The Variable Polarization XUV beamline P04 at PETRA III: Optics, Mechanics and their Performance.





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- > Raytracing Software: Shadow/XOP, RAY, REFLEC



PETRA III Parameters - Actual Performance in 2011/12

> Beam energy	6 GeV
> Beam current (top up)	100 mA
> Circumference	2304 m
> Revolution period	7.685 µs
> Bunches	240/60/40(320
> Bunch period	32/96/192 ns
> Bunch length (FWHM)	100 ps
> Emittance (horizontal)	1 nmrad
> Coupling	1%



In this summer, a total of 20 so-called wiggler magnets were built in and gradually started operation in the north and west sector of the 2.3-kilometre-long PETRAII accelerator. The wigglers "damp" the positron beam to guarantee the reduction of the beam's transverse size in longitudinal direction. Only with a small beam it is possible to provide the experimenters with small and highly intense light spots.





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200

250 300 pixel

350 400

PETRA III Beamlines

> 9 straight sections - 14 undulator beamlines:



• Usage of canted undulators to enlarge the number of beamlines

Cartoon made by O. Seeck





PETRA III - a Unique Soft X-ray Source

- > An VUV/XUV Beamline at PETRA III (6 GeV!)
 - Exceptionally wide range of photon energies: ~250-3000 eV with variable polarization (especially interesting for circularly polarized SR, using the 1st harmonic only)
 - High stability, low emittance (damping wigglers)



 \Rightarrow diffraction limited source (except horizontal source size)



• Large facility \Rightarrow space for dedicated experiments





PETRA III P04 - Scientific Fields and Experimental Techniques



Variable Polarization XUV Beamline P04 at PETRA III - Layout

> Plane grating monochromator with Varied Line Space grating



• As few as possible, only plane(-elliptical) optical elements \Rightarrow high transmission





P04 - Beamline Performance

- > Photon energy range:
- > Resolving power:
- > Photon flux:
- > Spot size at sample:

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(<100) 250 - 3000 eV
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>10^4 (up to >3 \times 10^4 @1 keV)
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>10^{12} photons/s (up to 5 x 10<sup>12</sup>)
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- 10 x 10 µm² / 50 x 50 µm²
- > Polarization (switching rate): circular, linear hor./vert. (<0.1 Hz)</p>



P04 - Plane Mirror/Plane Grating Unit (PM/PG-U)

2 high precision rotations (pre-mirror/grating in UHV)



- angular resolution:
 50 nrad (±7° range)
- > new motor concept for both "high" accuracy and "high" speed (10 eV/s)







P04 PM/PG-U Characterization with Autocollimator Elcomat HR



P04 - EXit Slit Unit (EXSU)

> Exit slit unit monochromatizes the radiation diffracted by the grating



slit height repeatability:

movable ±500 mm along optical axis (~1µm height accuracy)







P04 - Refocusing Mirrors Unit (RMU)

> 2 In-air hexapods act on 2 pairs of **KB-mirrors in UHV** > rigid KB-mirrors for 2 different focal spots

angular accuracy: 2 µrad (±0,3° range)

fine pitch: ~40 nrad (350 µrad range)

translational accuracy: 1 μm (±45 mm range)

current test shows: 0.5 µm p-p during daytime 0.2 µm p-p during night or weekends

climatization is important!





Multiple Electron Time-of-Flight Spectrometer Setup



- > Online beamline monitor at P04 for:
 - **Photon flux** (\leq 1% absolute, \leq 0.1% relative)
 - Beam position ($\leq 1 \mu m$)
 - Photon energy ($\leq \Delta E$, $\leq 1/10,000$)
 - **Degree of polarization** (accuracy ≤1%)

Linear horizontally polarized light:

- $S_1 = 1.0/0.9/0.8/0.7/0.6/0.5/0.4/0.3/0.2/0.1/0.0$
- Precise reference lines necessary for all hv



P04 Optics - How to cope with heat load



P04 - Optics Summary

Most of the optics have been delivered and they have been surveyed at the HZBerlin (BESSY) by Frank Siewert and Jana Buchheim

item	Size	Figure	Roughness (nm σ)		Slope error (arcsec σ)		
	(L x W x H, mm)		Specs	Measured	Specs	Measured	FLASH-type to be
M1	400 x 60 x 60	plane	0.5		0.1	0.06	 PLACINGPC, to be replaced by intrins. <i>l</i>N₂ cooled VLS 400 l/mm laminar VLS 1200 l/mm laminar focus onto exp. plattform
M2	560 x 60 x 60	plane	0.5		0.05		
G1	145 x 32 x 23	plane	0.5	0.3-0.4	0.05	0.037	
G2	130 x 32 x 23	plane	0.5	0.5-0.7	0.05	0.024	
M3b1	500 x 30 x 60	plane-ellipse	0.5	< <mark>0.1</mark>	0.2	0.2	
M4b1	600 x 30 x 60	plane-ellipse	0.5		0.2		
M3b2	500 x 30 x 60	cylinder	0.5	0.1	0.2	0.09	focus onto PIPE
M4b2	600 x 30 x 60	cylinder	0.5	0.1	0.2	0.13	



Problem: Slope Errors of the Grating

- > High quality of the source
 ⇒ slope error is main factor for resolving power
- > even "world record" slope errors degrade the theoretical performance
- > so far 10 grating blanks delivered with slope errors of 0.024 - 0.06 arcsec and a rms-roughness of 0.1 - 0.2 nm (before coating)

x: 6,0 µm

v: 6.0 um



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Improved Raytracing - (More) Realistic Numbers?



> Using the NOM results for the residual height as an input for the Shadow raytracing, we expect more realistic results

• For example:

The raytracing results of the "realistic" optics is showing focal properties close to the 0.1 arcsec case while having 0.2 arcsec slope error. This can be explained by the fact that the "inner region" of the mirror has a much better sloper error (0.07 arcsec)





P04 Time Table 2012

- > "Test beam" for "friendly users" since March 19, 2012
- > Alignment of the beam into PIPE successful, further beamline tests in parallel.
- > First high quality **pre-mirror** will arrive July 2012, installation **August 2012**.
- > Starting end of August, "high" photon energy resolution possible.
- > For July/August two sets of KB-mirrors are scheduled.
- > August/September small focus mode could be available.





Summary

> P04 is a powerful XUV beamline with unique properties (open to users 2012):

- Very wide photon energy rage: 250-3000 eV
- High flux with simultaneously high spatial and energy resolution
- Variable Polarization for different types of dichroism studies
- Instruments for diagnostics at P04 have been developed.
 - Fixed unit built into the P04 \Rightarrow ideal for commissioning
 - Transportable unit \Rightarrow available for collaborations
- Many challenges in terms of optics have still to be solved:
 - Mirrors: internally cooled mirrors, ℓN_2 cooling, improved KB-mirror schemes, ...
 - Gratings: HZBerlin developments, small blaze angles (<1°), mounting...





Brilliance

500

1000

1500 2000

Photon energy (eV)

2500

3000