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# Soft X-ray optics for the new PEARL beamline at the SLS

*M. Muntwiler, P. Oberta, J. Krempasky, U. Flechsig, C. Quitmann*

*SLS, Paul Scherrer Institut, 5232 Villigen, Switzerland*

## introduction

The Photo-Emission and Atomic Resolution Laboratory (PEARL) is a new soft X-ray beamline under commissioning at the Swiss Light Source. PEARL is dedicated to the study of local atomic structure of surfaces and adsorbates using photoelectron diffraction (XPD) and scanning tunneling microscopy (STM). Photoelectron diffraction experiments benefit from tunable photon energy, high photon flux, and good energy resolution of the synchrotron light [1-3]. The beamline is set up at a bending magnet. The X-ray optics are based on a plane-grating monochromator concept with a focusing and a refocusing mirror. The beamline delivered first light in December 2011. The end station will be installed in October 2012.

http://www.psi.ch/sls/pearl

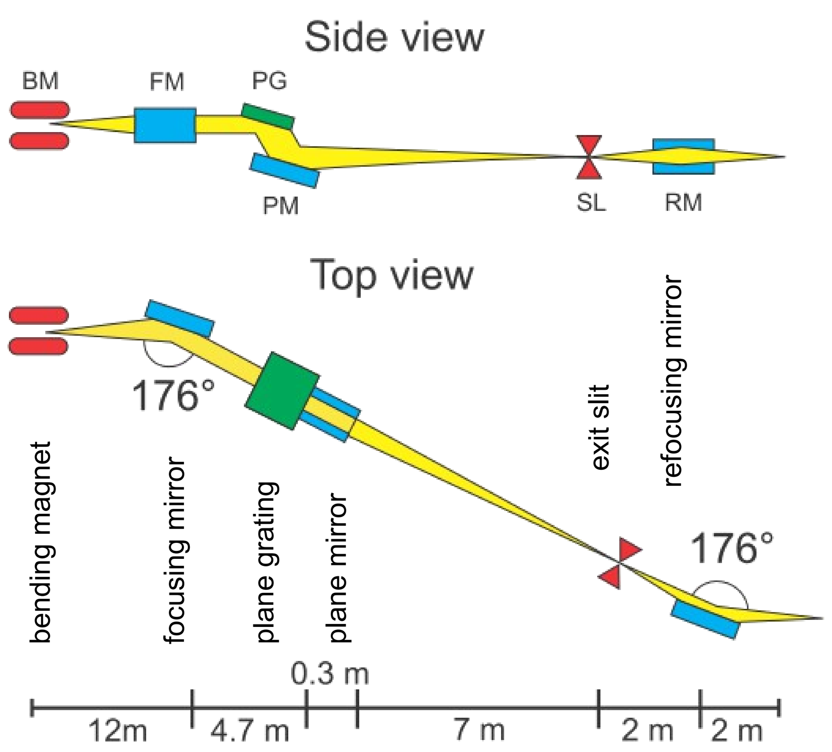
## key figures

| parameter | goals | considerations |
|---|---|---|
| photon energy | 100 – 2000 eV, scannable | photoemission cross section<br>diffraction condition<br>resonant excitation |
| optimum (flux, resolution) | 500 – 700 eV | core level binding energy<br>diffraction condition |
| energy resolution | < 0.1 eV (E < 1000 eV)<br>< 0.2 eV (E < 2000 eV) | XPS peak width ~0.1 eV<br>chemical shifts ~0.1 – 1.0 eV<br>multiplet splitting ~0.1 eV |
| polarization | linear horizontal<br>70% circular left/right | circular dichroism |
| switchable spot size | 170 µm x 73 µm<br>1000 µm x 1000 µm | radiation-sensitive samples |
| photon flux | $10^{11}$ / s at optimum | photoelectron counting statistics (photoemission cross section) |

