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Comprehensive 1D and 2D UHV Lens Changer At PETRA III Beamlines

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Abstract. For beam collimation and focusing at the new PETRA III undulator beamlines, UHV compatible 1D and 2D compound refractive lens changers have been designed. Since these units are going to be integrated in the upstream part of the beamlines in the optics hutches, the primary design goal was to ensure reliability, failsafe operation and convenient optical alignment combined with high mechanical precision. It was chosen to further develop established concepts and combine it with actuators on the air side rather than active in-vacuum actuators. Precise and reproducible alignment is achieved by pneumatic linear motion actuators that position the lens stacks in a high precision prism. Alignment is facilitated by on-axis pinholes and an integrated diamond beam monitor. Reproducibility and first tests of a 1D lens changer at beamline P22 for intermediate focusing down to <90 µm are shown.

INTRODUCTION

Compound refractive lenses (CRLs) are of key importance for beamlines aiming for micrometer and sub-micrometer beam sizes. Their small dimensions of the lenses allow for very compact and cost effective focusing solutions [1,2]. While classically CRLs were used for 2D focusing, recently 1D lenses and combinations of both are becoming widespread in the synchrotron community, particularly for hard X-ray beamlines. For pre-focusing, collimation and intermediate focal sizes CRLs should be positioned upstream, preferentially in the optics hutch of the beamline. Compact lens changer designs for use in ultra high vacuum (UHV) conditions are therefore required. We present here the design of transfocators where particular attention was paid to high reliability and low-maintenance operation as well as compliance vacuum requirements. The concepts for lens positioning are based on a design previously implemented at DESY [3]. In this project, great value was put into the robust and low maintenance design of the lens changing mechanics which were implemented as 1D and 2D variations at three beamlines [4]. In the following we present a lens changer design for the reliable use under ultra high vacuum conditions, with particular emphasis on 1D focusing requirements of P22 [5].

TECHNICAL LAYOUT

The lenses, calculated beam sizes [6] and photon fluxes for the focusing needs of P22 are listed in Table 1. In order to allow maximum photon flux at the relatively low photon energies required for HAXPES (2-8keV) the number of lenses was minimized. Installing the transfocator in the optics hutch results in a large depth of field and less constraints for the positioning of the experiments. The choice of horizontal beam sizes of ~100 µm is a good compromise with experimental needs of spectroscopy applications.

Optimum focusing at discrete energies is achieved by suitable combinations of lens stacks carrying different numbers of lenses. Pneumatic feedthroughs and the robust mechanical elements allow for a reliable, fast and reproducible switching between different configurations. High precision mechanical positioning is realized by

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TABLE 1. Lenses and lens combinations used for 1D focusing used in the transfocator installed at P22. The expected focal sizes and flux (in 10 -4 bandwidth) for the given energies. The radii of the lenses are given in mm.

Position	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**		
E [keV]	PH1 Ø 0.5	2 x R 0.3	4 x R 0.5	2 x R 0.5	1 x R 0.5	1 x R 1	1 x R 1	PH2 Ø 0.5	fwhm [µm]	Flux [ph/s]
3	0	0	0	0	0	0	1	0	134	$2.0 \cdot 10^{12}$
4	0	0	0	0	1	1	0	0	87	$4.5 \cdot 10^{12}$
5	0	0	0	1	0	1	0	0	87	$7.9 \cdot 10^{12}$
6	0	0	0	1	1	0	1	0	136	$9.7 \cdot 10^{12}$
6	0	0	0	1	0	1	1	0	146	$9.7 \cdot 10^{12}$
7	0	0	1	0	0	1	1	0	89	$1.1 \cdot 10^{13}$
8	0	0	1	1	1	1	0	0	87	$1.3 \cdot 10^{13}$
10	0	1	1	0	0	0	0	0	82	$1.5 \cdot 10^{13}$

pressing the lens stacks against prismatic reference planes. This core element ensures exact positioning by very tight shape and position tolerances. The design is readily adaptable to include any number of lens stacks by scaling its size.

