The adjustment laser system for the PETRA III frontends

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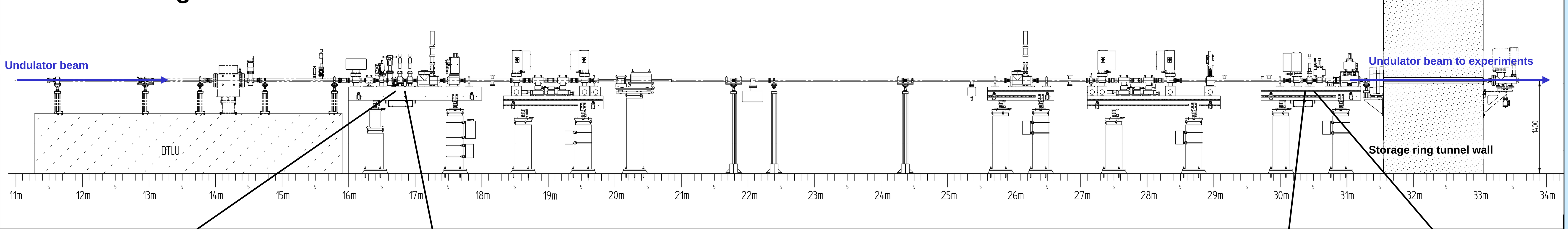
Motivation:

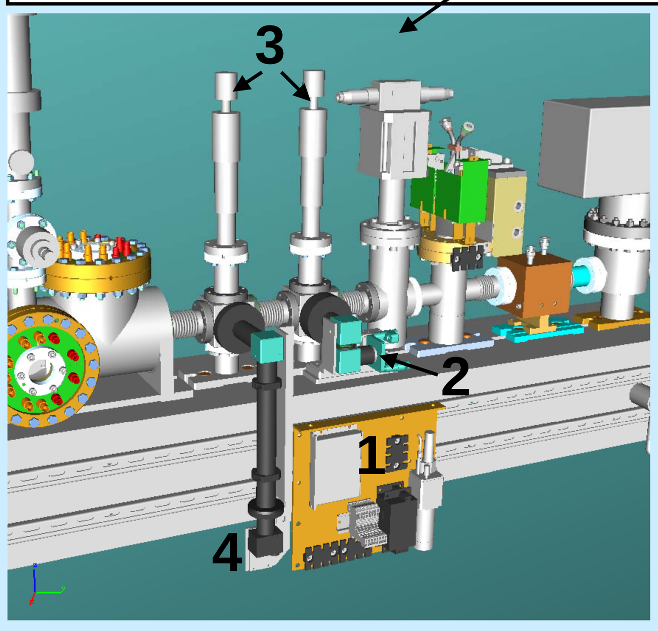
The PETRA storage ring at DESY will be upgraded to the third generation synchrotron radiation source PETRA III [1]. An adjustment laser system for the convenient alignment of the PETRA III frontend components [2] has been designed and prototyped. Especially in the start-up phase it will be a useful tool to check the alignment of components and to verify that the optical path is free of obstacles.

System overview:

A fibre coupled laser is fed into the beamline vacuum system via a view port and a switchable mirror. The position and direction of the laser beam inside the beamline is adjustable remotely. Two screens can be moved into the beampath and serve as position detectors for the alignment of the laser beam (Operation mode 1). The screens are monitored with cameras. The position of the laser spot on the screen is determined by an image processing algorithm (see "beam position measurement" below). For this purpose, each screen is provided with a reticule as a reference mark. The screens can also be used to monitor the attenuated white undulator beam. This mode monitors the fluorescence of screens made out of CVD diamond [3] (Operation mode 2).

The PETRA III generic frontend:





The laser unit and the first screen unit:

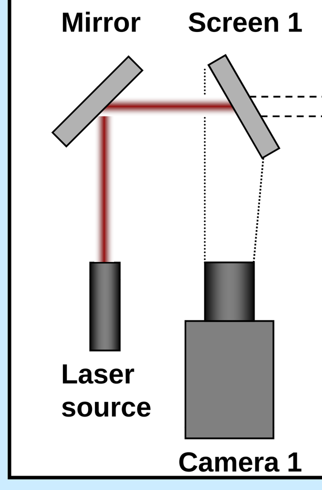
1: Electronics (laser source, Pico motor driver and power supplies)

2: Micro-positioning devices (Pico motor) for the alignment of the laser beam

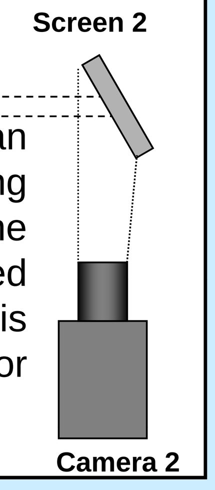
3: Pneumatic actuators move the mirror and the screens in and out

