FEM Simulations for a High Heat Load Mirror

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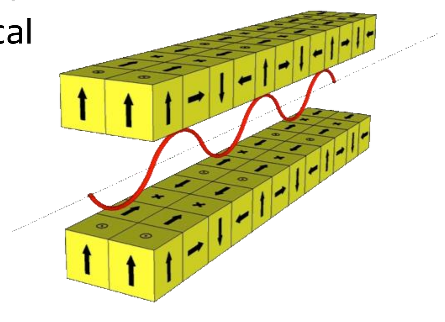
Heat Load

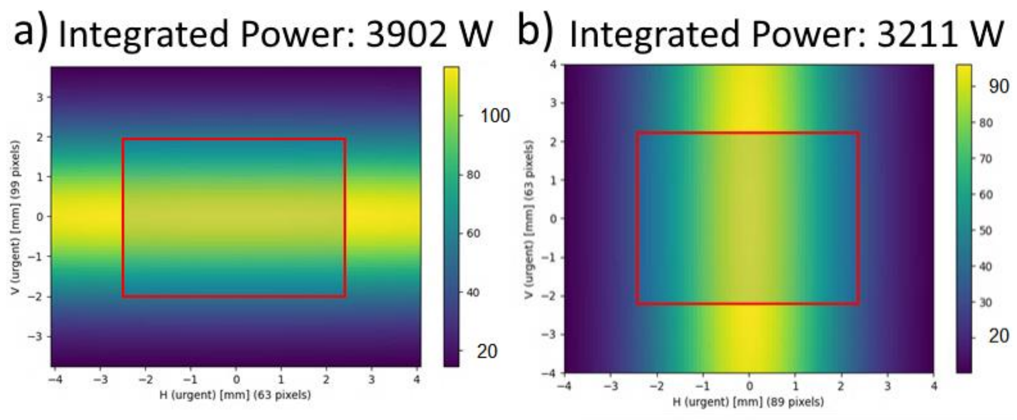
Variable heat loads with APPLE II undulator

APPLE II allows to use the polarization modes linear and circular and all their permutations:

- Highest power for linear horizontal polarization => 2.1 kW.
- High power density for linear vertical polarization => 1.5 kW.
- Lower power for circular polarization => 300 W
- Main power contribution by photons between 8-40 keV => attenuation length



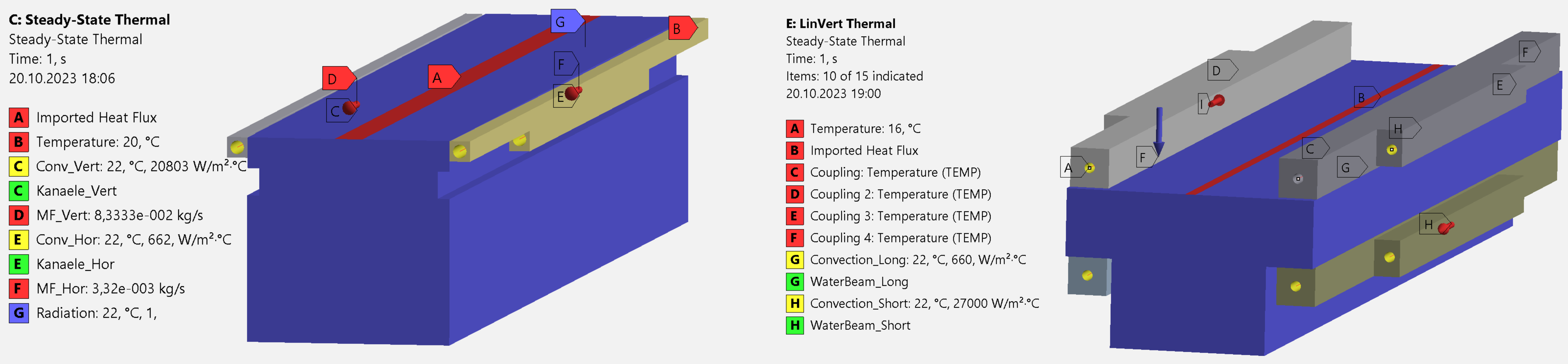
Schematic of APPLE II undulator magnetic arrays