The transfocator is comprised of a vacuum vessel and underlying motorized positioning mechanics. In order to secure the high vacuum quality all vacuum parts were cleaned thoroughly prior to assembly under ISO class 5 clean room conditions. The rails are lubricated with Krytox™ UHV lubricant. The residual gas analysis of the entire assembly complies with the strict DESY vacuum guidelines. The acceptance test showed a base pressure of $2.4 \cdot 10^{-7}$ mbar. Emitted gas is free of hydrocarbons and other contaminations. Within the optics hutch a steady pressure of $5 \cdot 10^{-8}$ mbar is reached without further (possible) baking. The individual components are presented in the following sections.

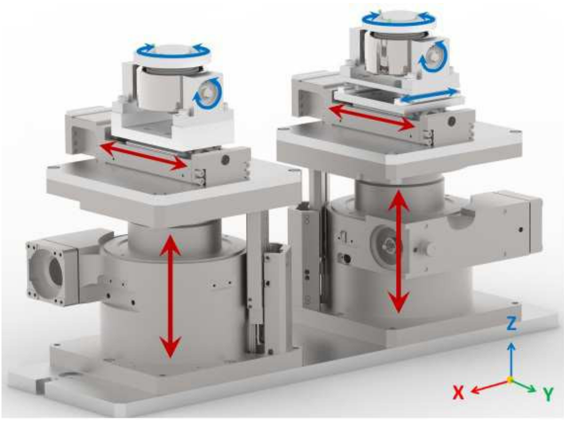
Support construction

The alignment of vessel and prism is done via a combination of two vertical and two horizontal translation stages under the vessel (Figure 1a). Translations are achieved by parallel motion of two motors, rotations result from antiparallel motion. Two Huber Z-stages (Z-stage 5103.A20-90) adjust height and rotation around Y. Two Misumi linear travels (LX3005-B1-A3038-125) adjust translation in Y and rotation around Z. Further rotational and translational degrees of freedom between actuators and vessel (marked in blue) compensate angle and length changes between vessel and ground plate due to the movement.

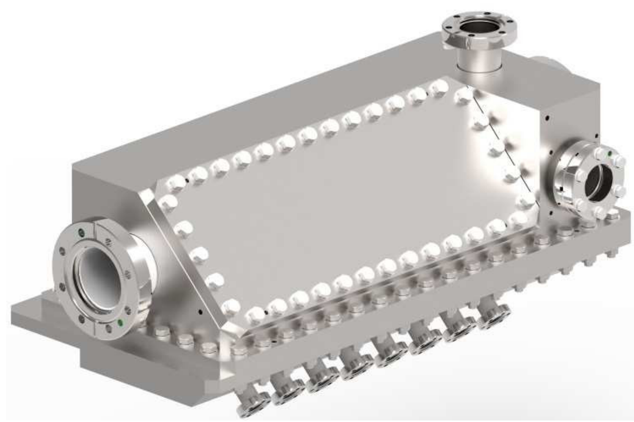
Vacuum vessel

The vacuum vessel consists of a base plate and a cover as shown in Figure 1b. All inner components are arranged on the base plate and therefore positioned in a well-controlled relation to each other. The cover part has an integrated service hatch for easy access to the lenses. The main vessel components are sealed with a FKM O-ring seal (Viton®). The calculated groove filling was chosen to be as high as possible and lies between 84 and 98% within the specified tolerances to ensure optimal sealing.

Furthermore, DN63 CF flanges connect the chamber to further beamline components and subsequent ion pumps. A DN40 window gives direct visibility onto the DESY standard diamond fluorescence screen [7]. The CVD diamond screen with an integrated graphitized cross was aligned during assembly to the center of lens axis close to the upstream port. The 8 DN16 flanges for the translational feedthroughs sit under an angle of 45 degree.



