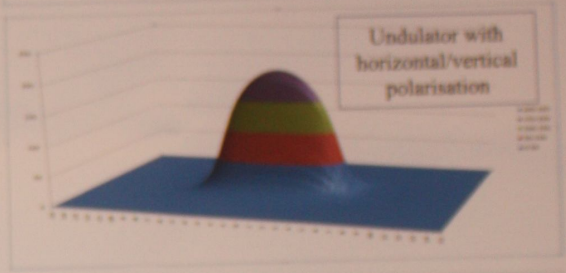
FEA Criteria for Thermal-Structural Analysis in Synchrotron Radiation

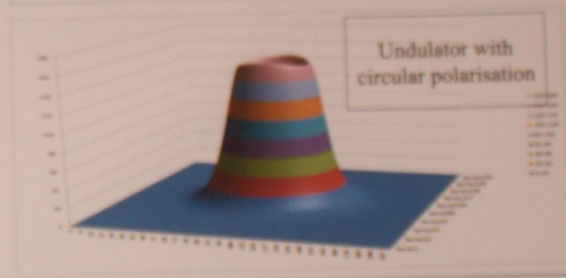
H. Huang, N. Hammond, & J. Kay, Diamond Light Source, Harwell Science and Innovation Campus, Didcot, Oxon OX11 0DE

Problem

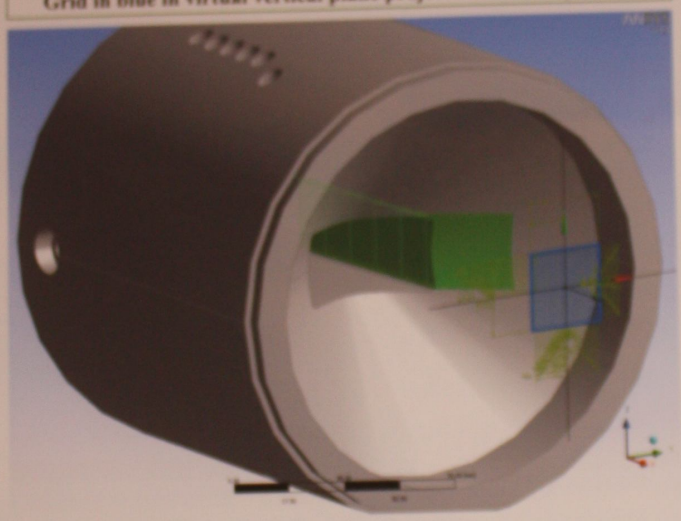
Thermal power with photon beams from synchrotron radiation has characteristic profiles as shown in figures on the right. 1) From dipole magnets, the maximum density is of the order of 10^2 W/mRad^2, 2) From Undulators with horizontal polarisation, the maximum density is of the order of 10^4 W/mRad^2, 3) From Undulators with vertical polarisation, the maximum density is above the order of 10^4 W/mRad^2, 4) from Undulators with circular polarisation, the maximum density is of the order of 10^4 W/mRad^2. To apply such thermal loads into an FEA model, a grid was created in a virtual plane perpendicular to the beam and then the power in each cell projected on to model surfaces as shown in the figure below.

Types of thermal power from photon beam

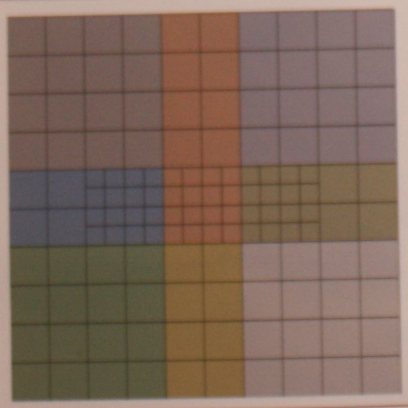




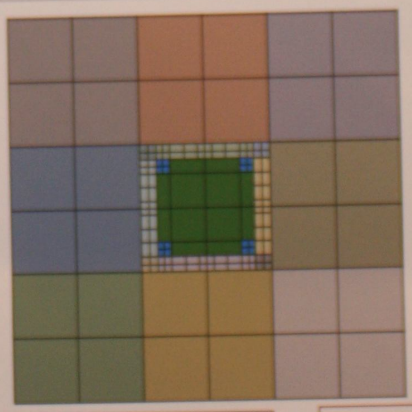
Grid in blue in virtual vertical plane projected onto an aperture



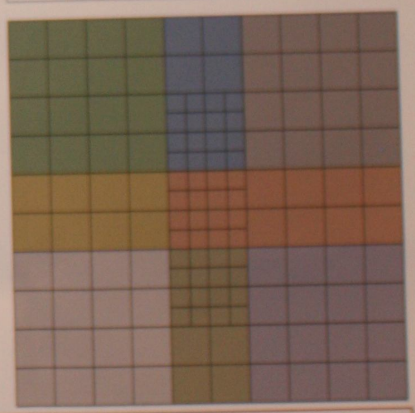
Adaptive grids for horizontal polarisation



Adaptive grids for circular polarisation



Adaptive grids for vertical polarisation



Effects of cell sizes of thermal grids on elastic and elasto-plastic analyses

Elastic analysis for I09 slit absorber

Load Cell size (no. cells) (peak power density%)	h x v (mm)	1x1(420) (97%)	2x2 (120) (84%)	6x4 (25) (65%)	10x6 (9) (48%)
Temperature	(C^)	407.0	399.7	381.9	363.2
Peak strain	(%)	0.154	0.16	0.14	0.14
Stress	(MPa)	166	172	154	149

Elasto-plastic analysis for I09 slit absorber

Load Cell size (no. cells) (peak power density%)	h x v (mm)	1x1(420) (97%)	2x2 (120) (84%)	6x4 (25) (65%)	10x6 (9) (48%)
Temperature	(C^)	407.0	399.7	381.9	363.2
Peak plastic strain	(%)	0.11	0.11	0.09	0.09
Bulk plastic strain	(%)	0.075	0.07	0.064	0.06
Stress	(MPa)	38.1	38.1	37.2	36.9

Conclusions

1) Thermal grids to assure the averaged power density in each cell of the vertical virtual plane is equal or greater than 90% of the actual power density generated from light sources.

2) Mesh size: at least "Medium" option in the ANSYS workbench is recommended for our analyses. Two consecutive mesh densities should be used to check convergence.

3) Heat transfer analysis: Heat transfer coefficient for water cooling: 0.01W/mm^{2}K to 0.02W/mm^{2}K. Maximum temperature of copper allowed: 400 C°. The temperature in the cooling channels must be below 165°C, which is the boiling point of water at 6bar.

4) Stress analysis for OFHC: Elastic Von-Mises stress should be under 250MPa and if stress is over 250MPa then elasto-plastic analysis has to be conducted to take strain into account. The design limits for plastic analysis are 0.5% peak strain and 0.1% in the bulk body.

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For more information please visit www.diamond.ac.uk or contact hou-cheng.huang@diamond.ac.uk