Compact beam conditioning unit
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Abstract. A new modular beam conditioning unit is presented. The unit can be freely arranged to meet the requirements of the specific experimental setup. Currently the following modules are available: High precision beam position monitor, slit screens, filter wheel, ultra-fast shutter, beam stop and an in-line microscope. Special emphasis was put on the flexible and space saving design.

Introduction
For measuring small samples – or even fractions of it – precise knowledge of the beam position and beam shape as well as the exposure time is of paramount importance. We have therefore developed a beam conditioning unit (BCU) which combines all major beam manipulation aspects in a modular and individually configurable system:

As a basis for precise beam handling, a beam position monitor with sub-micron resolution and kilohertz readout allows for passive beam diagnostic (vibrations, drift due to changing heat load of optical components) or active re-positioning of the sample to the beam can be installed as the first component of the BCU.

A set of high precision slits allows for an evenly precise definition of the beam size and in combination with the inline microscope, the beam can be precisely positioned to a certain detail of the sample, avoiding the exposure of the matrix.

The included shutter has an ultrafast opening/closing time of better than a millisecond which can be furthermore combined with a second shutter as a first/second curtain for ultra short and extremely well defined exposure times, like it is needed for fast rotating samples. Other components like e.g. a filter wheel or PIN diodes for diagnostics of the exposure time and dose round off the BCU.

In the following, we describe the performance of the individual modules in detail.

Technical description of the modules
The example below shows a typical configuration of a Beam Conditioning Unit. After the beryllium entrance window the beam position- and intensity monitor is located. After that two pairs of slits are following for in situ beam definition. Between the first pair of slits and the second one there is a filter
wheel and the shutter. Right before the exit of the beam (which is window free in this example) an optical system for inline observation of the sample is integrated. At the end of the unit there is a beam stop. The diffuse scattering of the beam at the beam stop/sample is recorded by a PIN diode in order to determine the exact exposure time and dose. The configuration showed here has a total length of about 420mm in beam direction. The typical energy range which is depending for example on the material used for the slits and the gas filling of the beam monitor is about 5 keV – 24 keV.

Figure 1. Arrangement of the modules in a BCU.

**Position and intensity monitor**

The beam position and intensity monitor [1] is realized by a split ion chamber in a nitrogen atmosphere. The measurement range is 6 mm in horizontal direction and 4 mm in vertical direction. For rough adjustment and for calibration the whole ion chamber can be scanned by means of built in high precision stages (backlash typically < 3µm, repeatability typically <0.5 µm) in a range of +/- 4 mm. The ion chamber requires an external power supply of -1.5 kV. In order to determine the lateral position of the photon beam within the ion chamber the anode is realized by two diagonally separated areas. Ion currents are measured with precise trans-impedance amplifiers. By comparing the ion currents, the beam position is calculated.

In order to test the split ion chamber a “Libera Photon” was used which is an x-ray beam position processor supplied by Instrumentation Technologies [2]. The Libera Photon features 4 current-type inputs having wide input current range (200 pA to 1.85 mA). Voltages from trans-impedance amplifiers are sampled with high speed 24-bit analog to digital converters. A FPGA computes and delivers the beam position at three different readout rates (ADC rate, 10 kHz and 10 Hz). The readout and control software allows multiple settings in order to facilitate the instrument integration and calibration.
The described beam position monitoring system was evaluated on beam line BM16 at the European Synchrotron Radiation Facility (ESRF). During measurements the storage ring at ESRF had 188mA of stored current with a 7/8 + 1 bunch fill pattern. The presented measurements were recorded at fixed energy of 12keV x-ray beam. Calibration constants for position and current dependency were extrapolated from diagonal scans.

Below results recorded at 10 kHz data rate were present. In Figure 2 (left), the integrated beam position is shown followed by fitted projections in X and Y coordinate. Performing a fast Fourier transformation on the same set of data, beam dynamics can be seen for both coordinates in Figure 3.

![Figure 2. Integrated beam position](image1)

![Figure 3. Beam oscillations in X and Y coordinate](image2)

**Slit modules**

Depending on the needs a variable number of asymmetric slit modules can be integrated in the system. The slits are available to be horizontal or vertical. Typically one slit pair is used at the beam entrance and another one at the exit working as guards for the scattered beam of the first slit pair. Each slit module consists of a pair of two blades (max aperture 6mm) which can be individually positioned and
can be equipped with encoders to improve the repeatability below one micrometer. Operation in a defined atmosphere (helium for example) or under vacuum is possible.

Shutter module
A high speed millisecond shutter is available for control of the exact sample exposure time. Opening and closing time are in the range <1ms. The beam absorbing blade is made of 1mm steel and is moved by means of two electromagnets for opening and closing respectively. For exact timing a PIN diode is available as feedback. If required also the shutter can be operated under vacuum.

Filter Module
Since filters for beam attenuation and energy calibration are very useful there is a filter wheel containing 12 positions (11 filters and 1 open position). The filter material is user configurable by changing the filter discs of 14mm diameter. Operation under vacuum or defined gas atmosphere is possible.

Inline Optics and Beam Stop
The last module towards the sample contains an in-line-optics with very high resolution for sample observation during the experiment or crystal alignment. The magnification of 4x/0.20 is fixed but since the resolution of the optics is well beyond 3µm zooming is realized by a high resolution (2448 x 2050 pixels) CCD camera. The working distance of the module to the sample is 40mm. For sample illumination two 3W LED’s are integrated in a focusing Wolter optics. Another PIN Diode is integrated here for feedback.

The beam stop is mounted on the optics stage. It is realize by a silver rod with 2mm diameter and 10mm length. The beam absorbing silver rod can be moved by means of a piezoelectric actuator for adjustment or observation of diffraction peaks of very high order. Since beam stops are always a critical and fragile part the whole beam stop can be driven in a protected parking position for sample change.

Controller
The Beam Conditioning Unit comes together with a modular control box. It is equipped with a RS232 interface to control the different units. With simple commands which also can be sent from SPEC for example the BCU can be addressed. Most signals and controls are also accessible via connectors directly on the back panel of the controller.

References
[1] W Schildkamp, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 258, Issue 2, 1 August 1987, Pages 275–280

[2] www.i-tech.si