

Precision Attenuator for Hard X-Rays

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Abstract. For many applications at hard x-ray beamlines at lab sources and synchrotron radiation sources the detected intensity spans more than six orders of magnitude [1]. An integrated flux of more than one million counts per second is far too much for most of the detectors in use, which can even be severely damaged on saturation. For this reason, x-ray beamlines are equipped with so-called attenuators (or absorbers) which reduce the beam load on the detector by blocking the beam with a (for x-rays) semi-transparent material (called filter or foil).

At Deutsches Elektronen-Synchrotron (DESY) in Germany a team of scientist and engineers developed a Precision Attenuator for Hard X-Rays that provided the ability for scientists to reduce the incident x-ray flux to any desired value at arbitrary photon energies between 5 and 30 keV [2]. This system uses 12 foil carriers, 2.1cm x 2.1cm square aperture (20 mm x 15 mm effective aperture) designed for high-vacuum capability (1e-7 mbar). An actual precision attenuator is shown in Figure 1.



FIGURE 1. ADC Precision Attenuator

Design Features

- 12 Foil carriers, 2.1cm x 2.1cm square aperture (20 mm x 15 mm effective aperture)
- Foil carriers can be loaded with other items of similar size such as photodiodes
- Foils can easily be exchanged for others of different metal and thickness, including calibration foils
- Low power electrically controlled
- Easy filter/absorber changes (using pressurized air: 3 – 8 bar), speed is adjustable through screws on the pneumatic actuators
- Usable in a wide energy range (Type 1: 5-30 keV; Type 2: 2.5-20 keV)
- High-Vacuum Capability ($1\text{e-}7$ mbar)
- No vacuum feed-through used
- Stiff structure and minimal vibration
- Reliable detection of the actual position of the slides (in or out of the beam)
- The ABS-300 precision attenuator is controlled using a Beckhoff BC9000 Bus Controller, but could be operated with other controllers. The BC9000 Bus Terminal Controllers are Bus Couplers with integrated PLC functionality and have a fieldbus interface for Ethernet.
- Can manually move the slides from the outside without venting or feedthroughs
- At 3rd generation synchrotron radiation sources the beam can be micrometer sized. As the foils are not made fully homogeneous it is mandatory for an absorber that it stand still and that the same spot is always illuminated. Our product does this well.
- NW40 or DN40 flanges, or adapters for Blake Industries beam tube available to meet customer needs
- Most similar products contain only 4 foils, requiring three stacked together to provide functionality through such a wide energy range
- Experimental Physics and Industrial Control System (EPICS) compatible



FIGURE 2. Precision Attenuator Controller

ABS-300 Controller

The ABS-300 precision attenuator is controlled using a Beckhoff BC9000 Bus Controller, seen in Figure 2, but could be operated with other controllers. The BC9000 Bus Terminal Controllers are Bus Couplers with integrated PLC functionality and have a fieldbus interface for Ethernet. They are intelligent slaves that can be used as a non-central intelligence in the Ethernet system. One unit consists of the Bus Terminal Controller, any number of

terminals between 1 and 64, and a bus end terminal. The Bus Terminal Controller is programmed using the TwinCAT programming system according to IEC 61131-3. The configuration/programming interface of the BC9000 is used for loading the PLC program. If the software PLC TwinCAT is in use, the PLC program can also be loaded via Ethernet.

The BC9000 Bus Terminal Controllers support the operation of all Bus Terminal types. As far as the user is concerned, the inputs and outputs are not handled any differently from the way they are by other coupler series. The information is made available for use as a byte array in the process image of the automation device. The analog and multi-functional Bus Terminals can be adapted to each specific application using the KS2000 configuration set. Depending on the type, the analog Bus Terminals' registers contain temperature ranges, gain values and linearization characteristics. With the KS2000, the required parameters can be set on a PC. The Bus Terminals store settings permanently and in a fail-safe manner.

