Novel UHV lens changer at the PETRA III Beamlines P22, P23 and P24.

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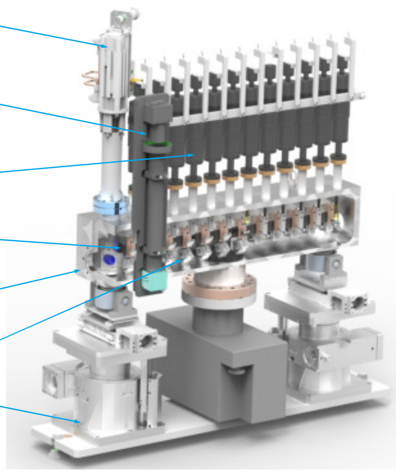
Motivation and Requirements

Refractive optics is of key importance for synchrotron beamlines aiming for micrometer and sub-micrometer beam sizes. Small dimensions of the lenses allow for very compact and cost effective solutions for beam focusing applications [1, 2]. Consequently, CRLs became widespread in the synchrotron community, particularly for hard X-ray beamlines.
Three new beamlines went into operation in the Ada Yonath hall at the high brilliance PETRA III storage ring at DESY (Hamburg, Germany) in 2017. At all beamlines compound refractive lenses are employed for in-vacuum X-ray beam focusing, collimation and conditioning [3].
In this project, great importance was attached to a robust and low maintenance design of the lens changing mechanics which was implemented with some minor variation at all three beamlines. Here we present a lens changer design, with particular emphasis on 2D focusing requirements at the In-situ and Nano Diffraction beamline P23 and at the Chemical Crystallography beamline P24.

A basic specification for the lens changer include

- main functionality: high precision for positioning of the lenses
  - with exact coaxial orientation of the lenses to the synchrotron radiation beam and to each other
  - high reproducibility
- UHV environment with extremely low residual hydrocarbon content
- Simplified adjustment mechanics with four motorized degrees of freedom for alignment with respect to the X-ray beam – y (horizontal, perpendicular to the beam), z (vertical), pitch and yaw
- all alignment mechanical parts should stay outside of vacuum for easy service, troubleshooting and high reliability
- integrated alignment screens
- CF-flange viewport(s) for inspection and alignment
- flexible remote control via a TCP/IP interface

The 2D CRL changer and its main components

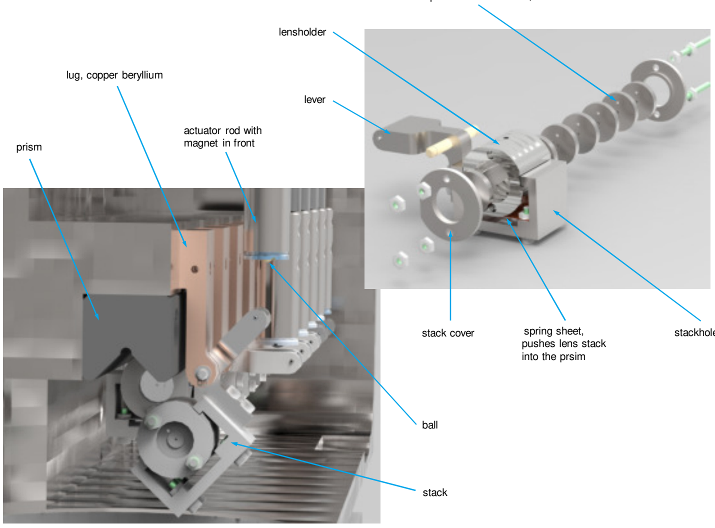


Technical details (2D)

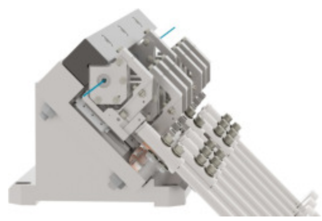
- 12 slots for lens stacks which can hold up to 8 lenses each
- reference plane for the lens stacks is a high precision prism with permitted tolerance of the guide plane parallelism of 2µm over the whole length
- stacks are pressed with a spring sheet into the prism
- pneumatically driven linear translation actuators with feedthroughs for the use under UHV conditions
- all actuation components outside of UHV chamber
- design can be adapted to include any number of lens stacks by scaling up or down the size
- dimensions of the whole assembly: length 662mm, height 824 mm, width 230mm
- beam position monitor with flourescence screen and additional pinholes for beam monitoring and alignment
- fail safe: In case of any complications, lens stacks fall out of beam path in a controlled way by gravity
- DN 63 viewports for easy control of the lenses and UHV mechanics
- pressures down to $1.8*10^{-8}$mbar
- precise parallel kinematics, offering two translational and rotational degrees of freedom ensure the alignment
- controlbox: Industrial standard components for valve control on 24V basis
- widget for easy valve control from control hutch computer