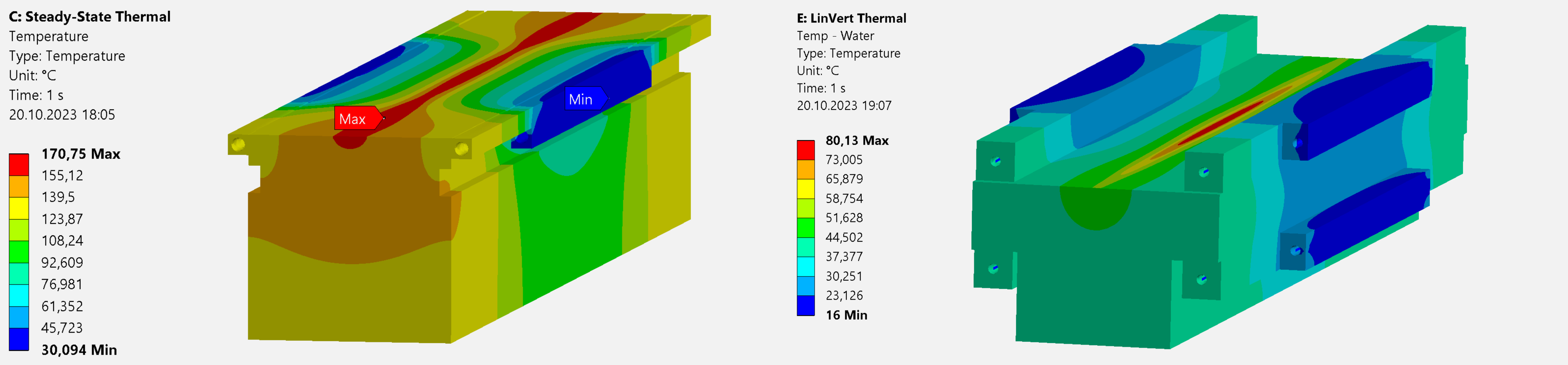
Power density [W/mm²] distributions of a) linear horizontal and b) linear vertical polarization. Mirror footprint is shown in red.

Comparison of Notched and Double Bracket Design

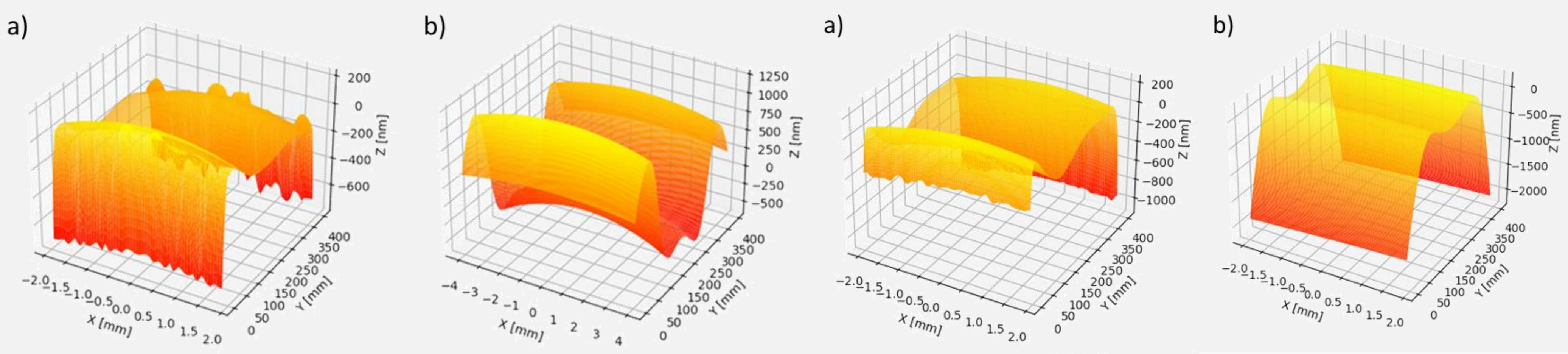
Steady State Thermal setup.



Steady State Thermal result.



Height profiles for a) linear horizontal and b) linear vertical polarization.



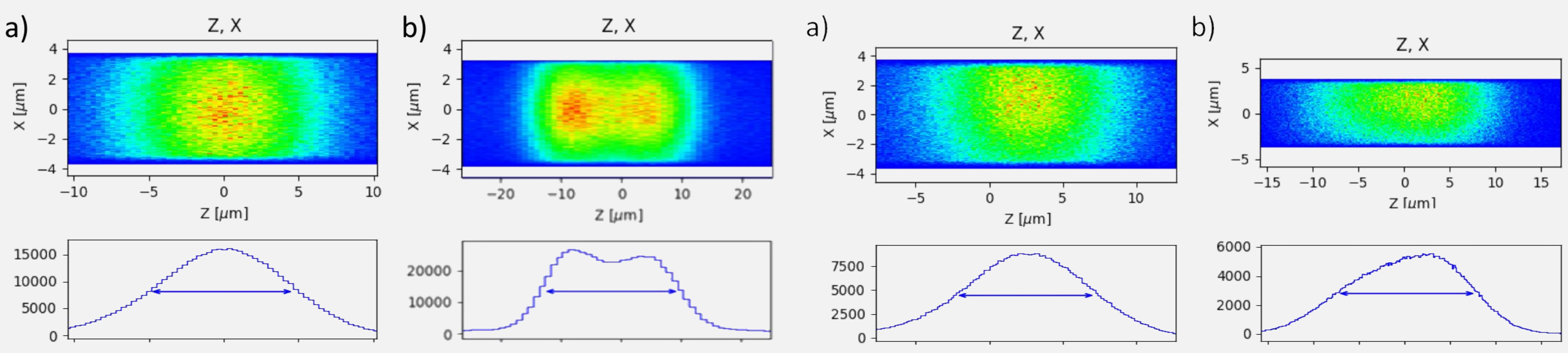
Slope error rms in X direction: 250.840300 µrad
Slope error rms in Y direction: 14.515270 µrad
Figure error rms in X direction: 28.148229 nm
Figure error rms in Y direction: 103.810480 nm