4: Camera observes the screens

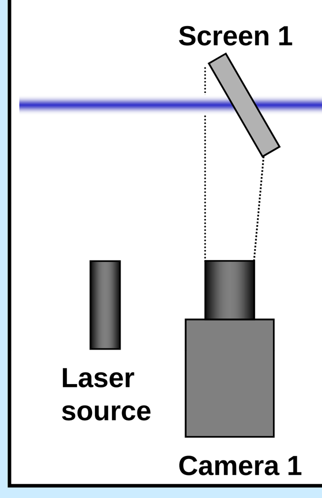
Operation mode 1: Adjustment laser



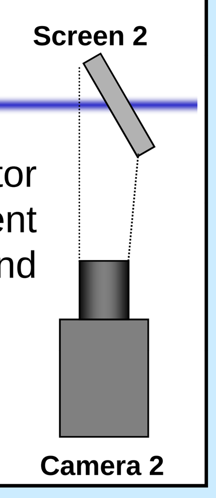
The undulator beam is switched off. The mirror is moved into the beamline. The laser beam can now be adjusted by moving the screens 1 + 2 into the beam pass alternately and then adjusting the laser to the center of the screens. This is repeated until the laser beam is centered to the beamline axis. Alternatively, the laser beam can be aligned to any arbitrary axis, e.g. the shifted beam axis of the undulator, that was detected in operation mode 2 (see below). Once the laser is aligned, one can check front end components such as apertures, slit systems or filter units for their proper operation and alignment.

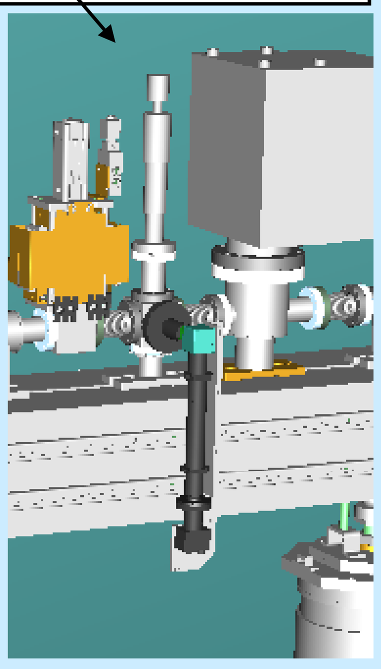


Operation mode 2: Fluorescence monitor



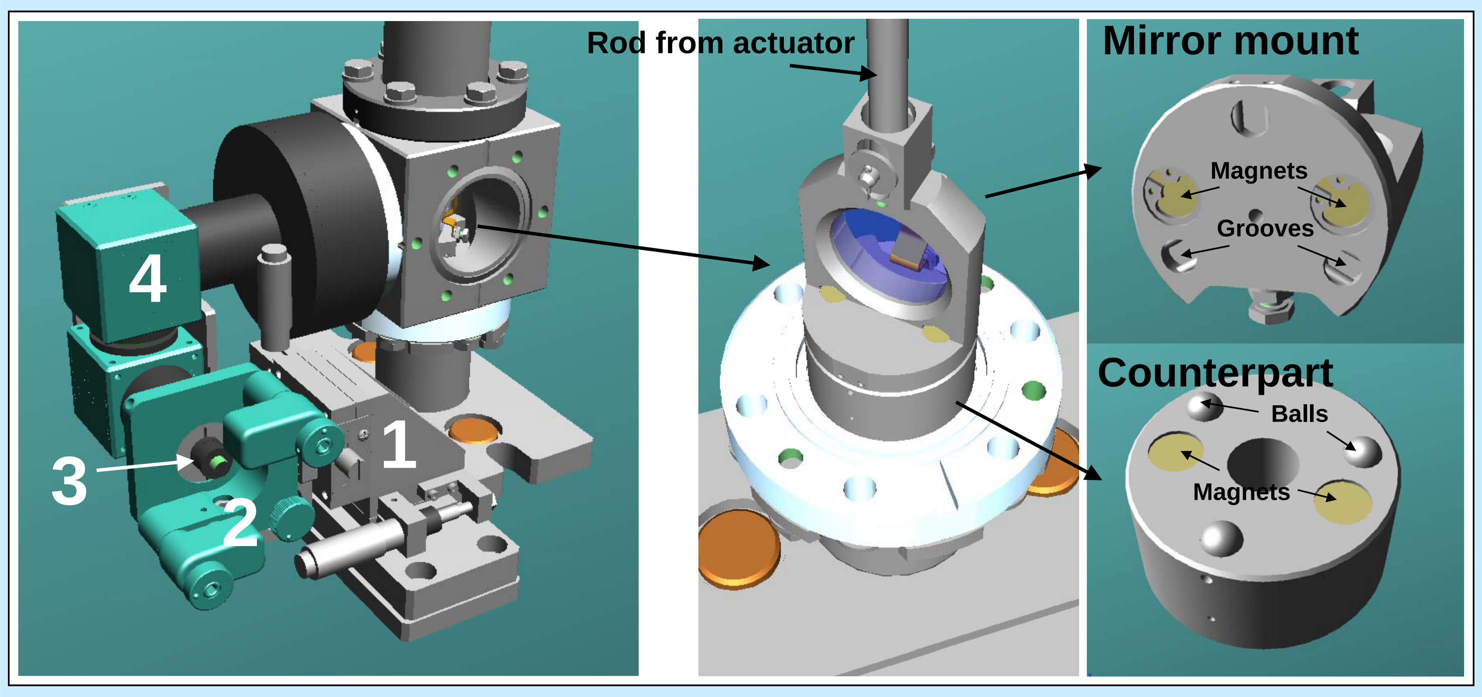
The laser beam is switched off and the laser mirror is moved out of the beam. The undulator beam operates with very low power (few Watts). In this mode, the screens work as fluorescent beam position monitors. Operation of front end components can be checked and the shape and position of the undulator beam can be detected.





