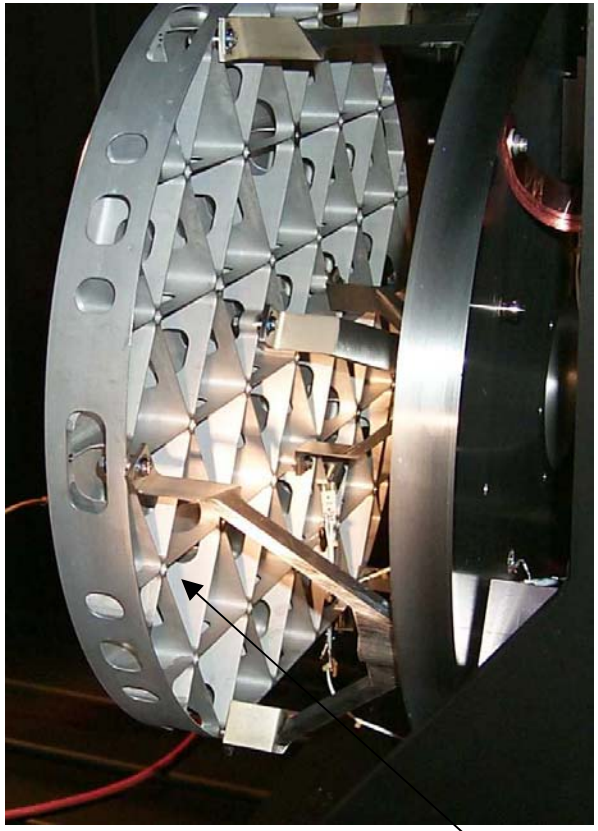
PREDICTING PRINT-THRU for the SUB-SCALE BERYLLIUM MIRROR DEMONSTRATOR (SBMD)

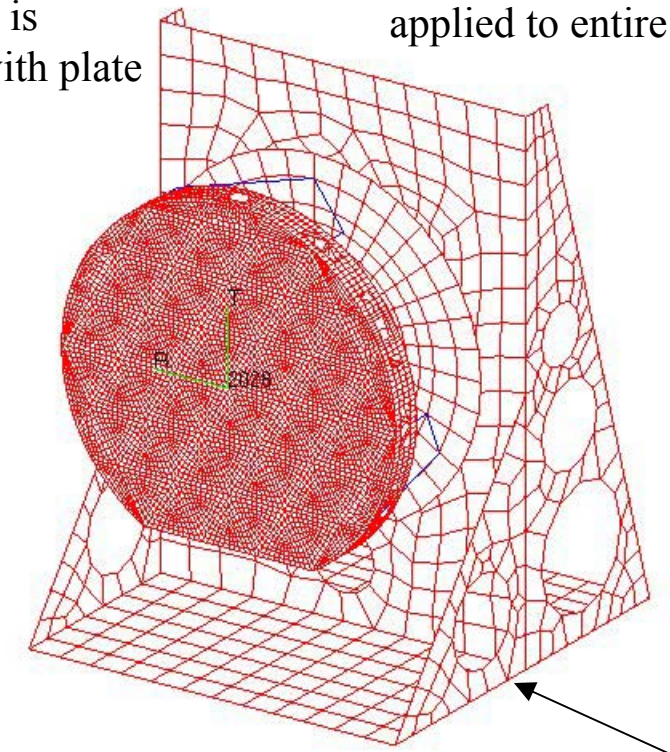
SBMD



triangular pocket

Be O-30 mirror is representated with plate finite elements

Thermal load of –263 K uniform temperature change applied to entire model.