(a)



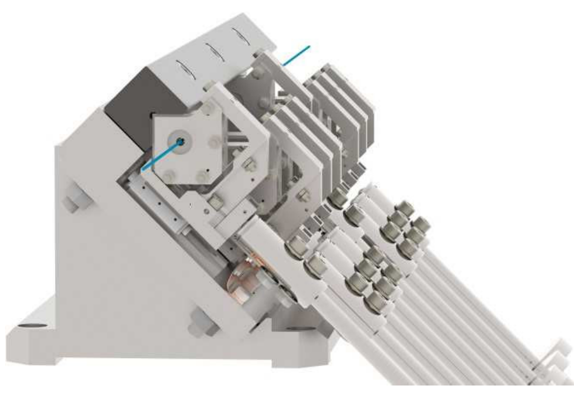
(b)

FIGURE 1. Rendered images of support stage and vessel of the transfocator. a) Motorized translation stages (red) for alignment, linear slide and bearing for compensation movements (blue). b) Vacuum vessel with service hatch with the 8 DN16 CF flanges under an angle of 45° for the pneumatic feedthroughs. Two DN40 flanges are used for the diamond screen and camera.

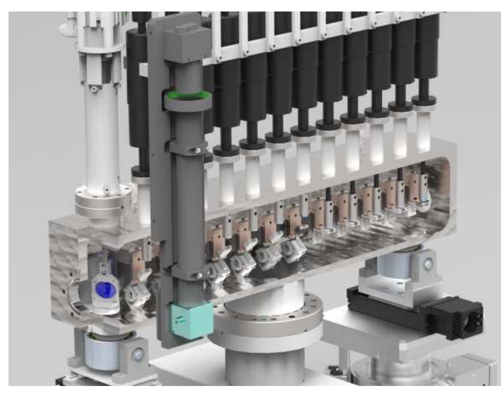
Positioning mechanics

Details of the 1D mechanics are shown Figure 2a. For horizontal focusing the prism is mounted in a 45° angle to align the parabolic beryllium cylinder vertically. 1D lenses are delivered in rectangular frames with the focusing direction parallel to one of the frame edges. These frames are combined to firm stacks that exhibit two reference planes for alignment. The stacks are held loosely at the front of the pneumatic drives. The pneumatic MDC linear feedthroughs (Model K075-ABLM-1) with a travel length of 1 inch are mounted to the 8 DN16 flanges of the vacuum vessel. Lateral stability of the stack holder is ensured by guide rails on the vacuum side. Extension of the pneumatic drives press the lens stacks towards the prism. For precision alignment a spring sheet pushes the reference planes of the lens stack onto the prism planes. In case of non-use or pressure loss, the frames slide out of the light path and a spring plate at the end of the travel ensures a gentle hold.

The key difference of the 2D lens changer is the rotational lever mechanic used for lens stack positioning (Figure 2b). The circular parabolic lenses require no rotational alignment around the beam axis and are delivered in a round lens frame. The actuators push from above onto the lever arms of the stack holders and rotate them towards the prism. To avoid abrupt contact between lever and actuator, both parts are separated by strong opposing magnets. Similar to the 1D design, the lens stack is pushed to the prism faces with a spring sheet that is mounted to the stack holder.

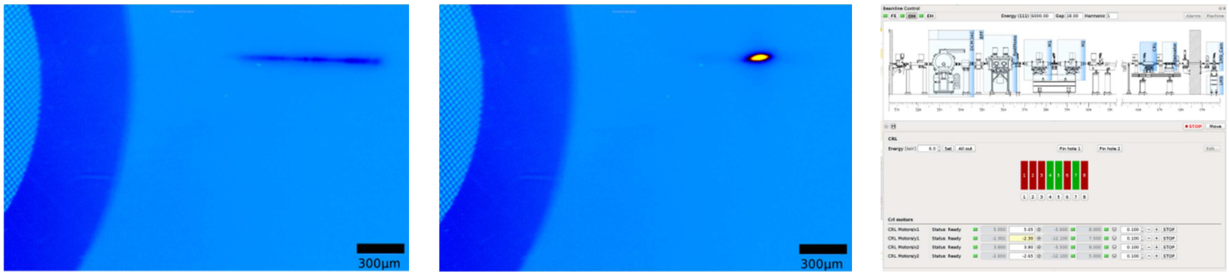


(a)