The second screen unit with camera

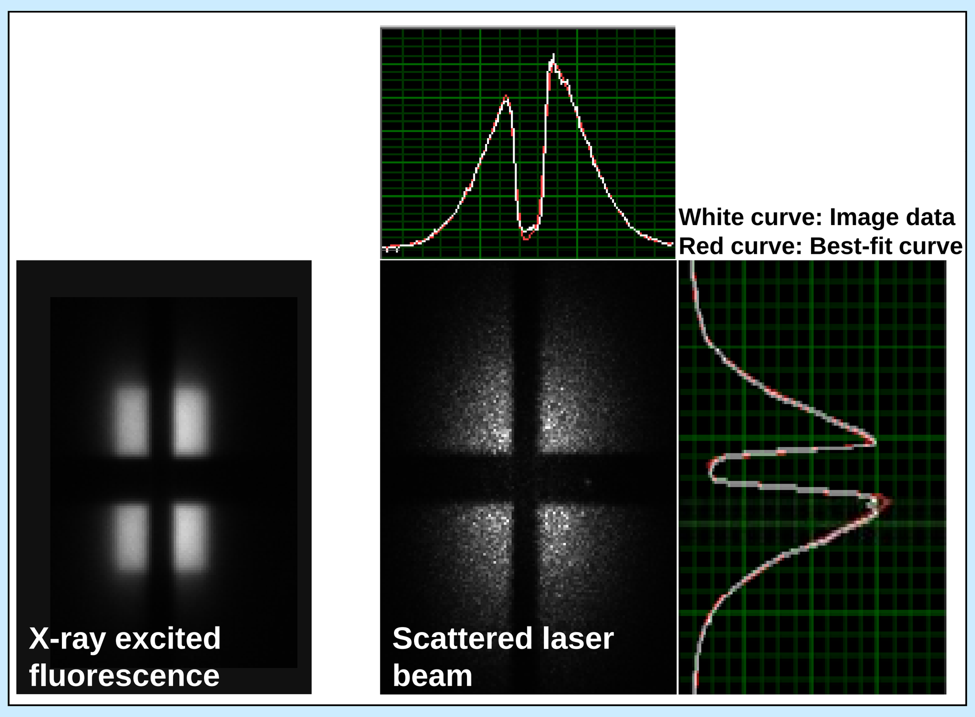
Mechanics:



The laser unit:
1: Horizontal and vertical position adjustment of the laser beam, manually operated
2: Horizontal and vertical angle adjustment of the laser beam, motorized with picomotors
3: Laser collimator; the fiber from the laser source is connected here (not visible)
4: Flight-tube with mirrors