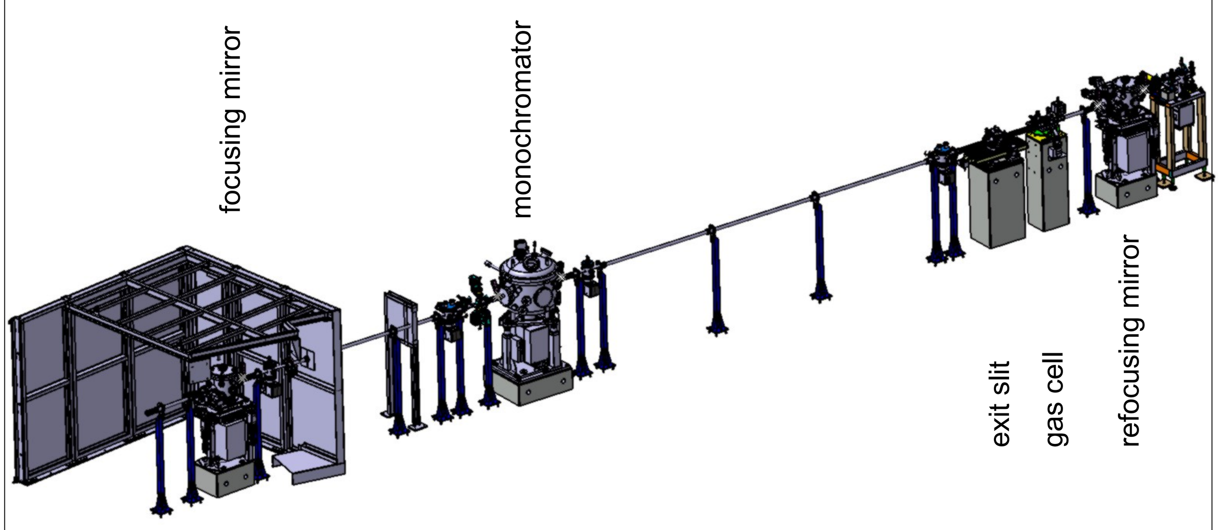
## photon source

| | |
|---|---|
| radiation device | bending magnet |
| electron energy | 2.4 GeV |
| critical energy | 5.36 keV |
| magnetic field | 1.4 T |
| bending radius | 5.729 m |
| total integrated power | 32.7 W/mrad |
| on-axis power density | 101 W/mrad$^2$ |
| source size vertical (σ) | 7 µm |
| source size horizontal (σ) | 45 µm |

