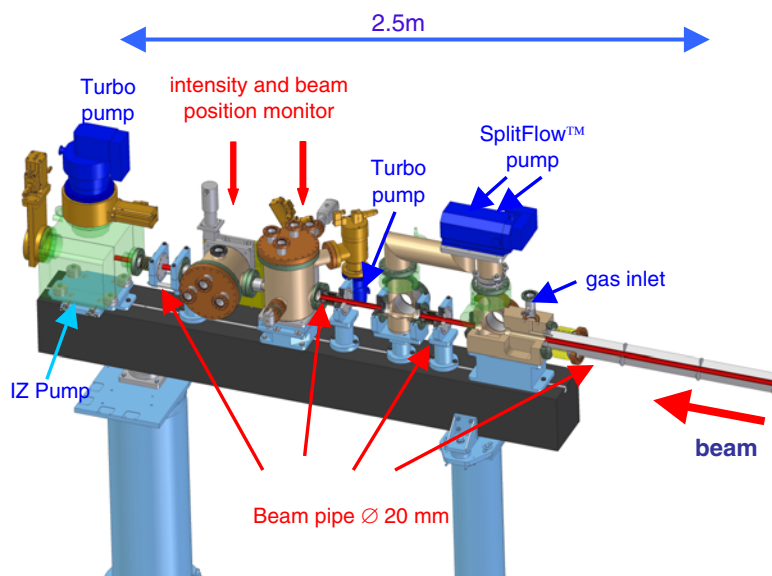


Figure 3: Differential pumping system at the entrance to the experimental hall.

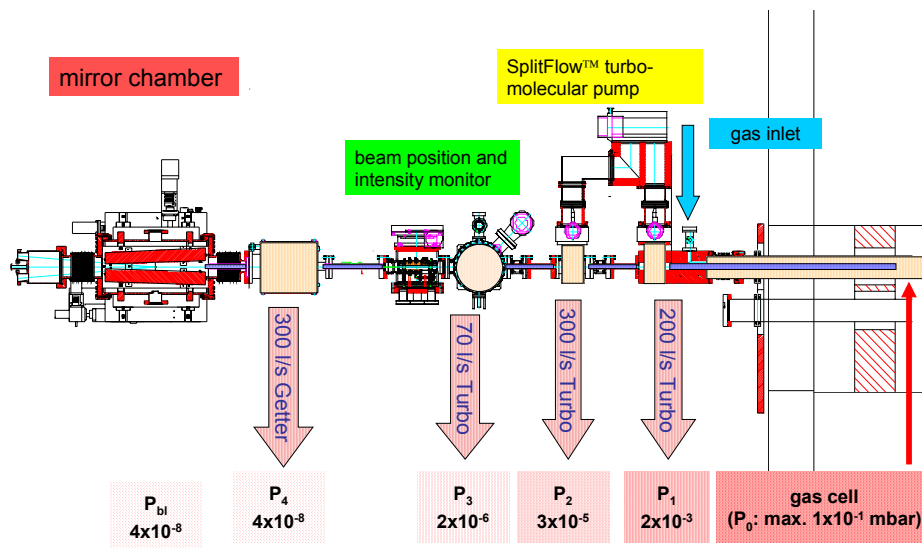


Figure 4: Calculated pressure distribution of the gas attenuator for  $N_2$

Both sides of the windowless drift section, which is formed by a  $\varnothing 100$  mm beam pipe, are terminated by a differential pumping stage to preserve the beamline vacuum. Thus, the whole drift section of PETRAII can act as a gas cell. Figure 3 shows one differential pumping stage with integrated intensity and beam position monitor (GMD)[1]. The system is arranged in four pumping sections. Each of these sections is connected by conductance limiting pipes with inner diameters of 20 mm. Since the lower limit of the inner diameter is defined by the clear aperture of the optical system, the lengths of the pipes are determined by the desired pressure gradient of each pumping section. We installed three pumping steps. One section, which is used for the GMD device, does not contribute to the differential pumping. The whole pumping system has to cover 8 orders of magnitude pressure gradient between beamline and gas cell. Therefore, each real pumping step has to reduce the pressure by a factor of  $10^2$ . In the molecular flow regime this factor is achieved by pumping speeds  $>100$  l/s and  $\sim 250$ mm long (20mm  $\varnothing$ ) pipes reducing the conductance to about 1 l/s. The first pumping step is operated in the transition range between 0.1mbar in the gas cell and  $2 \cdot 10^{-3}$  mbar in the beamline. Conductance calculations [2] for  $N_2$  in the Knudsen range result in a length of 1.3m to achieve a conductance of 1 l/s. A scheme of the calculated pressure distribution along the differential pumping unit is shown in Fig. 4. The arrows represent the applied pumping speeds and the underneath panels show the resulting pressures in each section. A pumping speed of 70 l/s at the GMD position is required to regulate the pressure in this diagnostic device. All the pipes have to be aligned with a tolerance of  $<0.3$ mm in order to avoid perturbations of the photon beam.

