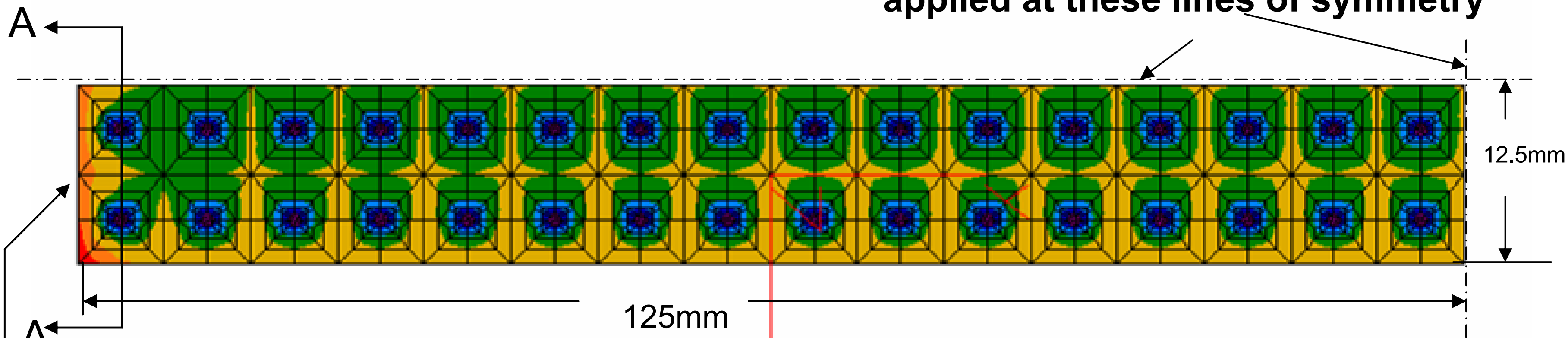
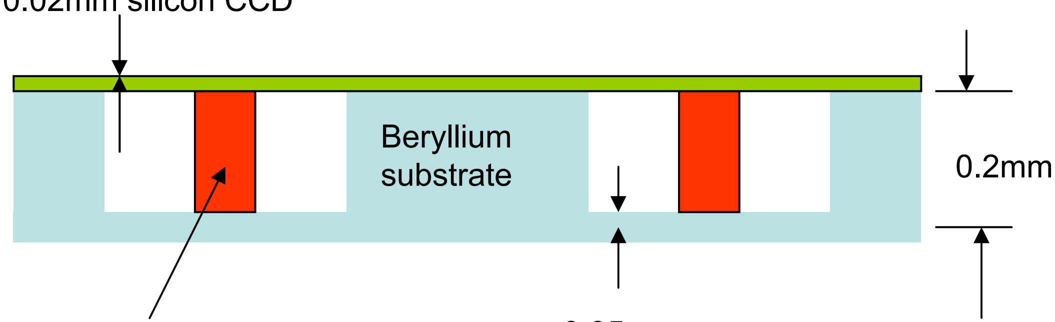
Main Points of discussion:

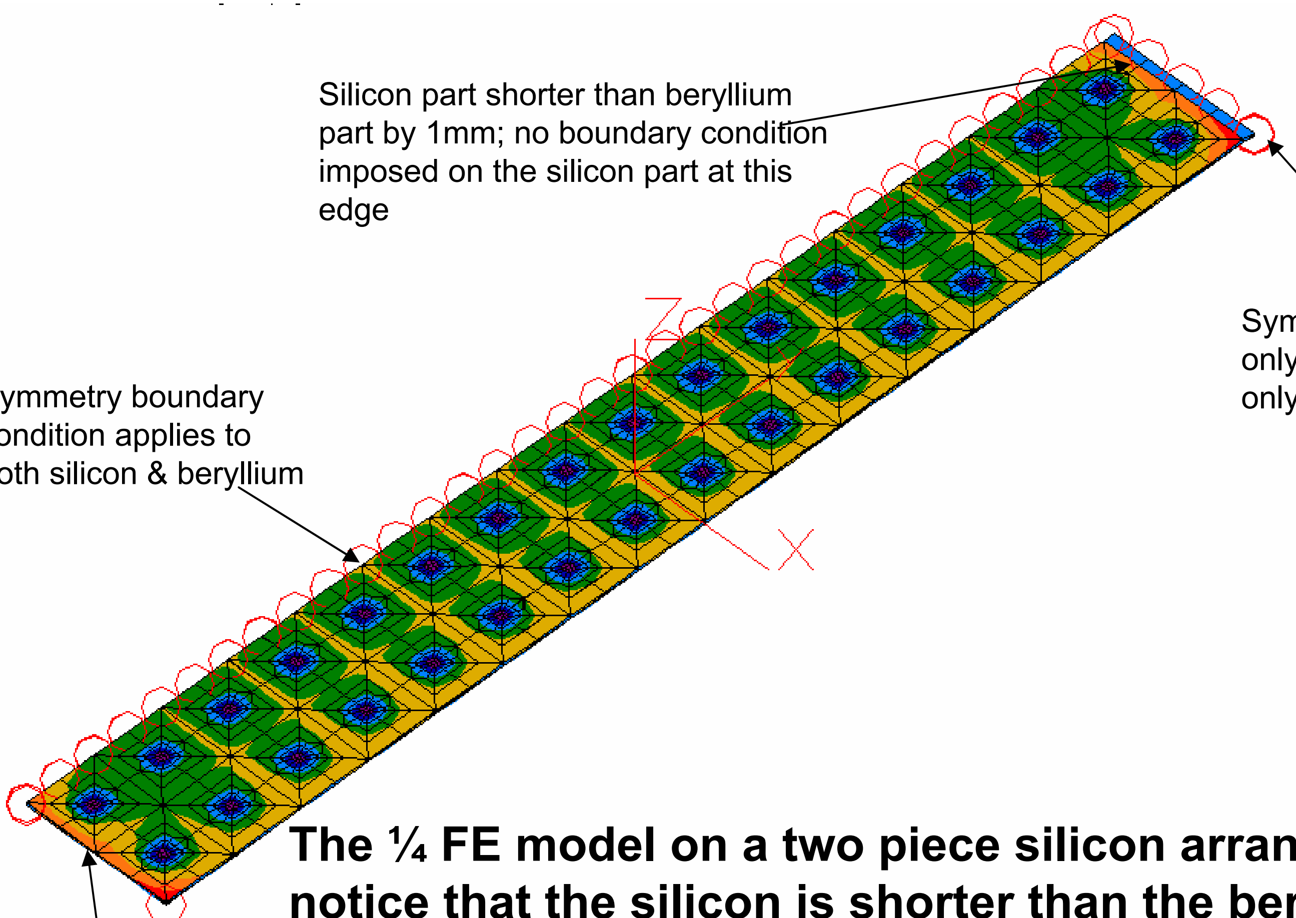
1. **To look at the deflections at a one piece silicon CCD (1 x 250mm long) due to the differential expansion between the silicon and the beryllium substrate (using a ¼ model);**
2. **To look at the deflection of a two-piece silicon CCD (2 x 125mm long) due to the differential expansion between the silicon and the beryllium substrate (using a ¼ model);**
3. **To look at the stresses at the glue pillars to see if they are within an acceptable level.**
4. **To see if results of (2) would be any different when a ½ model is used, i.e. taking the full width of the structure;**
5. **To look at the magnitude of deflection of the structure (silicon + glue pillars + beryllium substrate) due to gravity load and see if pre-tension is still needed to keep it to the required straightness level**



The ¼ FE model on a one piece silicon arrangement



Cross-section A-A



Silicon part shorter than beryllium part by 1mm; no boundary condition imposed on the silicon part at this edge

Symmetry boundary condition only applies to the beryllium part only

Symmetry boundary condition applies to both silicon & beryllium

The ¼ FE model on a two piece silicon arrangement – notice that the silicon is shorter than the beryllium by 1mm and is not constrained to simulate any symmetry condition