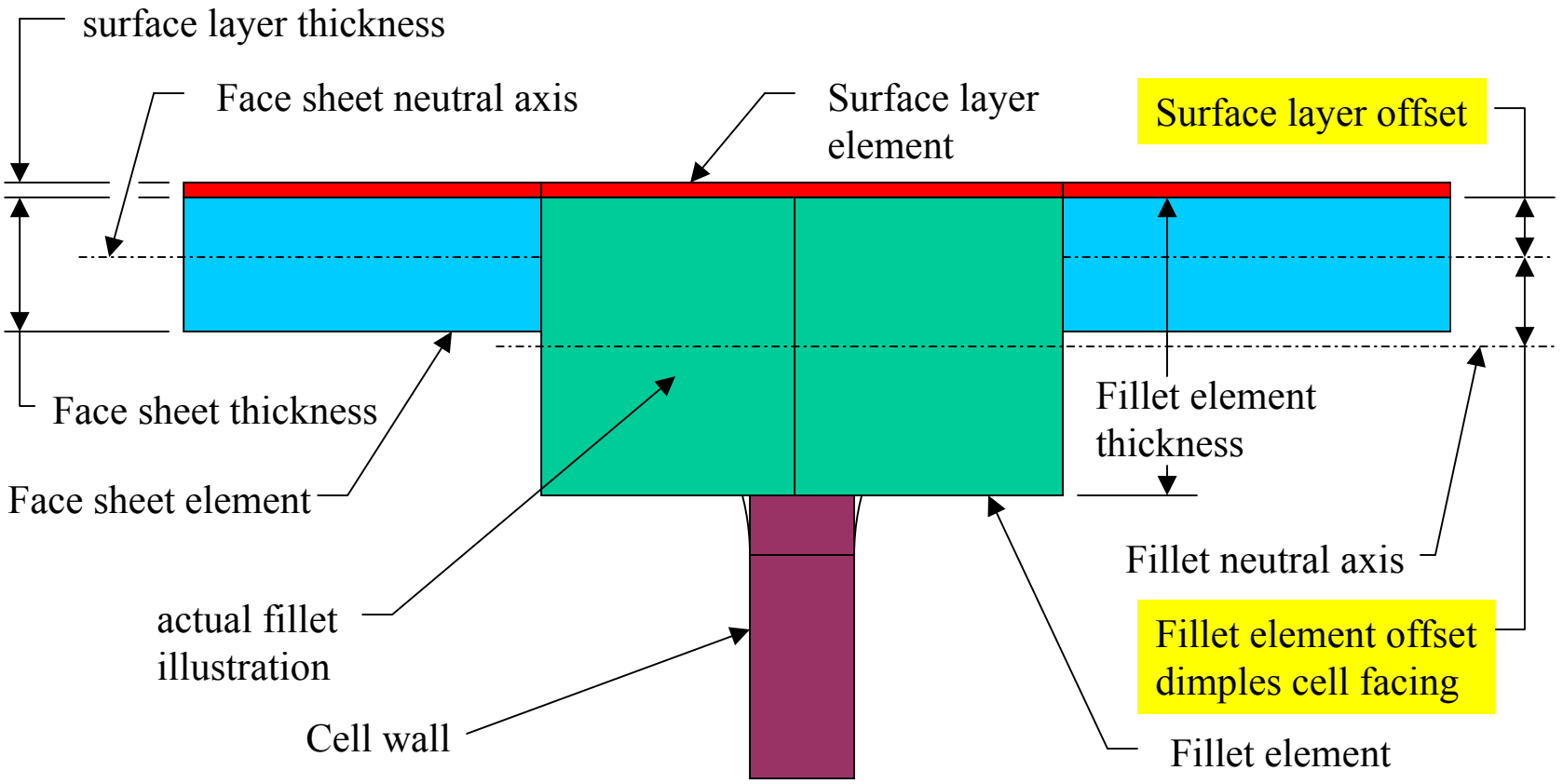
NASTRAN model

Model is constrained over test stand base surface

SBMD Print-Thru Study

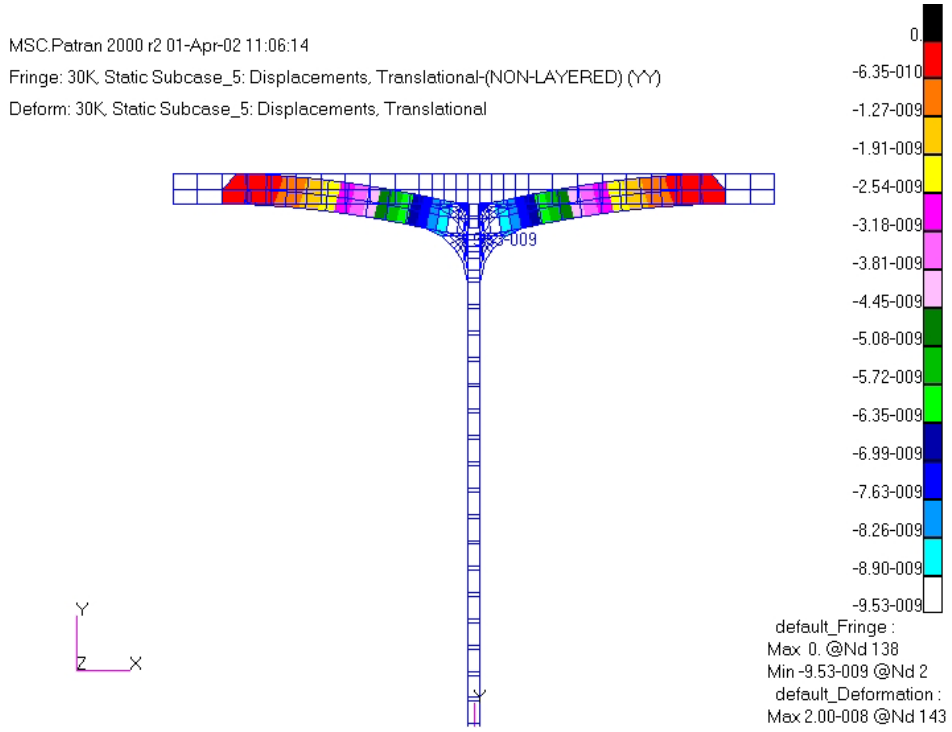
- Fillets between facesheet and cell walls were investigated.
- Thin surface layer (due to polishing) with different material properties was investigated.
- Individually neither produced print-thru.