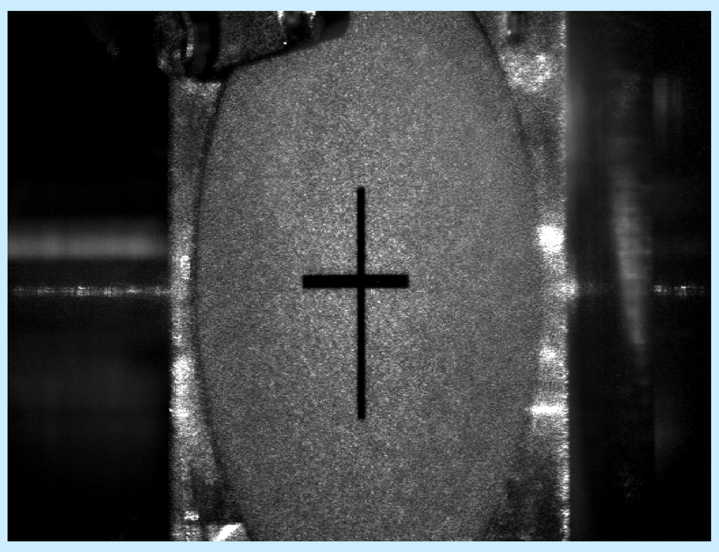
Before the laser beam can be used to check the alignment of the beamline components, it needs to be aligned to the principal axis of the beamline. The aim is to achieve an accuracy of the laser beam alignment of +/- 0.1 mm along the frontend. As the frontend is about 15 m long, an angular laser beam alignment of ~ 1 µrad is needed. For this purpose, a Pico motor-driven mirror-mount is used (No. 2 in the image to the left). It has an angular resolution better than 0.7 µrad and is remote controllable via Ethernet or RS 232. Furthermore, the switchable mirror for the in coupling of the laser should have an angular reproducibility < 1 µrad. To achieve this high reproducibility, a kinematic mirror mount was designed. In contrast to the "groove, cone and plane" design, the three grooves solution, each defined by a pair of hardened dowels, was chosen. To keep the mirror mount free of any force or torque from the actuator, a special link has been designed: As soon as the mirror mount is settled on its counterpart, there is no mechanical contact between the actuator rod and the mirror mount. This is achieved by simply providing this link with a large play (see the middle image on the left). Additionally, the mirror mount is pulled down onto the counterpart by means of two pairs of strong permanent magnets.

Beam position measurement:

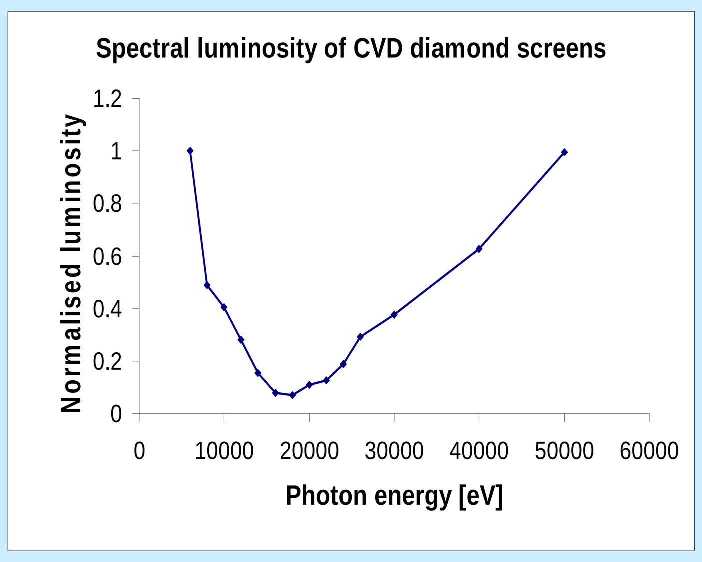


Processing of the images acquired by the cameras. The principle is the same for undulator beam excited fluorescence and scattered laser light. The evaluated region of the image is kept as small as possible to increase the sampling rate.

The images acquired by the cameras are averaged along the rows and the columns. These projections are then fed into a fit algorithm. From the best-fit parameters, the position of the laser beam with respect to the reticule is determined. The resolution of this position measurement has proven to be around 1 µm. The sampling rate of the position measurement is about 5 Hz, which is due to the amount of data that have to be processed. Since the reticule is positioned precisely on the principal axis of the beam line, the laser beam can be adjusted to the principal axis by using two screens that have a distance of roughly 15 m.



Total field of view of the camera. The diameter of the screen is 30 mm. The directions top, bottom, left and right can be identified by the different lengths of the reticule bars. The reticule is graphitized diamond. It was written into the screen with a high power laser.



The luminosity of the diamond screens is strongly photon energy dependent. This must be taken into account when looking at the images. Especially when the screens are used in a white undulator beam, it is not straight forward to make conclusions on the beam profile.

References: [1] PETRAIII "A low Emittance Synchrotron Radiation Source", Technical Design Report DESY 2004-035, 211-218
[2] The Generic Beamline Concept of the PETRA III Undulator Beamlines, U. Hahn, H.B. Peters, R. Röhlsberger, H. Schulte-Schrepping, 9th SRI 2006, AIP Conference Proceedings 879 (2007) , 539 - 542
[3] M. Degenhardt, U. Hahn and H. Schulte-Schrepping: " CVD diamond screens as fluorescent screens for synchrotron applications", to be published