This edge is free to slide in the horizontal plane

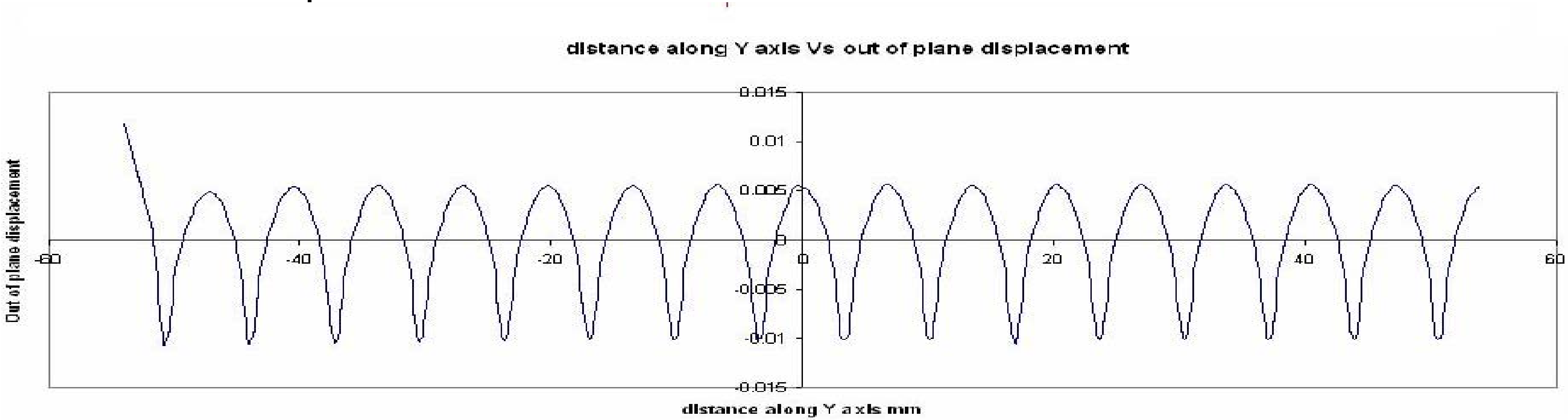
The results:-

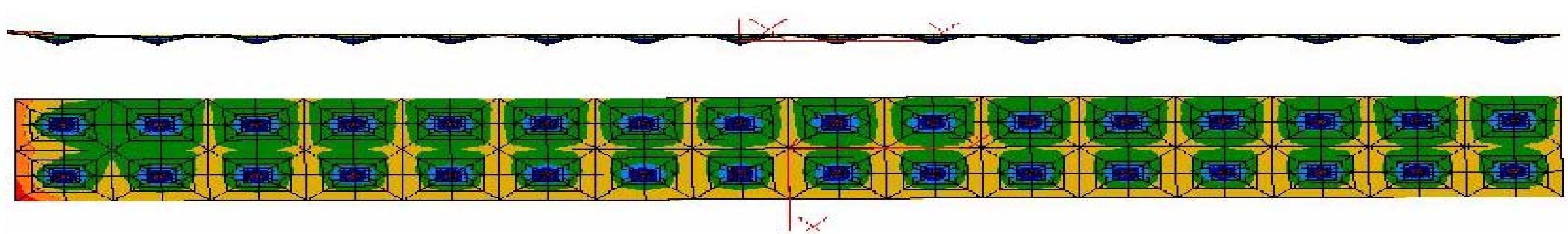
We use a non-linear step loading analysis. It took 4 hours to complete the run;