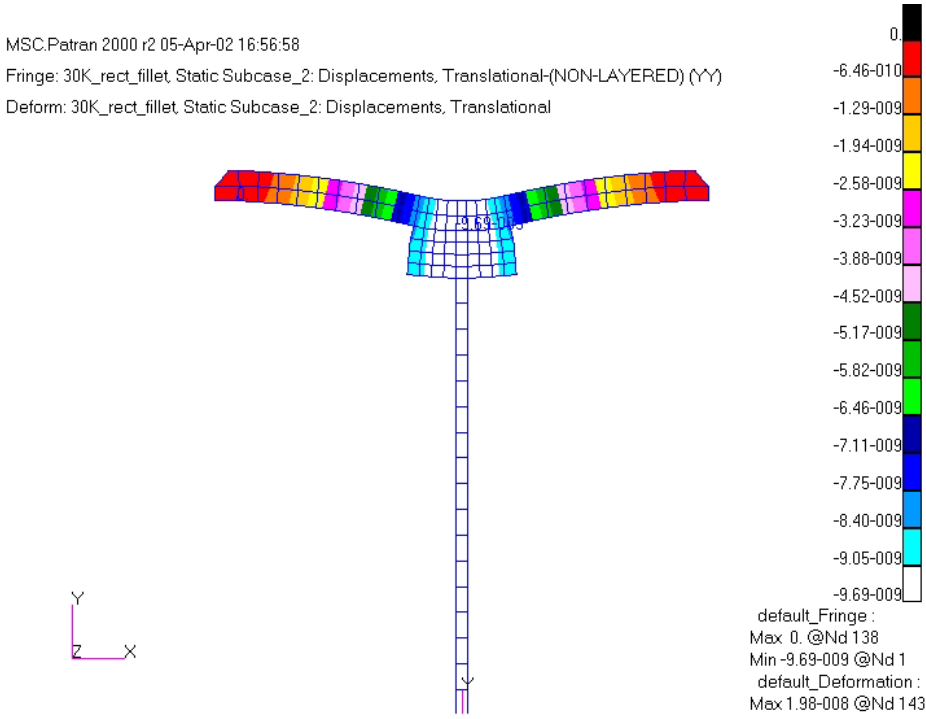
Finite Element Analysis Method



Face sheet/cell wall cross-section geometry and finite element representation

Cross-section Model to Determine Fillet Element Thickness



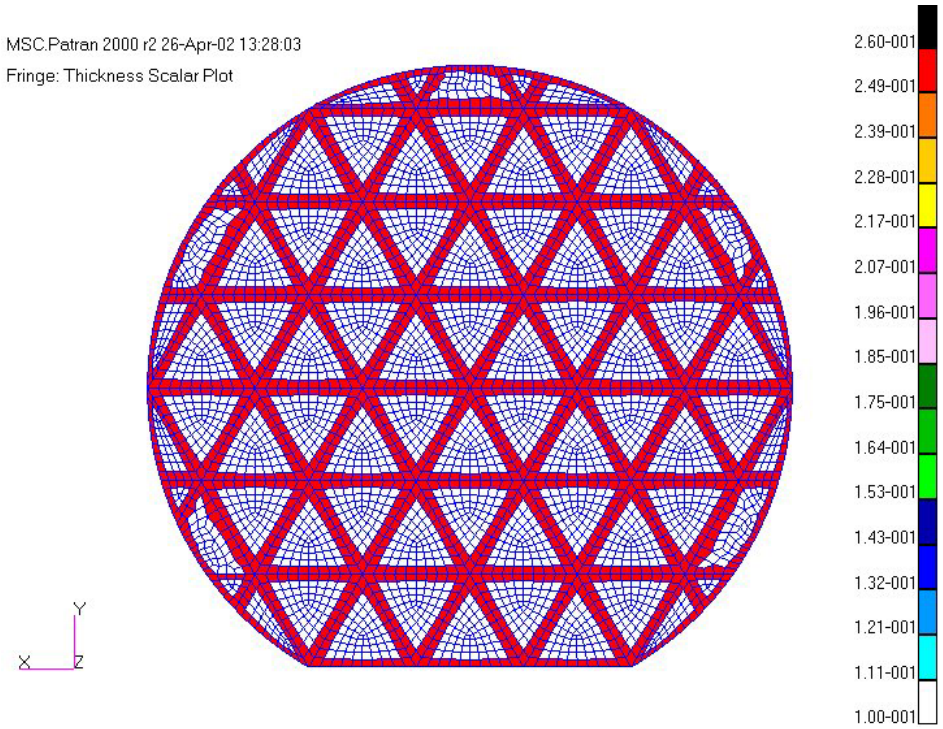


With as designed fillet, Y displacement (m)

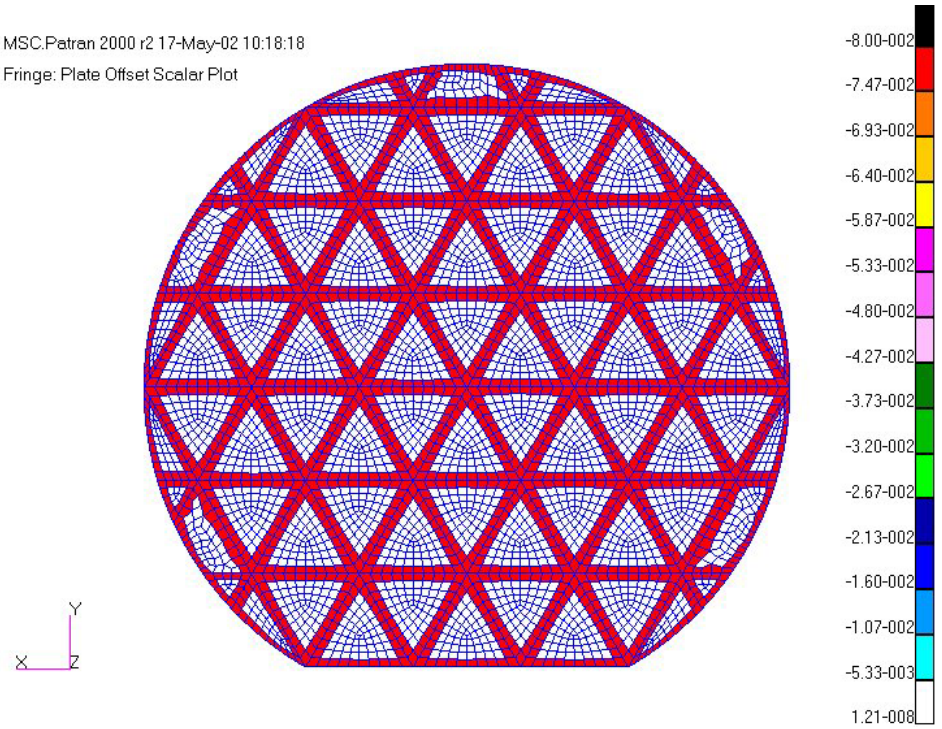
6.5 mm thick (face sheet + fillet) rectangular fillet

Cross-section model parameters: surface layer CTE = 0.513 ppm/K, surface layer thickness = 12.7 microns

Fillet and Facesheet Finite Element Representation



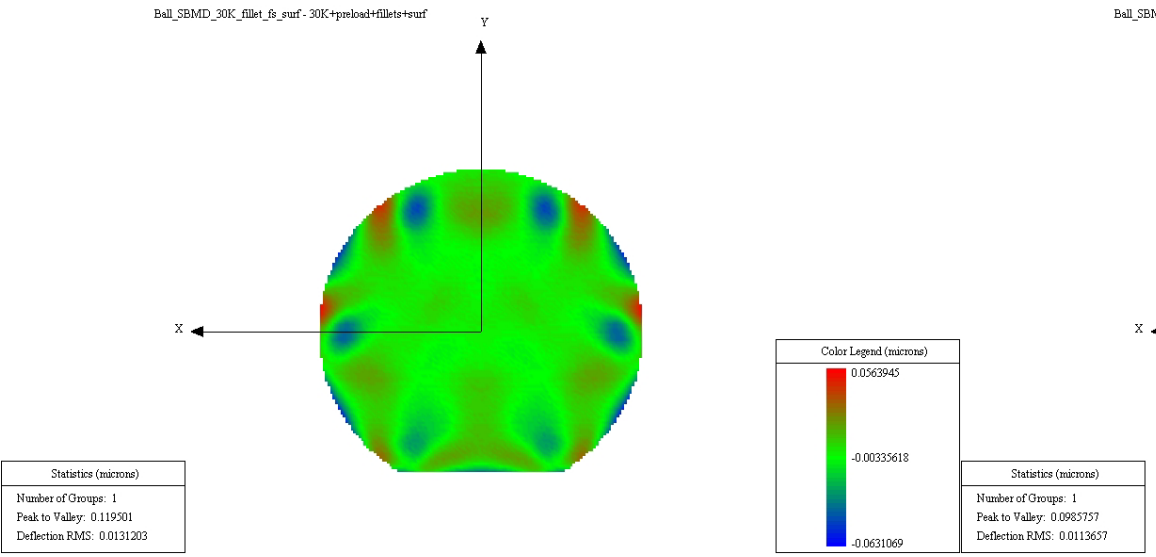
Fillet and facesheet thickness (in)