Mechanical details

2D lenses are delivered in circular metal frames. These frames are combined to firm stacks that exhibit cylindrical reference plane for alignment. The stacks are held loosely by a lever which can rotate in an lug. During the assembly the height of the lug is adjusted to ensure an optimal pivot point.
The stacks are pressed against the reference prism by pneumatic drives and the lever mechanism. For precision alignment a spring sheet pushes the reference planes of the lens stack into the prism planes. When removed from the beam, or in case of air pressure loss, the frames slide out of the X-ray path and a spring plate at the end of the travel ensures a gentle hold.
The insertion of a lens stack into the beam is implemented in two stages. In the beginning, there is no direct mechanical contact between the levers and pneumatic actuators: in a first step the force transmission is implemented in a contactless manner over repulsing permanent magnets built into the lever and the pneumatic drive tip. Under the magnet, adapted to the pneumatic drive rod, sits a small ball, so that in a second step the end of the rod has contact just in one point to the lever. This construction ensures both a damping of the mechanical impact by the drives and a self-aligning low contact motion transmission and allows avoiding complex adjustments in the force transmission mechanism.
The MDC linear feedthroughs with a travel length of 1 inch are mounted to the 12 DN16 flanges of the vacuum vessel (Model K075-ABLM-1).

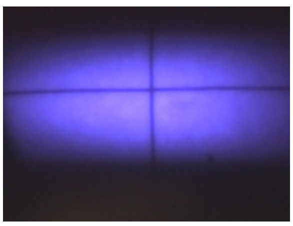


1D CRL details



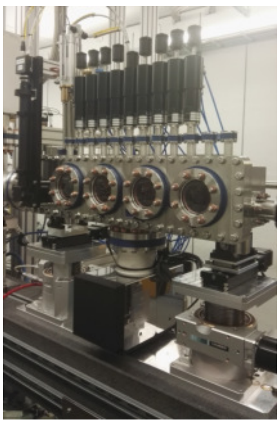
- 1D lenses differ from the 2D ones by a square holder form
- focusing direction of a 1D lens is parallel to one of the frame edges
- the lens changer prism is mounted under a 45° angle to align the rectangular lens frames in the vertical or horizontal planer
- extensions of the pneumatic drives press the lens stacks against the prism
- lateral stability of the stack holder is ensured by guide rails placed inside the vacuum vessel

Performance



Unfocused beam in the experimental hutch

Focused beam, the cross lines are 50µm wide



Alignment and control

For easy alignment two built in apertures allow fast positioning to the main axis parallel to the X-ray beam. Different lens combinations can be set remotely according to the experimental requirements, operated from the beamline control hutch. A control box with an Acromag XT1112 16 channel I/O modules is designed to switch the FESTO valve terminal used for driving the pneumatic feedthrougs. Communication is facilitated via the ModBus protocol in the Tango middleware. The interface is fully integrated in the user software and allows for automated lenses changes during experimental runs.

Performance

First test for focusing showed good reproducibility and repeatability results for intermediate focus sizes, lens positioning in the prism and alignment by the parallel kinematic.
The figures demonstrate the results of the first test of the 2D transfocator at beamline P23. The total beam intensity loss of about 40% was observed after focusing with a stack of 4 beryllium lenses with 500µm radius. By focusing, the flux density in the focal spot was increased by several orders of magnitude.

Summary

We have presented two UHV compatible lens changer designs for 1D and 2D lenses for the use at synchrotron radiation beamlines. All active elements are placed outside the vacuum vessel, which allowed a compact vacuum chamber design and facilitates easy access for repair and maintenance work. Alignment aperture and fluorescent screens are integrated into the vacuum vessel. The design can be easily adapted for any number of lens stacks.

Acknowledgements

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