A total delta T of 80 degree C was applied

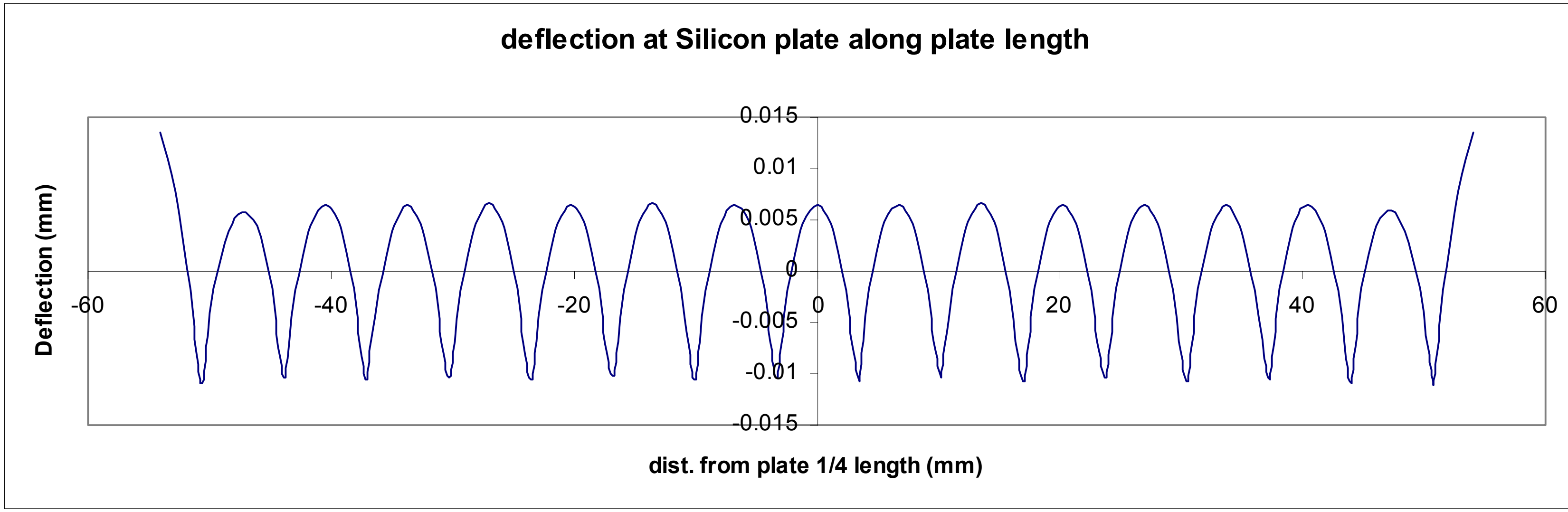
The deflection of the silicon along its length is as follow:-