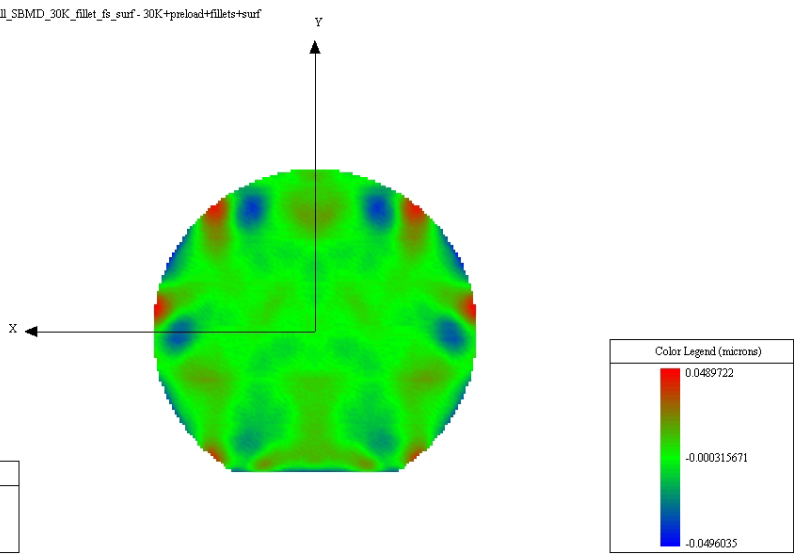


Fillet and facesheet offset (in)

Thin surface layer not shown

SBMD Print-Thru Prediction



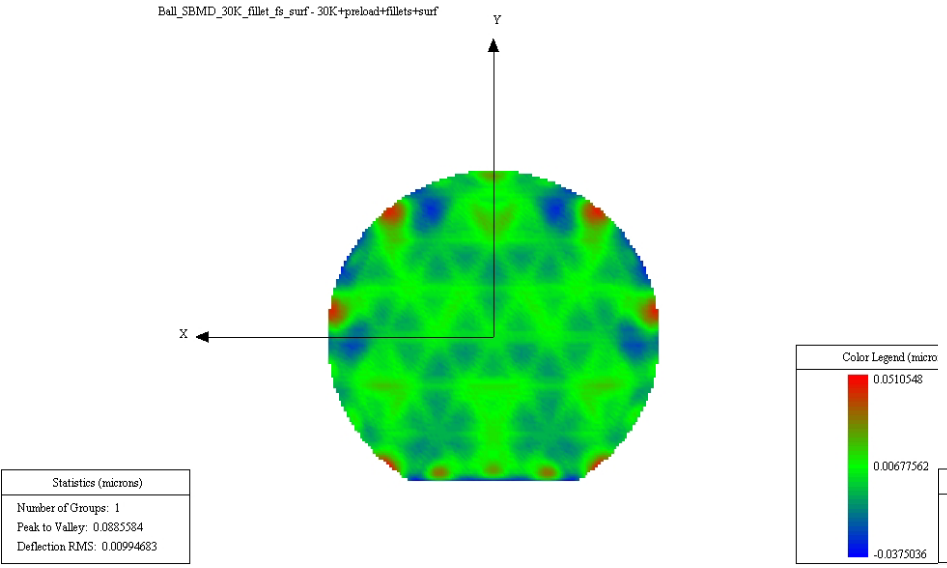


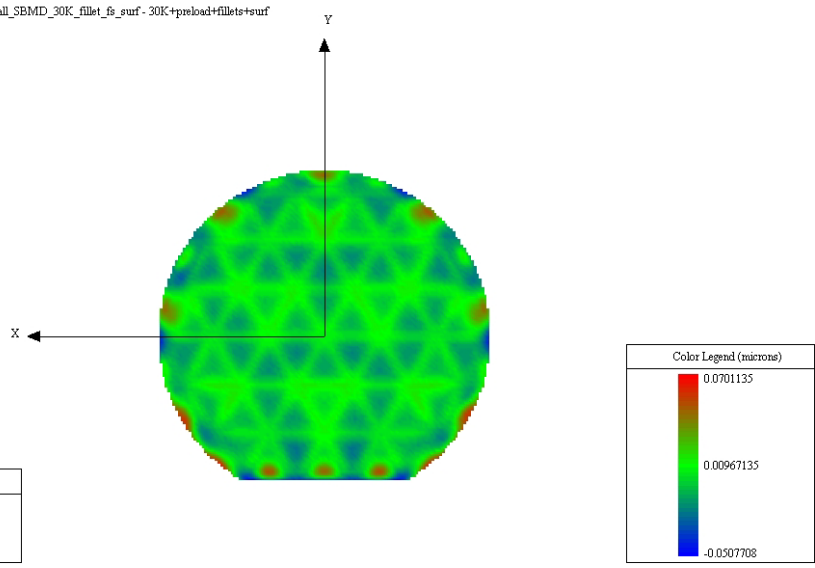
Residual surface –43 wavescope Zernikes
5.08 μm surface layer thickness. Surface layer CTE same as face sheet.
P-V 120 nm, RMS 13.1 nm

Residual surface –43 wavescope Zernikes
5.08 μm surface layer thickness. Surface layer CTE 10% larger than face sheet.
P-V 99 nm, RMS 11.4 nm

Left plot shows result without surface layer CTE effect (no quilting).
Quilting is beginning to appear in the right-hand plot.