Slope error rms in X direction: 81.326268 µrad
Slope error rms in Y direction: 14.443486 µrad
Figure error rms in X direction: 32.609595 nm
Figure error rms in Y direction: 577.958439 nm

Slope error rms in X direction: 70.740220 µrad
Slope error rms in Y direction: 15.441804 µrad
Figure error rms in X direction: 43.703559 nm
Figure error rms in Y direction: 139.288365 nm

Slope error rms in X direction: 30.619273 µrad
Slope error rms in Y direction: 17.357458 µrad
Figure error rms in X direction: 45.674079 nm
Figure error rms in Y direction: 555.580309 nm

Beamline focus profiles for a) linear horizontal and b) linear vertical polarization.



Conclusions

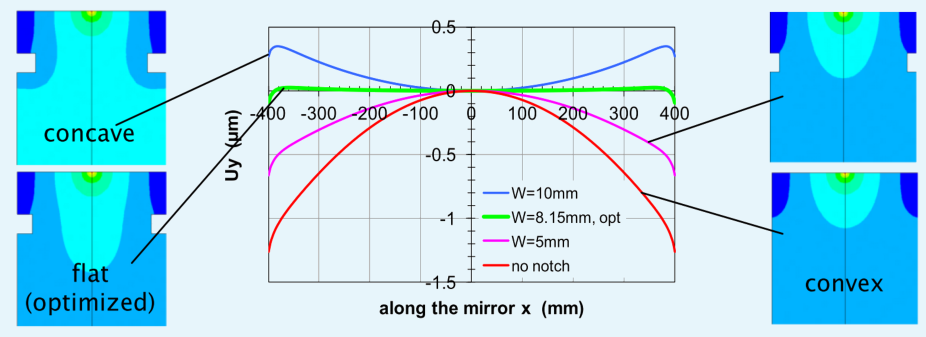
- Notched design works best with linear horizontal polarization.
- Second cooling loop allows use of linear vertical polarization.
- Double bracket design results in lower temperatures which also improves the linear vertical profile.

What lies ahead

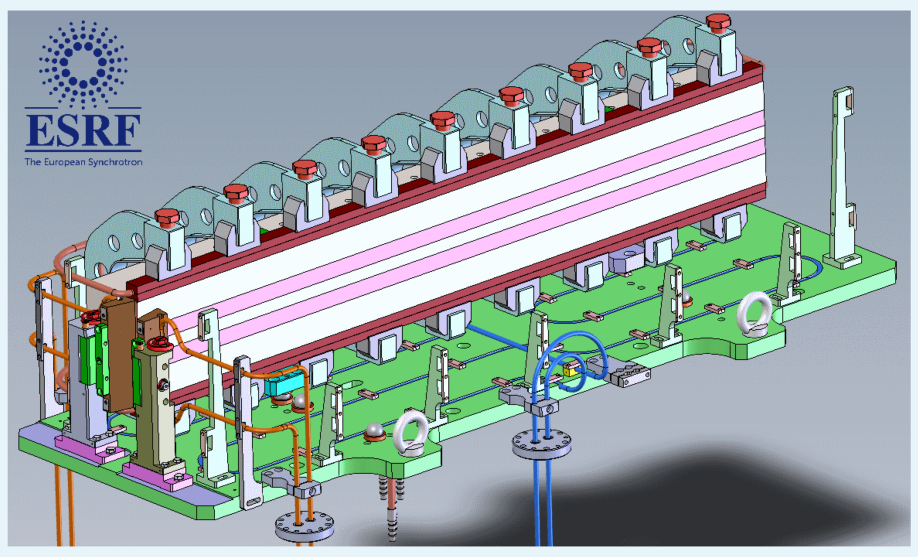
- Influence of clamping pressure on thermal conductance between copper and silicon
- Mirror support structure
- Specs of water chiller
- Chin guard performance -> additional Frontside effects?