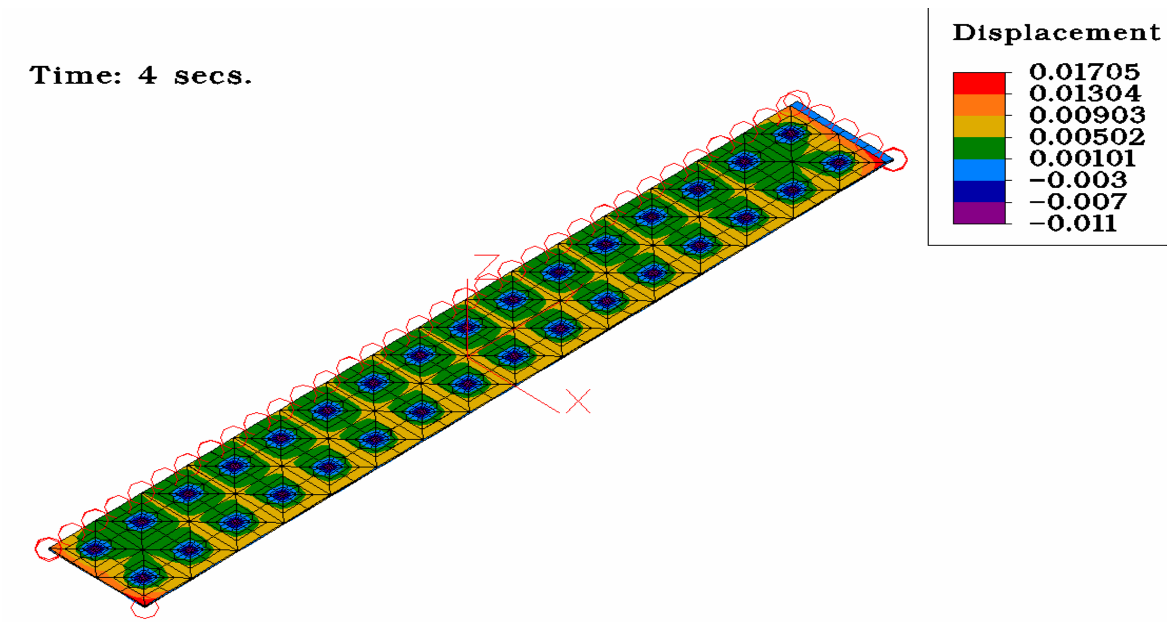
For the one-piece silicon model





For the two-piece silicon model





Observation of the ¼ and ½ model results

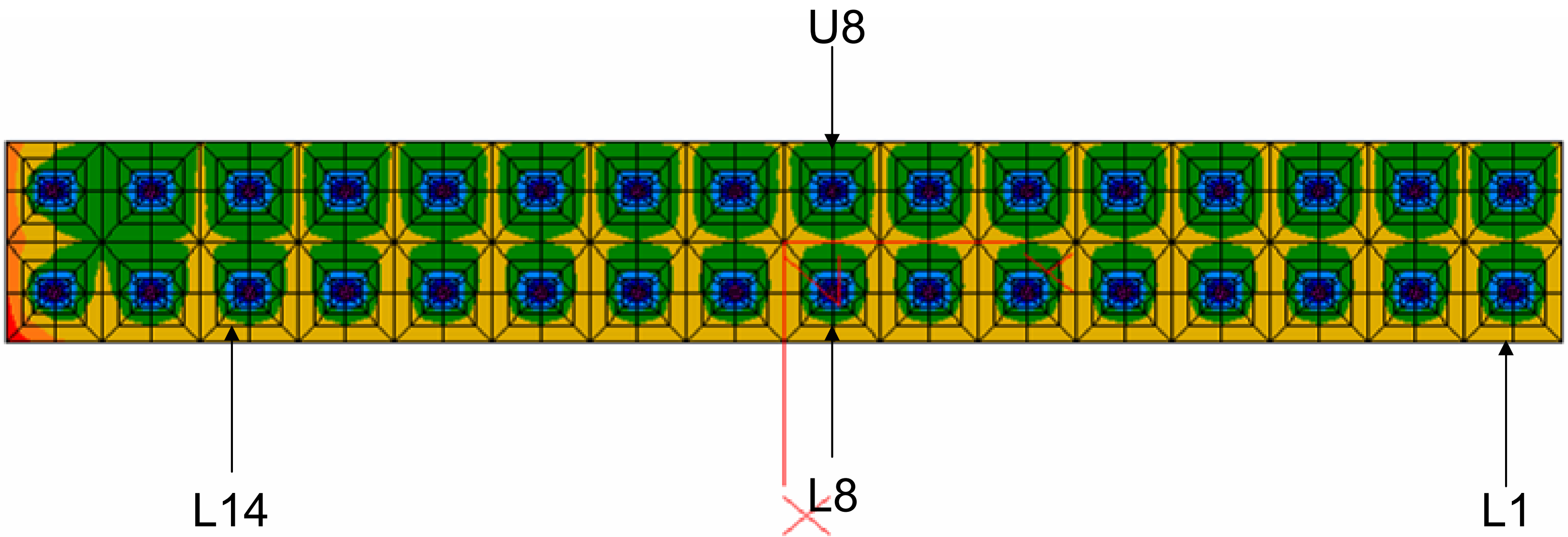
There are ripples formed between glue pillars due to compression loads between glues as a result of the differential contraction between silicon & beryllium;

The maximum upward deflection is about 5 microns which is as expected and which is smaller than that predicted by the linear analysis;

The max. downward deflection caused by the contraction of glues is about 10 microns which is the same as those predicted by the linear analysis

Except at the free ends, magnitude of the deflections is quite uniform across the silicon length indicating equal compression force between glues.