The ABS-300 precision attenuator is of the filter bank rather than wheel type. It is an economical and robust absorber system which can be used in a wide energy range, depending on the choice of filters. The provided filters may easily be swapped for filters of other thicknesses and metals as needed by the researcher. It is high-vacuum capable to $1\text{e-}7$ bar. The filters are moved by means of pneumatic actuators which are located on the outside and are coupled magnetically to the filters inside the vacuum. This means that no vacuum feed-through has been used for this design and that the absorber moves promptly and quickly.

In the presented setup 12 different filters (made from ultrapure aluminum, titanium and copper) can be moved into the beam and small reed-sensors detect success of the movement. The communication with external control systems is in the presented setup done by a stand-alone Beckhoff controller. However, any external 24V-toggle signal can be used to drive the single pneumatic actuators, and the reed-sensors are simple switches which can be read by TTL-logics.

In terms of the filters, it has been taken care that, beginning from the thinnest filter, every other absorbs twice as much as the former (in the linear configuration) so that the filter bank can be accounted as a bit-number. By proper bit-combinations any absorption factor can be approximated in a photon energy range from 5-30 keV. Another nonlinear filter is offered which spans 2.5-20 keV.

TABLE 1. Absorber Configuration 1 (Linear Increase in absorption)

Thicknesses t of the foils				
	theoretical	theoretical	theoretical	actual combination
number	t Al (μm)	t Ti (μm)	t Cu (μm)	All figures given in μm
1	25			Al25
2	50			Al50
3	100			Al100
4	200			2 x Al100
5	400			Al250 & Al100 & Al25
6	800			Al500 & Al250 & Al50
7	1600	234.1		Ti125 & 2 x Ti50 & Al50 & Al10
8	3200	468.2		3 x Ti125 & Ti50 & Al250 & Al50
9	6400	936.4		7 x Ti125 & Al250 & Al50 & Al25
10	12800	1873	403.4	4 x Cu100 & Al100
11	25600	3746	806.8	2 x Cu250 & 3 x Cu100 & 2 x Al100
12	51200	7491	1614	Cu1000 & 2 x Cu250 & Cu100 & Al250 & 2 x Al100

TABLE 2. Absorber Configuration 2 (Non-linear increase in absorption)

Thicknesses t of the foils				
number	theoretical t Al (μm)	theoretical t Ti (μm)	theoretical t Cu (μm)	actual combination All figures given in μm
1	6			Al6
2	12			2 x Al6
3	24			Al125
4	48			Al50
5	106			Al100 & Al6
6	230			2 x Al100 & Al25 & Al6
7	500			Al500
8	1070			2 x Al500 & Al50 & Al25
9	2300	327.6		7 x Ti125 & Al250 & Al50 & Al25
10	5000	712.1		4 x Ti25 & Ti50 & Al250
11	10700	1524	341.8	3 x Cu100 & 3 x Cu25 & 2 x Al250 & Al25
12	23500	3347	750.7	3 x Cu250

Standard devices for this are wheels with a number of different foils or filter banks. These simple devices have several disadvantages:

- Mostly they are not in vacuum and are therefore not appropriate for photon energies below 5keV. If they are in-vacuum devices they are extremely expensive.
- Especially wheels are restricted to a quite narrow photon energy range due to a lack of sufficient number of different foils.

For further flexibility the system has several possible mounting configurations. It can be placed entirely upside-down and the pneumatic manifold can be removed and placed separately or placed on top of the chamber unit. Note that more tubing will be required for other manifold mounting locations. The lower leg and manifold assembly is held in place using just four bolts, so that reconfiguration is easy.

CONCLUSIONS

ADC has taken a laboratory Precision Attenuator for Hard X-Rays system by Deutsches Elektronen-Synchrotron (DESY) in Germany and has turned it to a robust commercial work horse. In this process ADC implemented more user friendly features as well as many improvement that are based on feedback we receive from our customers. Users are now able to use this Precision Attenuator for Hard X-Rays that provided the ability for scientists to reduce the incident x-ray flux to any desired value at arbitrary photon energies between 5 and 30 keV.

REFERENCES

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