## beamline design

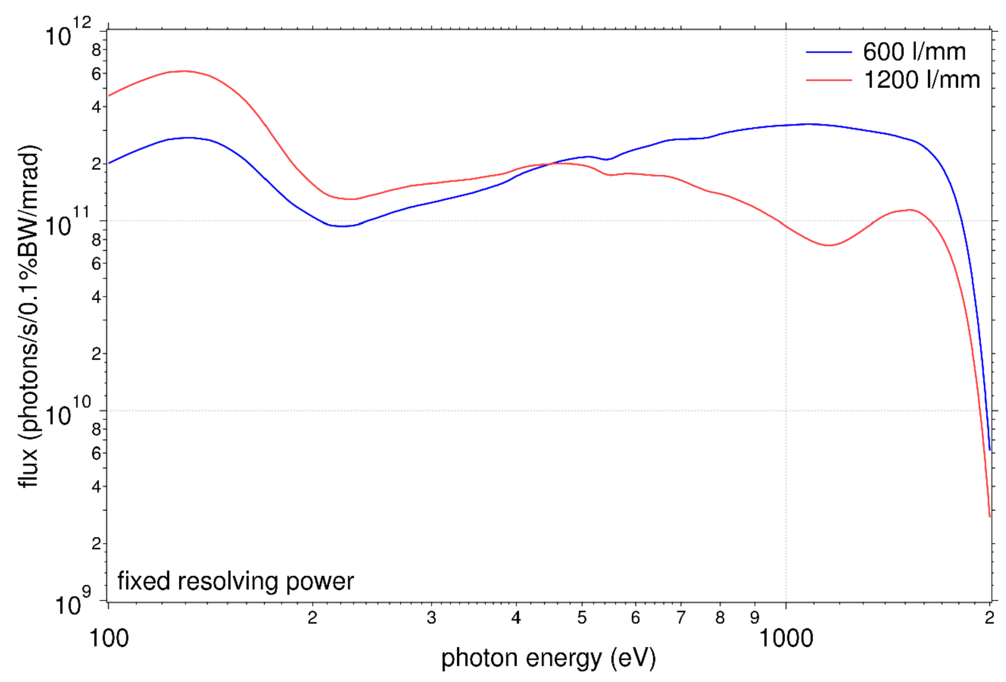



Plane-grating monochromator scheme operating in converging beam and negative diffraction order [1,4]. The X-rays are focused onto the exit slit by the focusing mirror and the plane grating. Drawing not to scale.

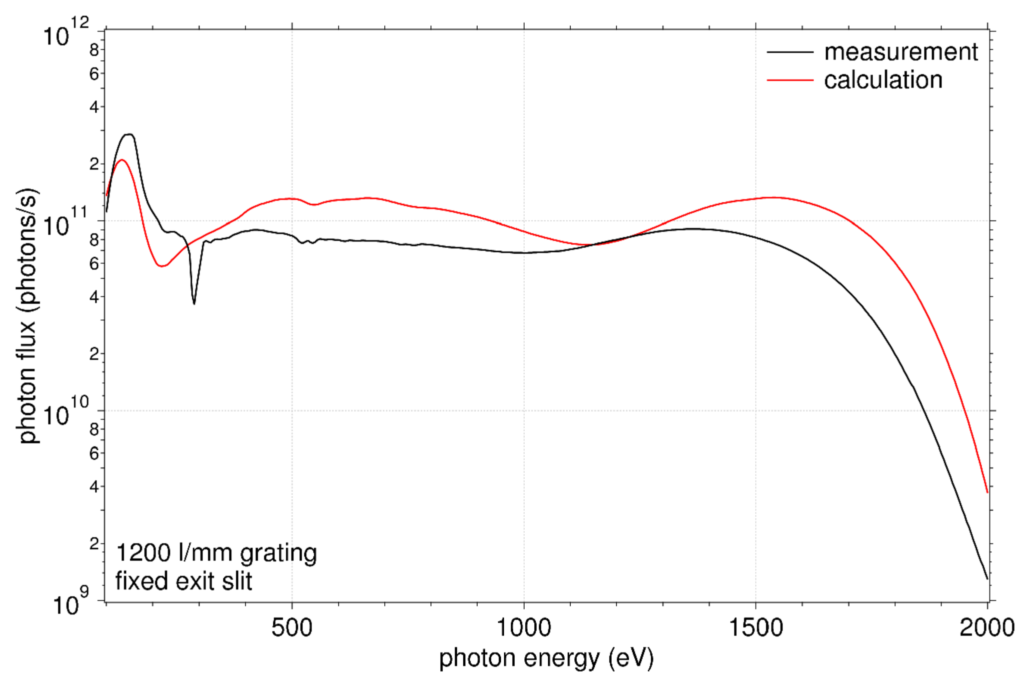



3D rendering of the beamline from focusing mirror unit to refocusing mirror unit.