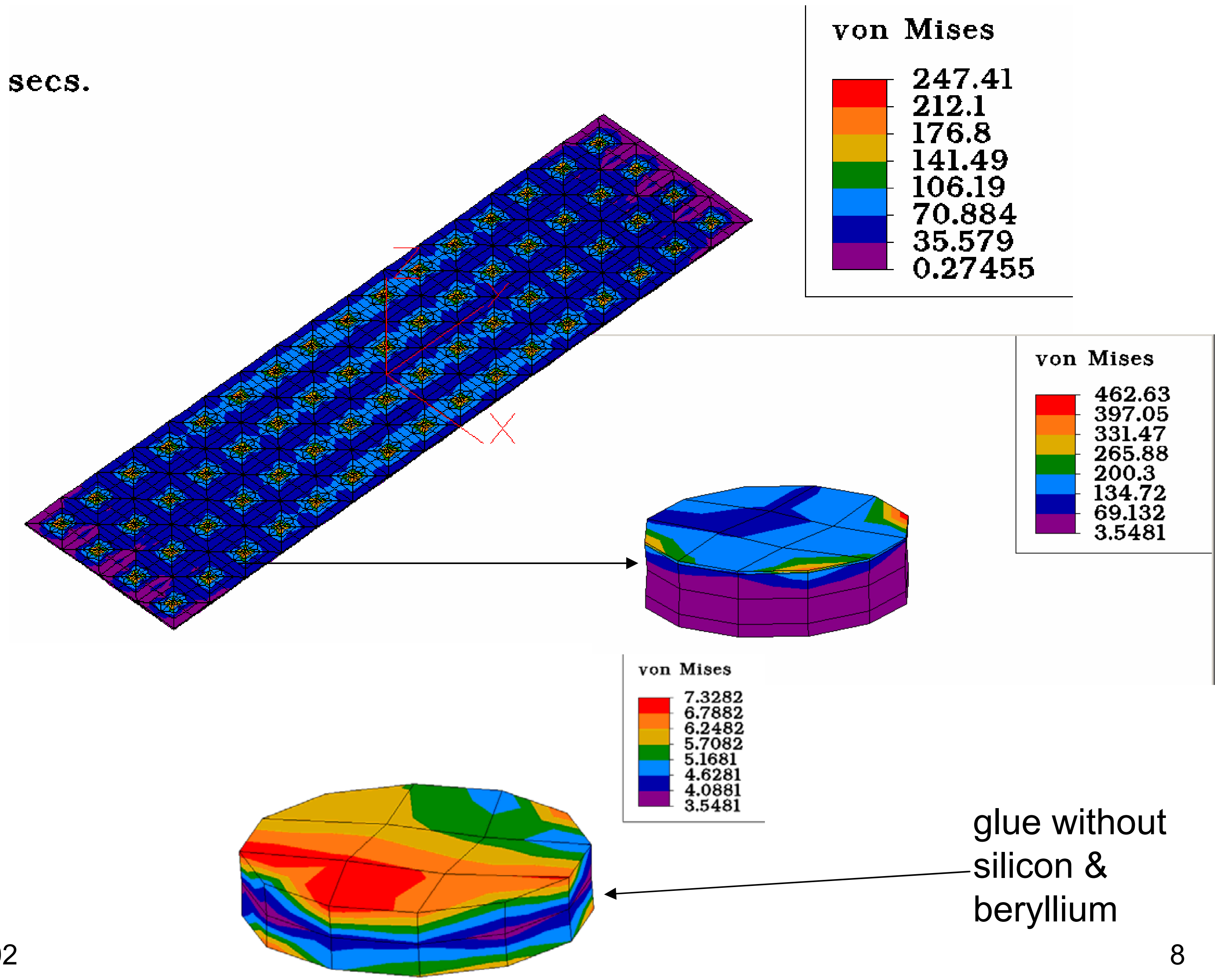
Shear stresses in the glue pillars



The deflection plots show that the deflections between the glues are uniform regardless of their locations. However, the overall stress plots indicate that there are high stresses in the glue areas. We need to examine the stresses in detail so that we can tell whether the stresses are coming from the silicon, the beryllium or from the glues themselves. We have chosen 4 typical glue pillars for this study with the following reasons:

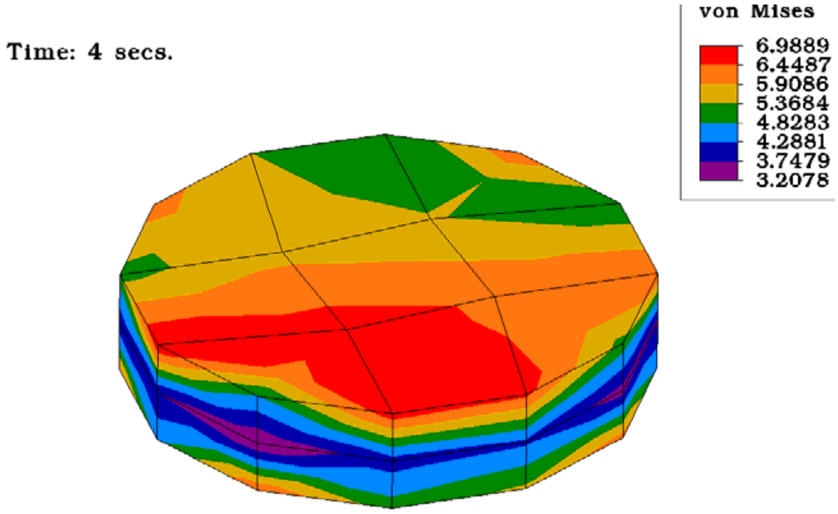
Glue L1, L14, U8 & L8 were chosen because they represent the glues in different locations.