SBMD Print-Thru Prediction



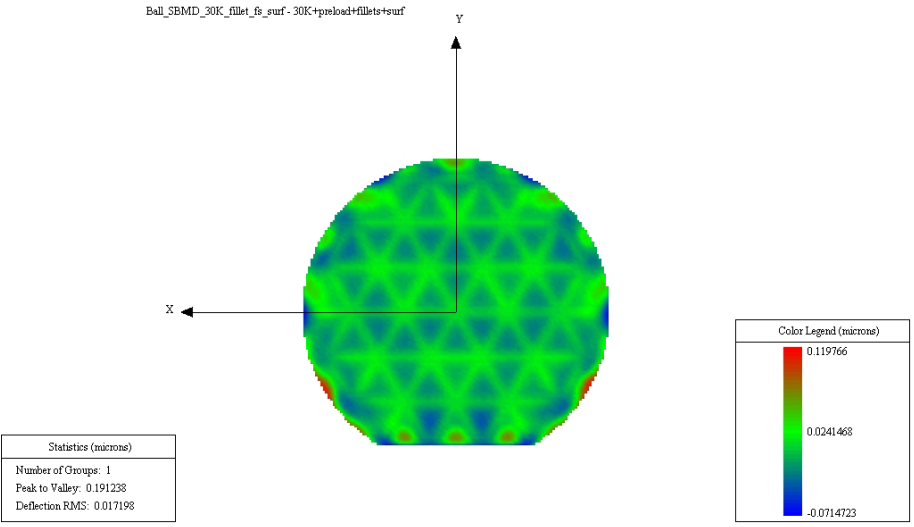


Residual surface –43 wavescope Zernikes
12.7 µm surface layer thickness. Surface layer CTE 10% larger than face sheet.
P-V 89 nm, RMS 9.9 nm

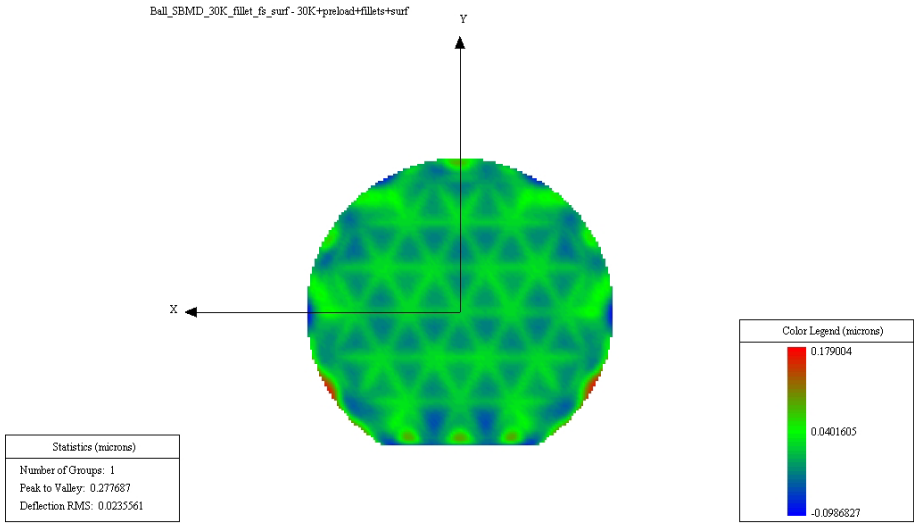
Residual surface –43 wavescope Zernikes
25.4 µm surface layer thickness. Surface layer CTE 10% larger than face sheet.
P-V 121 nm, RMS 11.9 nm

As the surface layer thickness increases print-thru becomes more pronounced.

SBMD Print-Thru Prediction

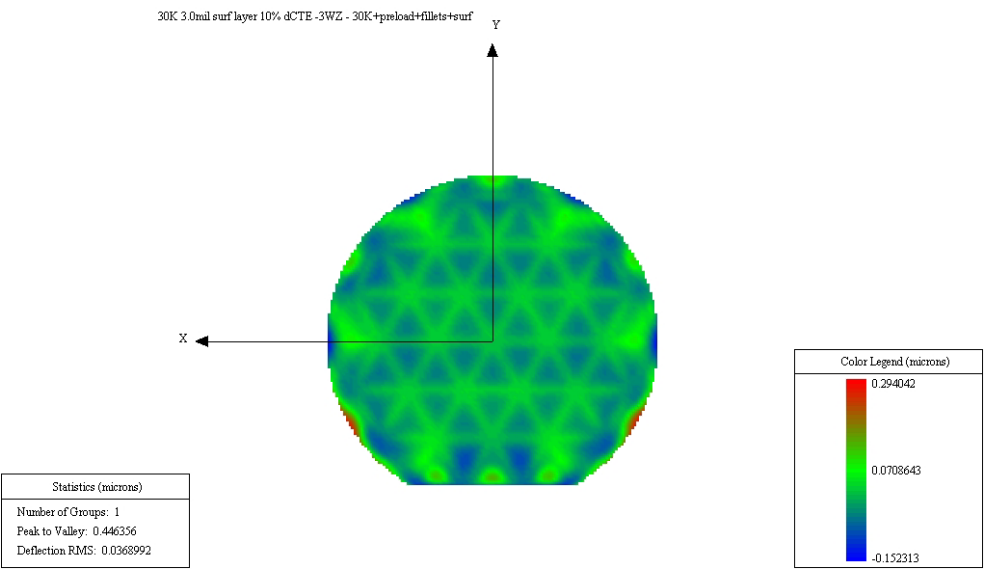


Residual surface –43 wavescope Zernikes
38.1 µm surface layer thickness. Surface layer CTE 10% larger than face sheet.
P-V 191 nm, RMS 17.2 nm