## photon flux

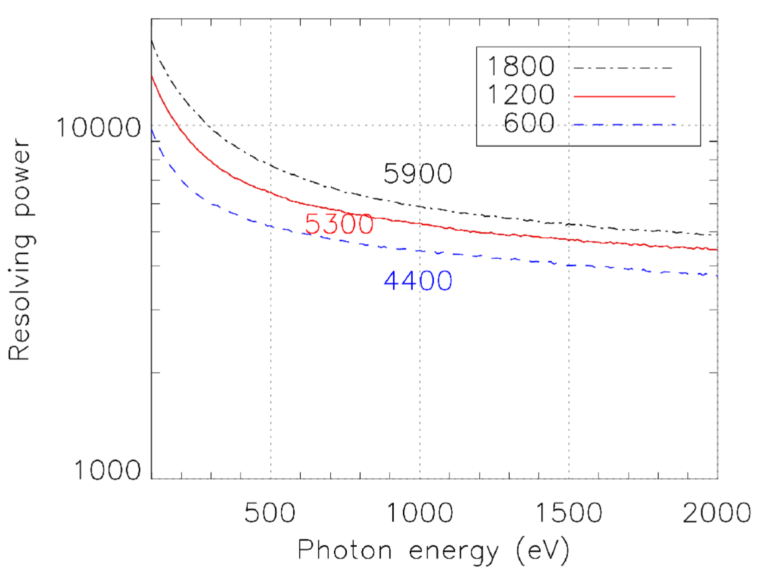



Calculated photon flux based on the dipole radiation spectrum and the transmission factors of the optical elements. The horizontal acceptance is 1 mrad, and the vertical acceptance infinite. The spectrum is normalized to constant resolving power 1000 and to 400 mA ring current.

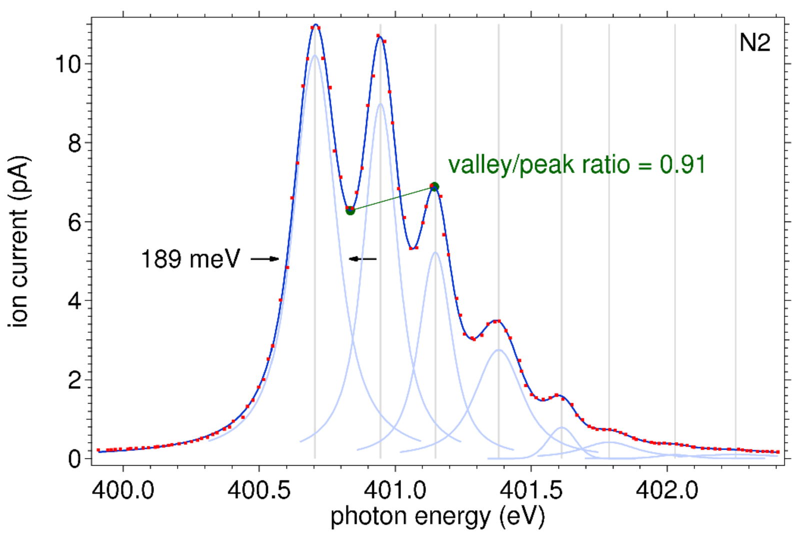



Maximum photon flux measured with a silicon photodiode. The calculated spectrum is normalized to the same acceptance (0.7 mrad H x 1.4 mrad V) and fixed exit slit size (200 µm). 200 µm correspond to a resolving power of about 1000 at 1000 eV. Currently, only a preliminary 1200 lines/mm grating has been commissioned.

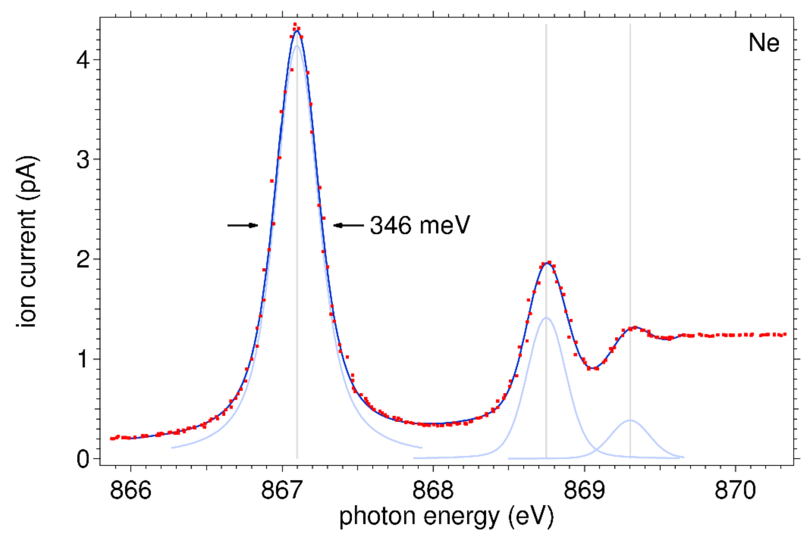
## energy resolution




Calculated maximum resolving power (from ray tracing) for optimum source size 7 µm x 45 µm, horizontal acceptance 1 mrad, including optical aberration and nominal slope errors. Values at 1000 eV are indicated.
The maximum resolving power is limited by the grating parameters, the source size, optical aberrations, and imperfections of the optical surfaces (slope errors).