## TECHNICAL REALIZATION AND FIRST MEASUREMENTS

### Pumping

At the high pressure side we have chosen a SplitFlow™ turbomolecular drag pump, which serves the two “high” pressure pumping ports. The capability of the SplitFlow™ pump has been tested in the setup shown in Fig. 5. Here, the pumping ports and the gas inlet are connected with a conductance of  $\sim 10$  l/s. The graph on the right depicts the results of the measurements. It shows that the intermediate port of the pump is able to handle a gas pressure of 0.1mbar.

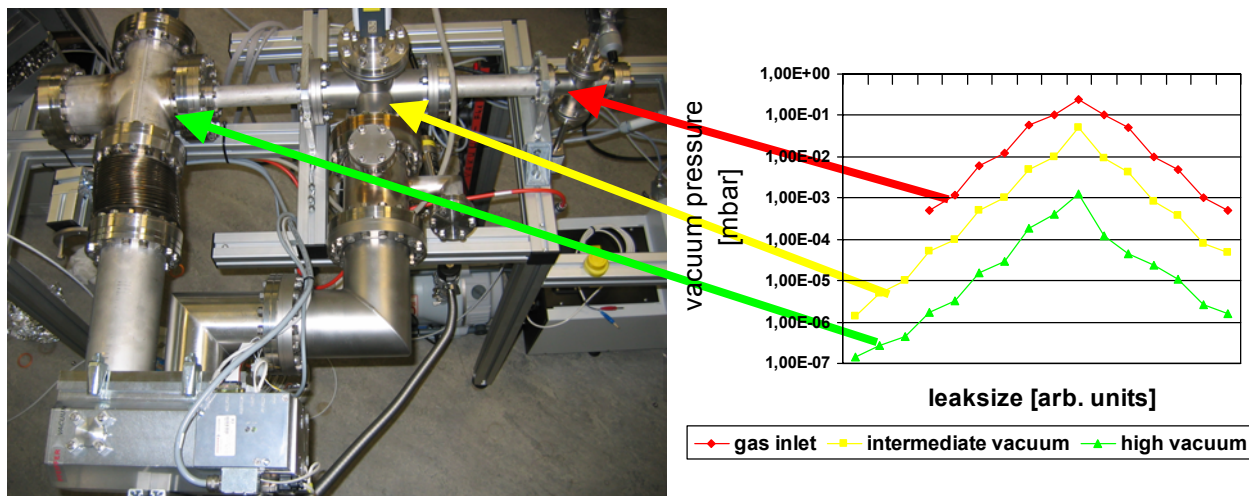


Figure 5. Set up to investigate pumping capabilities of the SlitFlow™ turbomolecular drag pump [3]. On the right are measurements of the inlet pressure (diamonds), the pressures on the intermediate (squares) and the high vacuum port (triangles).

The interface section to the beamlines is equipped with a 300 l/s noble diode ion getter pump in inline configuration (the beam passes directly the pump body). Noble diode ion pumps are chosen, because of their high stability when pumping rare gases. This inline pump is supplied with an additive Ø150mm flange to enable the installation of an additional turbomolecular pump (see Fig. 3), which will support and stabilize the pumping system in case of highest rare gas load.

## Alignment

A crucial point is the alignment of the narrow and long pipes of the differential pumping set up. All components of the differential pumping system have been placed, aligned and fixed on granite girders (see Fig. 3) before setting in place. Here, T-slots on the granite girders allow precise alignment by tongue and groove joints in an easily reproducible way. The joints guarantee an exact positioning (<0.3mm) of the installed components with respect to the beamline axis. The alignment of the girders on the other hand is realized by a special supporting structure. This procedure saves a lot of individual alignment work. Due to technical reasons the 1.3 m long pipe (Fig. 3) is supported on the gas inlet side only. To minimize the bending of the pipe a sophisticated supporting rip structure was designed. This enables a deflection free installation of the beampipe.