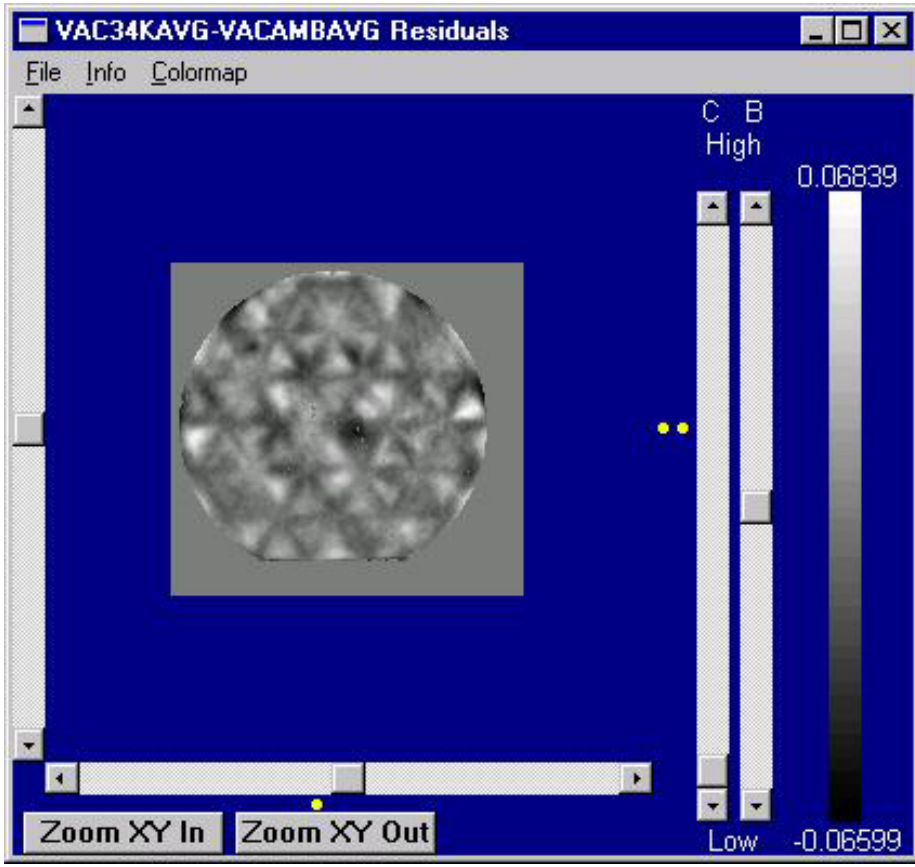


Residual surface –43 wavescope Zernikes
50.8 µm surface layer thickness. Surface layer CTE 10% larger than face sheet.
P-V 278 nm, RMS 23.6 nm

SBMD Print-Thru Prediction

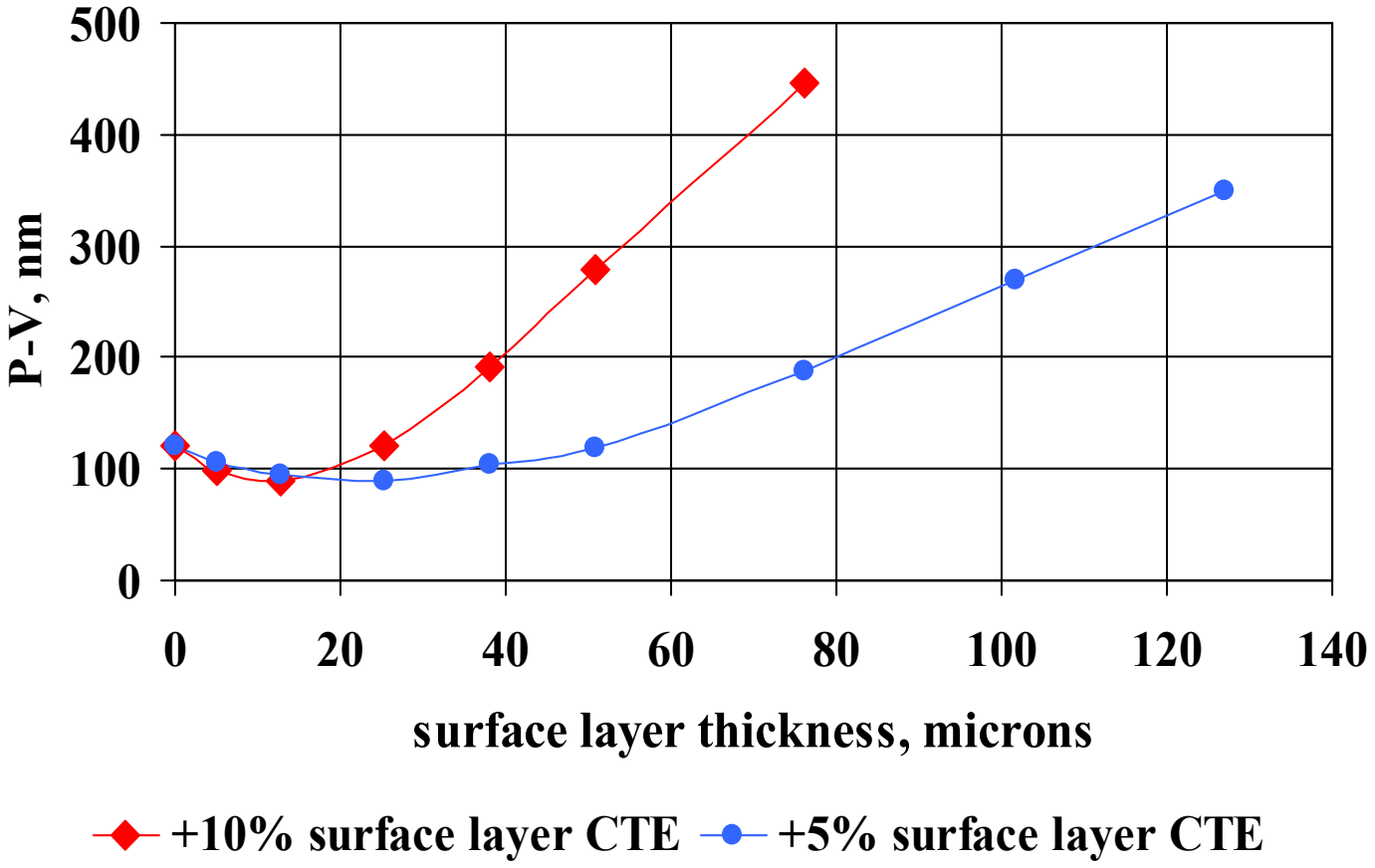


Residual surface –43 wavescope Zernikes
76.2 µm surface layer thickness. Surface layer CTE 10% larger than face sheet.
P-V 446 nm, RMS 36.9 nm