Glues near the free edges were not chosen here because they are likely to be affected by the free end boundary effects.

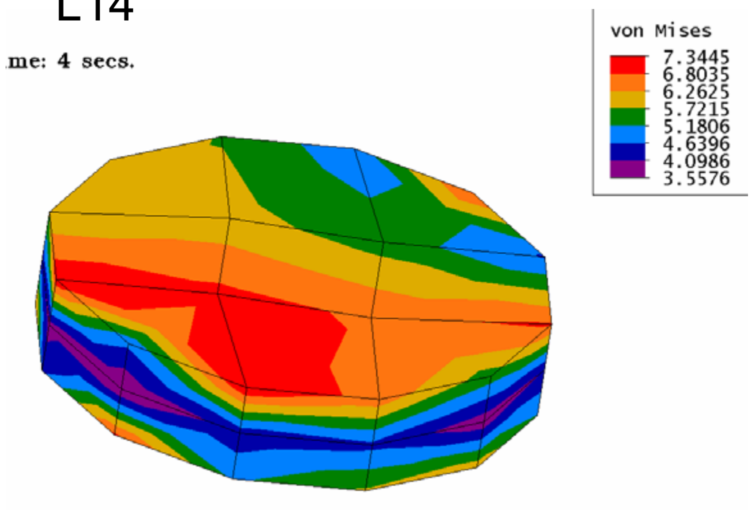

secs.
von Mises
247.41
212.1
176.8
141.49
106.19
70.884
35.579
0.27455
von Mises
462.63
397.05
331.47
265.88
200.3
134.72
69.132
3.5481
von Mises
7.3282
6.7882
6.2482
5.7082
5.1681
4.6281
4.0881
3.5481
glue without silicon & beryllium