## First Results

Figure 6 depicts the comparison between the calculated and measured transmission of the gas attenuator for a photon wavelength of 30nm. The transmission has been determined with help of the GMDs in front and behind the gas attenuator. The gas pressure was controlled by a gas dosing valve.

The pressure readings and the transmission are plotted on double logarithmic scales. The plot shows a fairly good agreement between the calculated and the measured transmission. The

detection efficiency of the second GMD set a lower limit of 5% for the transmission measurement. The overall good agreement allows to extrapolate the expected transmission to higher gas cell pressures.

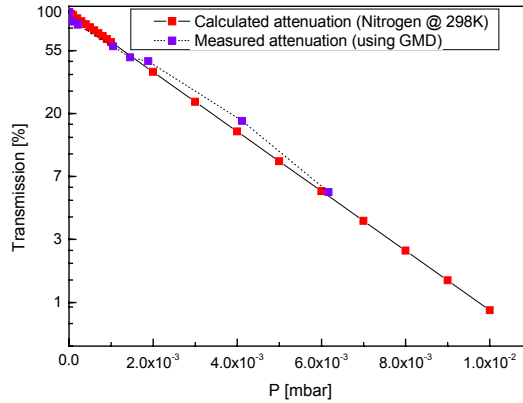


Figure 6: First transmission results with the gas attenuator.

Figure 7 depicts a performance test of the attenuator system. The blue line represents the measured transmission versus time for different attenuator settings. One can see that the system is capable to change the transmission within minutes depending on the active gas and wavelength.

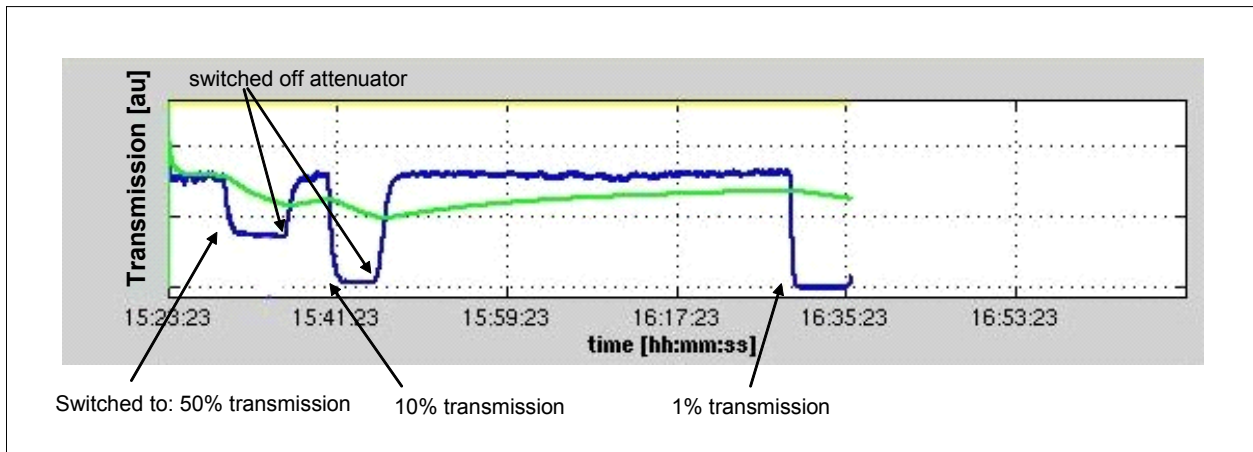


Figure 7: Performance test of the attenuator. The blue curve shows the transmission signal in real time, while the green curve shows a time-average with a time-constant of 30 min.

## References

- [1] M. Richter, A. Gottwald, U. Kroth, A. A. Sorokin, S. V. Bobashev, L. A. Shmaenok, J. Feldhaus, Ch. Gerth, B. Steeg, K. Tiedtke, R. Treusch, *Measurement of gigawatt radiation pulses from a VUV/EUV Free-Electron-Laser* Appl. Phys. Lett. **83**, 2970-2973 (2003)
- [2] M. Wutz, H. Adam, W. Walcher, and K. Jousten, *Handbuch Vakuumtechnik*, Vieweg Verlag, ISBN 3-528-54884-3, (2000)
- [3] SplitFlow™ turbomolecular drag pump, *TMH 261-250-010P*, Pfeiffer Vacuum Technology AG, [www.pfeiffer-vacuum.net](http://www.pfeiffer-vacuum.net)