(b)

FIGURE 2. Detailed view on the 1D and 2D mechanics. a) Lens mechanic of the 1D setup. The lenses are indirectly pushed into the prism with the translation stages under a 45° angle to achieve a vertical alignment of the beryllium cylinder. b) Mechanic of the 2D setup. The round lens frames are pushed into the prism with a lever mechanism and spring metal sheet.



(a) (b) (c)

FIGURE 3. First test of the transfocator at P22 with 4keV photons: a) Horizontally unfocussed beam b) Horizontally focused beam with a width of 82 µm (fwhm). For calibration a 1000lines/inch TEM grating is placed in the field of view of the microscope. c) Screenshot of the control widget at P22 for easy lens selection and alignment.

Alignment and control

For easy alignment with beam, the X-ray fluorescence screen was pre-aligned with a crosshair to the main axis of the lens system and two alignment apertures allow fast beam positioning parallel to the main axis. First tests for intermediate focusing requirements showed high reproducibility and repeatability for lens positioning in the prism and alignment by the parallel kinematic. Figure 3 illustrates the results of the first test of the 1D transfocator at beamline P22 where intermediate focus sizes between 80 and 150µm (fwhm) were specified. The horizontally unfocussed beam (Fig. 3(a)) is imaged by highly magnifying optics. Figure 3(b) shows the focused beam at a photon energy of 4keV. The beam is well aligned in the center of the unfocussed beam illustrating the quality of the alignment procedure. The focus size of ~83µm (fwhm) is in excellent agreement with the expected value at 4keV of 86.95µm fwhm.

According to the experimental needs different lens combinations can be set remotely form the beamline control cabin. A control box with an Acromag XT1112 16 channel I/O modules was designed to control the valve terminal used for switching the pneumatic feedthroughs. Communication is facilitated via the ModBus protocol in the Tango middleware. A dedicated control widget in the P22 control software (see Fig. 3(c)) allows a visualized and automated energy dependent selection of optimal lens combination. The interface is fully integrated in the user interface and allows for automated lenses changes experimental runs.

SUMMARY / OUTLOOK

We introduced a UHV compatible lens changer design for 1D and 2D lenses where active elements are placed outside the vacuum vessel. This approach allowed for a compact vacuum chamber design which facilitates easy access for repair and maintenance work. Alignment is facilitated by integrated apertures and fluorescent screens as well as a user-friendly software interface.

Single lenses are stacked in groups depending on the experimental requirements (energy, spot size). The lens stacks are pressed with a spring sheet into a high end prism as reference plane. Lens stacks are positioned in the beam path by pneumatic linear motion drives. 1D lens stacks are placed in the beam path by linear translation, the 2D stacks with rotational lever mechanics. The designs allow easy adaption to systems with more or less lens positions. Fast and precise alignment possibilities of the prism allow frequent changes of beam path between measurements.

Synergies in design, manufacturing and maintenance were exploited by reusing the same design concept at all three beamlines. First tests confirm that the desired functionality and repeatability of the devices and focal sizes are matching very well the specified values.

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REFERENCES

1. B. Lengeler *et al.,* **6**, 1153–1167 (1999).
2. B. Lengeler *et al.,* J. Phys. D Appl. Phys. **38**, A218–A222 (2005).
3. A. V. Zozulya *et al.,* Opt. Express **20**, 18967-18976 (2012)
4. W. Drube *et al.,* AIP Conf. Proc. **1741**, 020035 (2016).
5. C.Schlueter *et al.,* doi:10.1080/08940886.2018.1483656
6. K. Klementiev *et al.,* Proc. SPIE 92090A (2014).
7. M. Degenhardt *et al.,* J. Phys.: Conf. Ser. **425** 192022 (2013)