Nitrogen 1s → π* gas phase spectrum
1200 lines/mm grating
0.12 mrad x 0.12 mrad acceptance
25 µm exit slit
ΔE ~ 84 meV, E/ΔE ~ 4800 (Voigt profiles)

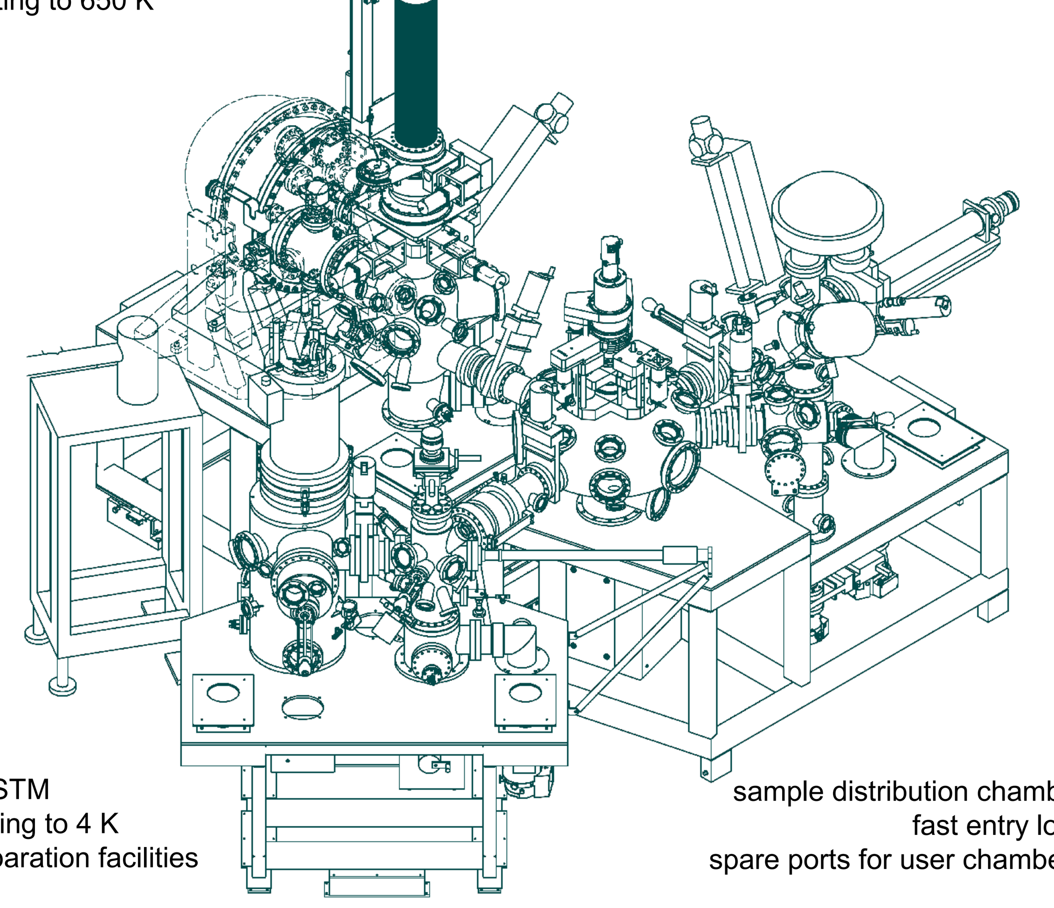



Neon 1s → *n*p gas phase spectrum
1200 lines/mm grating
0.12 mrad x 0.12 mrad acceptance
25 µm exit slit
ΔE ~ 200 meV, E/ΔE ~ 4300 (Voigt profiles)