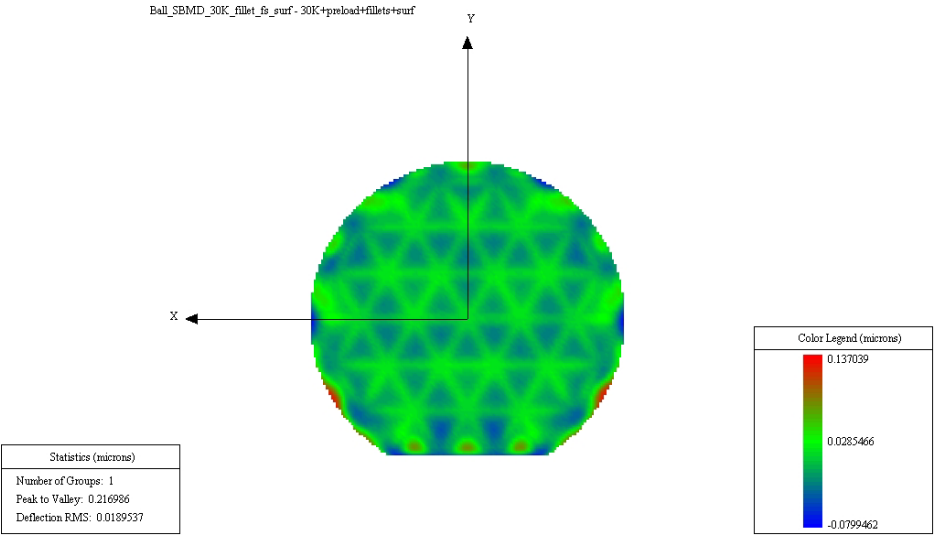


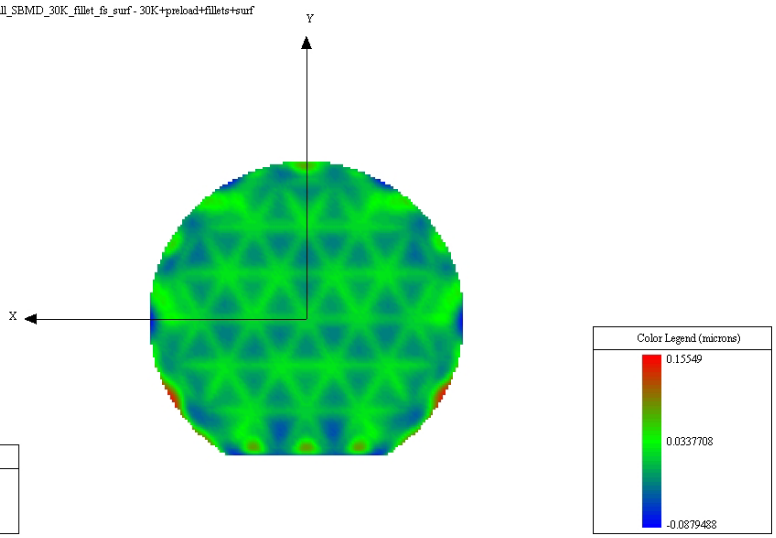
Measured data

P-V vs Surface Layer Thickness
43 Wavescope Zernikes Removed



Surface Layer Elastic Modulus Effect



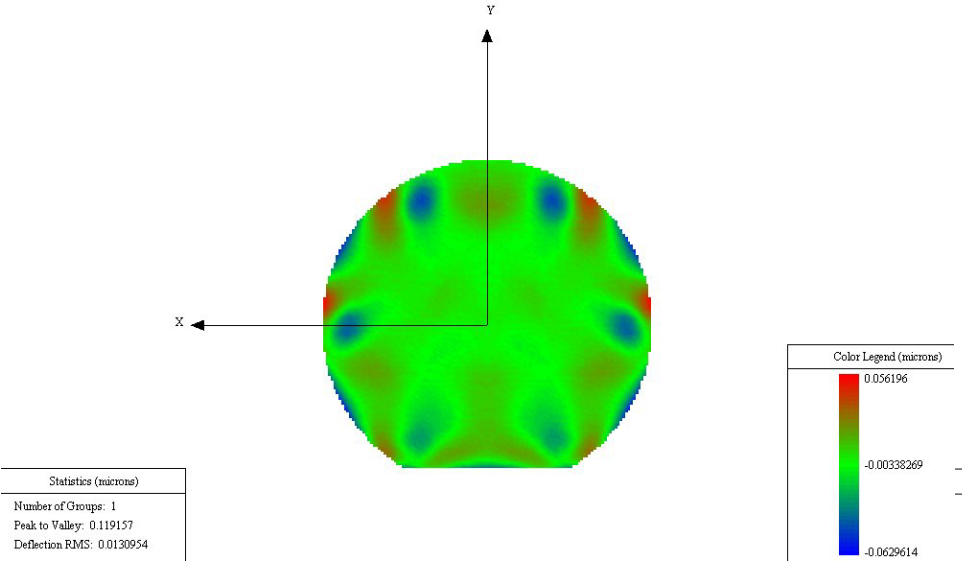


Residual surface –43 wavescope Zernikes 38.1 µm surface layer thickness. Surface layer CTE 10% larger than face sheet and 10% larger E modulus. P-V 217 nm, RMS 19.0 nm

