The Generic Beamline Concept of the New PETRA III Undulator Beamlines


The conversion of the PETRA storage ring at DESY to a third generation synchrotron radiation light source [1] poses a challenge to the design of the beamline transport system. The total power in the white beam will be as high as 7.5kW in the case of the 5m long undulator at 100mA. The power density will be 476 W/mm² at 20m from the source. Upgrades to a beam current of 200mA are accounted for in the design of the beamline components. For the beam transport between the undulator and the experimental hall the design of a generic beamline is presented. This generic beamline consists of the estimated maximum of components for this purpose. Special experimental needs may reduce the number of proposed devices in the generic part and add special optical devices close to the experiment. The girder concept for the support of all major beam transport components is presented, as well as the design of the high power shutter - slit system.

![Figure 1: A look into the PETRAIII tunnel section with two 2 m undulators (left) with their beamline front end. On the right a 5 m undulator is installed.](image)

14 independent undulators will deliver high quality beams for experiments. Four of the undulators are 5m long single devices. The other ten are 2.5m long. Pairs of the 2.5m long devices are arranged canted by 5 mrad in the 5m long straight sections. In Fig. 1 a PETRA III tunnel segment with the undulator and the beamline front end is shown.

The main tasks of the generic beamline are the following:

- provide a hydrocarbon free and dust free vacuum system connected directly to the storage ring
- transport the photon beam from the undulator to the experiment, conserving the beam properties in spite of the high power density
- shape the beam with fixed and movable masks, reduce the power load on optical components
- ensure radiation safety by collimation and suitable beam stops
- ensure equipment protection by an appropriate vacuum interlock system
- give access to the experiment conserving the thermal balance of the optical components
- monitor the photon beam position
- filter the white beam to reduce the power load and to suppress harmonics
- monochromatize the white beam
- collimate or focus the white or monochromatic beam
The layout is split into two parts separated by the storage ring tunnel wall. Optical components, as mirrors and monochromators, will be placed outside the ring tunnel.

**GENERAL BEAMLINE INSTALLATIONS**

Inside the ring tunnel all components in the photon beamline dealing with radiation safety, beam position and beam collimation will be placed as shown in Fig. 2.

![Diagram of beamline layout](image)

**Figure 2**: The generic beamline layout for a single beamline covering the transport inside the tunnel and the first optics hutch. The scale measures the distance from the undulator source.

PETRA III will run in a continuous filling mode which requires a special arrangement of radiation safety components. For a fail-safe particle injection, each beam outlet has to be equipped with a permanent magnet which extracts misguided particles out of the photon beamline. The beam shutter will be placed directly in front of the storage ring wall. A photon shutter protects the beam shutter absorbing the full photon beam power.

Space is also needed for the fast acting valve to protect the vacuum system against accidental venting. The pressure rise trigger devices will be installed in the first optics hutch. The windowless beam transport system will connect the storage ring and the first optics hutch. The high heat load monochromators, possible mirror chambers and Bremsstrahlungs stops with secondary beamshutters are placed inside this hutch.

In the following two main aspects of the generic beamline layout are described: The girder concept for all major beam transport components and the collimating slit and shutter system which has to deal with the high power density of the PETRAIII undulator.
THE GIRDER CONCEPT

Figure 3: The four granite girders of the canted undulator beamline. The interleaved arrangement of the components allows for an optimized usage of space. Functional units are kept together on one girder for an easy and reproducible exchange.

There is a lack of space in the PETRA III storage ring tunnel. The lateral distance to the tunnel wall is 50 cm only. Because of the large PETRA III bending radius and the small bending angle between the straight sections the photon beamline separates from the machine very slowly. Additionally, the 10 canted beamlines have an angular separation of 5mrad only. Therefore all major beamline components in the storage ring tunnel will be placed, aligned and fixed with granite girders (see fig. 2 and 3) before setting in place in the storage ring tunnel. Precision T – slots on the granite girders allow to align and to fix the components supported by the girder in an easy reproducible way. These slots guarantee an exact relation of the installed components to the beamline axis. There are several suppliers for such granite beams with high precision (flatness <10µm, straightness of the slot <10µm). The beamline components are aligned to each other very precisely on the girder. This is especially advantageous for the canted beamlines with the 5mrad horizontal angle between the beamlines. The girders are supported with a three point kinematic mount system on two sand filled steel columns. The kinematical mount, which are used as the supporting elements, are precision balls with the same size as the retro reflectors of the laser tracker system used for the basic alignment. This allows the alignment of the support system with high precision. The girder system allows a precise pre-alignment of the beamline components outside the storage ring tunnel. The initial positioning and replacement of a whole girder using a backup system reduces the setup and the maintenance time of the beamline components.
HIGH POWER SLIT AND PHOTON SHUTTER SYSTEM

There exist several approaches for high power slit systems [2, 3, 4]. The design of the PETRA III slit systems is shown in Fig. 4. The first slit collimates the beam vertically by absorbing the off-axis radiation of the undulator. The second slit system additionally acts as a power absorber to shut off the photon beam [4]. While the first slit collimates only in the vertical direction, the second slit also collimates in the horizontal direction. Fig. 4 shows a vertical cut through the slit jaws of the shutter - slit system [5]. The upper and lower jaws consist of an inclined water cooled absorber which accepts the beam power. The absorber material is GlidCop®. The cooling channels are machined to wind in a spiral around the central copper block.

Figure 4: High power slit system and photon shutter suitable for PETRA III undulator beamlines.

This absorber block finally is brazed into a stainless steel body. Pockets in front of the jaws allow dissipating the low energetic radiation in carbon, whereas a tungsten disk behind the jaw will stop most of the high energetic radiation to reduce the background radiation at the experimental area. The slit height is controlled by one drive moving both jaws.

Figure 5: Calculation of the typical thermal (left) and von Mises stress (right) distribution of the absorbed undulator beam at the second shutter - slit jaw.
The vertical slit position is adjusted by moving the whole assembly up or down, the slit opening by a relative movement of both slit jaws. The shutter function is achieved by a pneumatic cylinder incorporated in the vertical slit drive.

Fig. 5 shows a single slit jaw shaping the beam vertically at 28m from the source. FEM model calculations (ANSYS) with a typical power load on a single slit jaw at an inclination angle of 1.4° have been performed. The calculations for a 5m undulator at a current of 100mA show, that the beam shaping with the slit system will cause a maximum temperature of 150°C at a water-cooling temperature of 20°C. The 2.5 m long canted devices will deliver the same power at 200mA beam current. The stress inside the L-shaped jaw is lowered by the relief cut in the slit corner ending in the relief bore as shown in Fig. 5. The maximum von Mises stress of approx. 500 MPa is uncritical for Glidcop®.

References