## end station design

angle-resolved XPS
energy and angle multiplexing detector
60° acceptance angle
6 axis manipulator
cooling to 30 K
heating to 650 K

surface preparation
evaporator sources
analytical devices

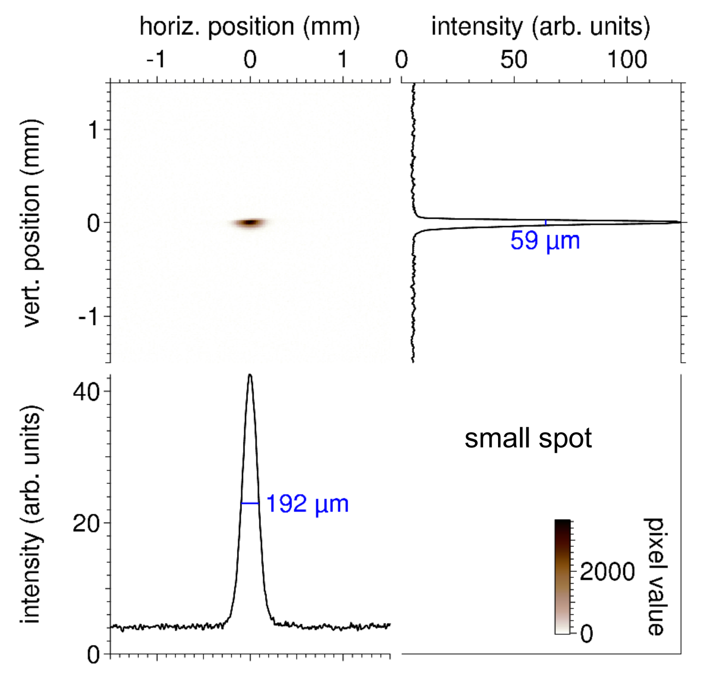


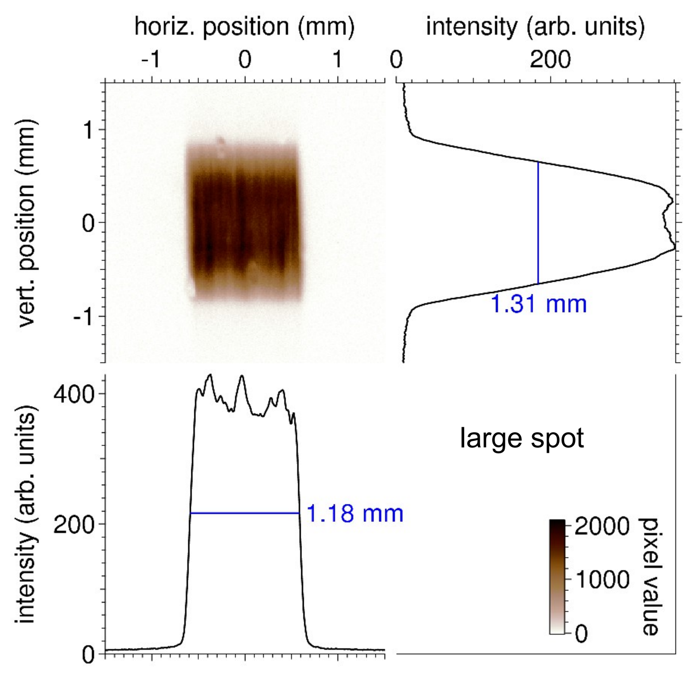
LT-STM
cooling to 4 K
preparation facilities

sample distribution chamber
fast entry lock
spare ports for user chambers

3D rendering of the experimental station (due for delivery in October 2012).

## spot size




Beam spots at the sample position produced by the two toroidal refocusing mirror surfaces. The images are measured with a scintillator plate and a CCD camera. Profiles are integrated in the respective normal direction.

The small spot is a 1:1 image of the exit slit produced by a toroidal mirror.

The large spot is produced by increasing the image distance to beyond the sample position. Horizontal and vertical image distances are not equal in this case.

## references

1 P. Oberta et al., Nucl Instr Meth Phys Res A 635, 116 (2011) and refs. therein
2 C. S. Fadley, Prog Surf Sci 16, 275 (1984)
3 D. P. Woodruff, Surf Sci Rep 62, 1 (2007)
4 H. Petersen et al., Rev Sci Instr 66, 1 (1995)

## acknowledgements

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