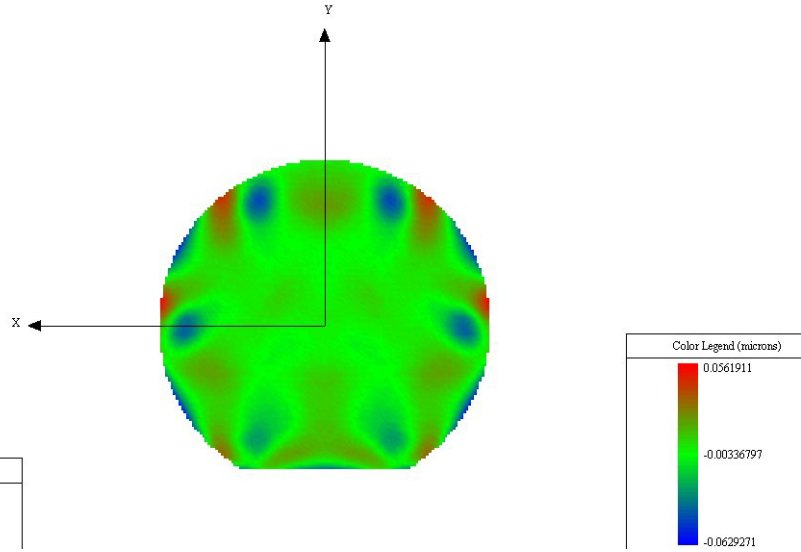
Residual surface –43 wavescope Zernikes 38.1 µm surface layer thickness. Surface layer CTE 10% larger than face sheet and 20% larger E modulus. P-V 243 nm, RMS 21 nm

This shows that increasing the surface layer modulus E increases the quilting magnitude

Surface Layer Elastic Modulus Effect



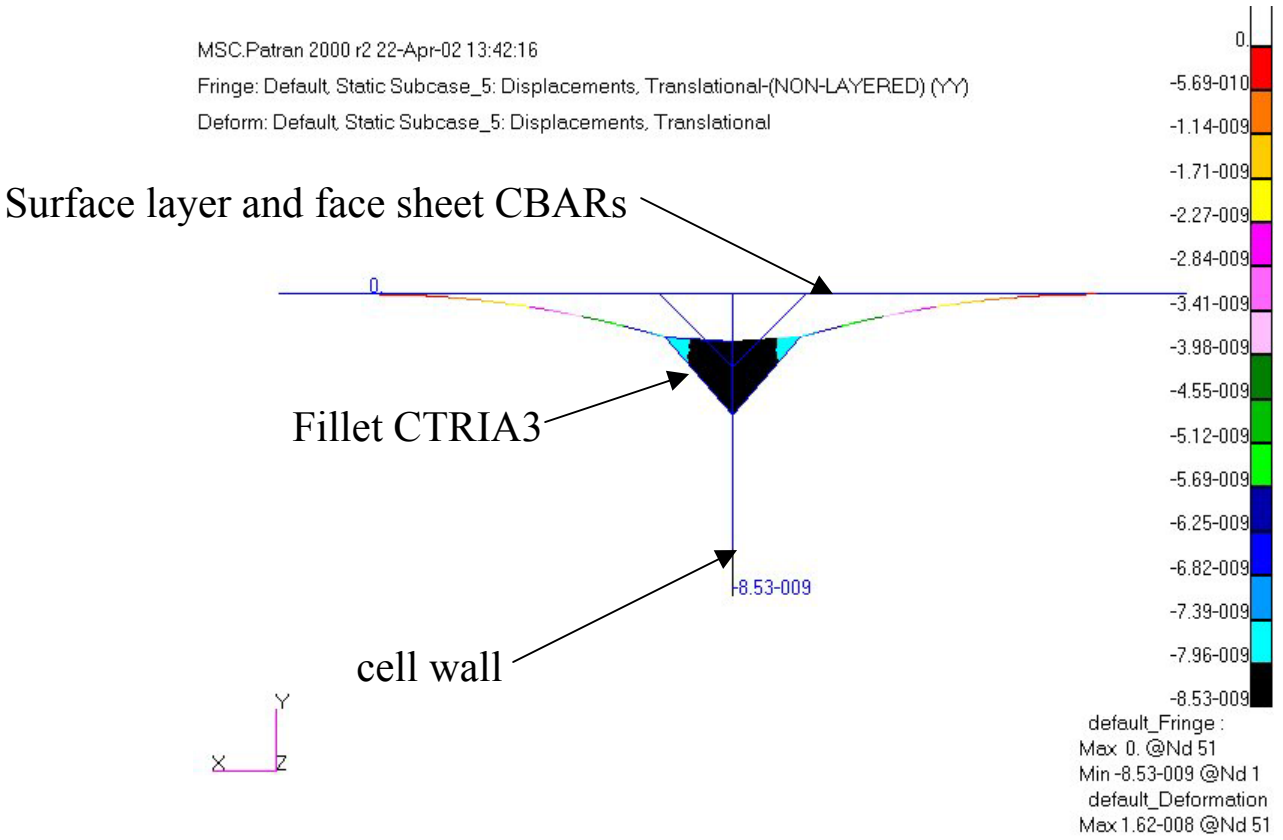
Residual surface –43 wavescope Zernikes 12.7 µm surface layer thickness. Surface layer E modulus 10% larger than face sheet and both have same CTE. P-V 120 nm, RMS 13.1 nm



Residual surface –43 wavescope Zernikes 12.7 µm surface layer thickness. Surface layer E modulus 20% larger than face sheet and both have same CTE. P-V 120 nm, RMS 13.1 nm

These results indicate that a differential E modulus alone will not produce quilting. The differential CTE is necessary for quilting.

Alternate Analysis Method



If this model were extended in and out of the page the CBARs would become plates and the CTRIA3s would be CPENTAs (wedge elements). This model provides some evidence that a hybrid model will predict print-thru.

Hybrid cross-section model parameters: surface layer CTE = 0.513 ppm/K, surface layer thickness = 12.7 microns

Conclusions

- Print-thru can be predicted with a mirror model represented with plate elements.
- SBMD print-thru is produced by the fillets between the facesheet and cell walls coupled with a thin mirror surface layer with a larger CTE and the mirror subjected to a uniform temperature change.