ESRF-Design

The notched mirror design [1-2] is used for some white beam mirrors at ESRF [2-3]. Depth of notch changes resulting surface profile along centerline.

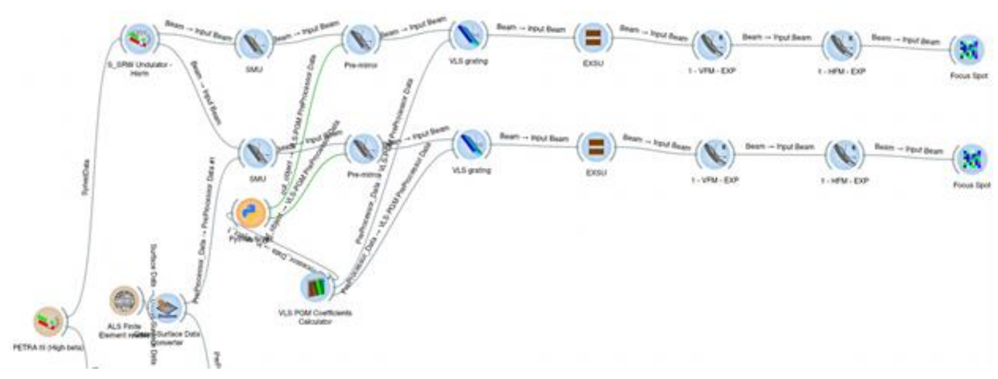


Influence of notch depth



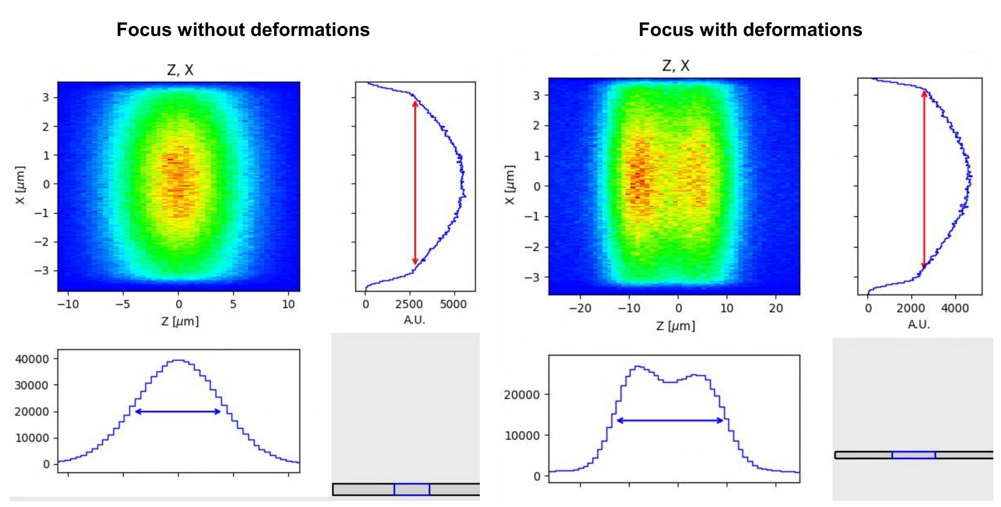
ESRF mirror design.

OASYS – Shadow



OASYS [4] setup for parallel evaluation of P04-focus.

The results from ANSYS Static Structural were forwarded to the raytracing program Shadow to evaluate the difference of the focus profiles for a beamline without and with deformations on the first mirror.



Notched mirror with linear vertical polarization.

References

1. Ali M. Khounsary, "Thermal management of next-generation contact-cooled synchrotron x-ray mirrors", Proc. SPIE 3773, X-Ray Optics Design, Performance, and Applications, (16 November 1999); https://doi.org/10.1117/12.370114
2. L Zhang et al, "Thermal distortion minimization by geometry optimization for water-cooled white beam mirror or multilayer optics", J. Phys.: Conf. Ser. 425 052029 (2013); https://doi.org/10.1088/1742-6596/425/5/052029
3. R Baker et al, "New generation mirror systems for the ESRF upgrade beamlines", J. Phys.: Conf. Ser. 425 052015 (2013); https://doi.org/10.1088/1742-6596/425/5/052015
4. Luca Rebuffi, Manuel Sanchez del Rio, "Interoperability and complementarity of simulation tools for beamline design in the OASYS environment," Proc. SPIE 10388, Advances in Computational Methods for X-Ray Optics IV, 1038808 (23 August 2017); https://doi.org/10.1117/12.2274232

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