The chosen glues

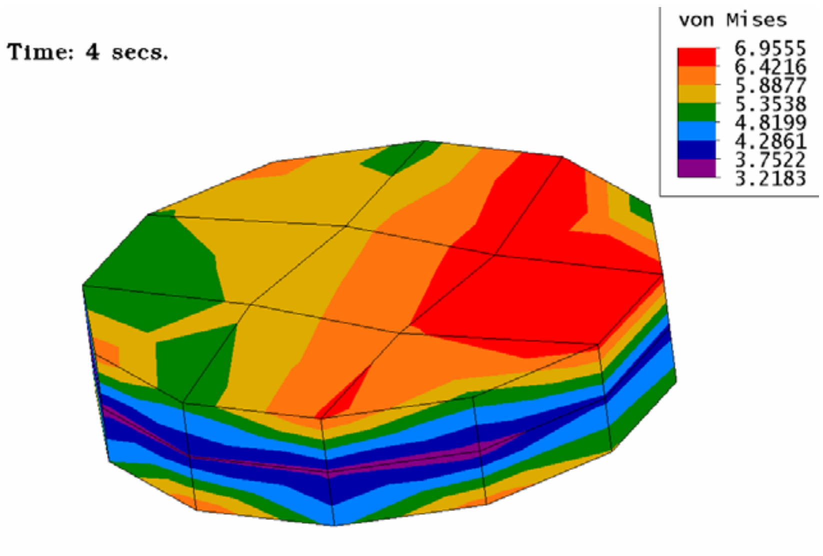
L1



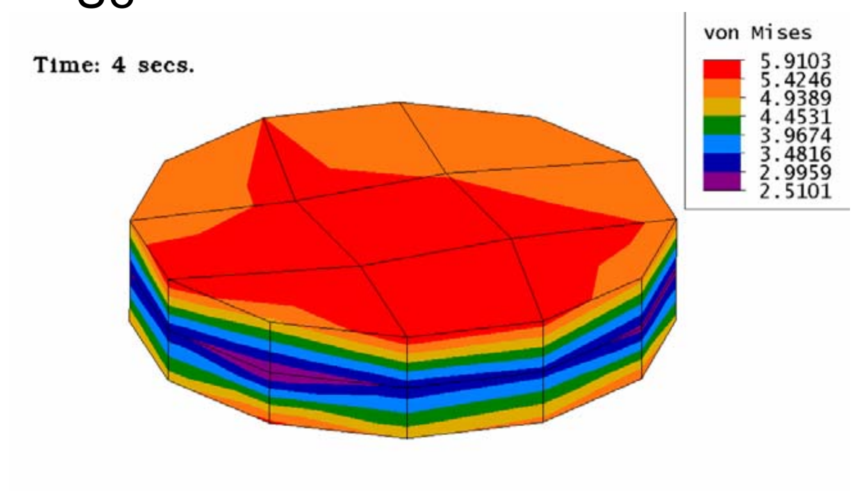
L14



L8



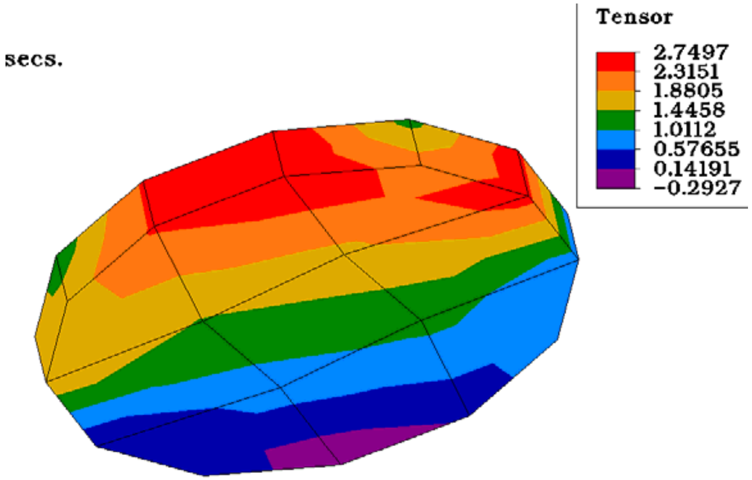
U8



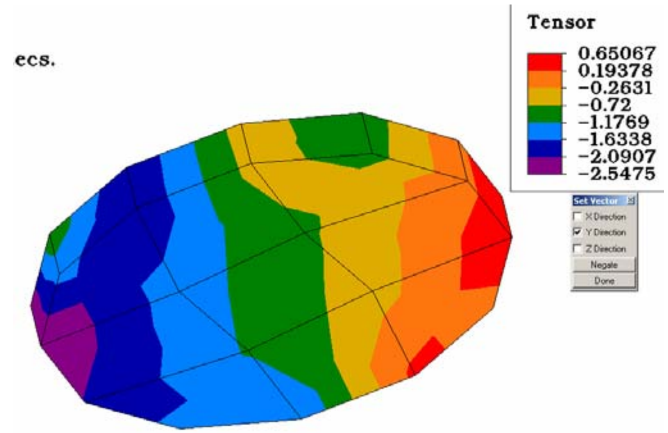
L14

Max. shear stress on the glue itself

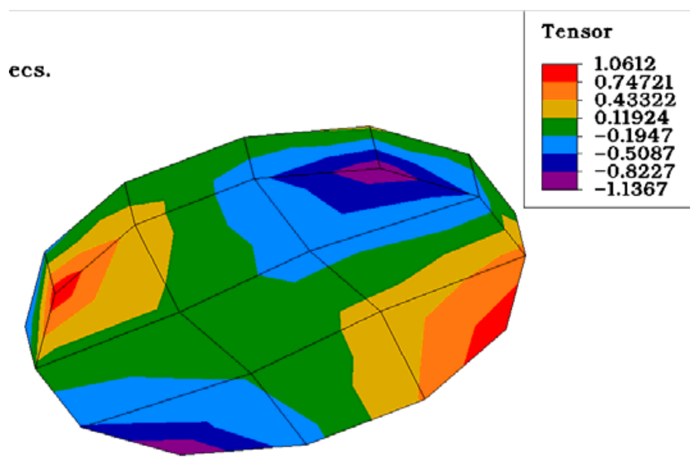
GZX-direction

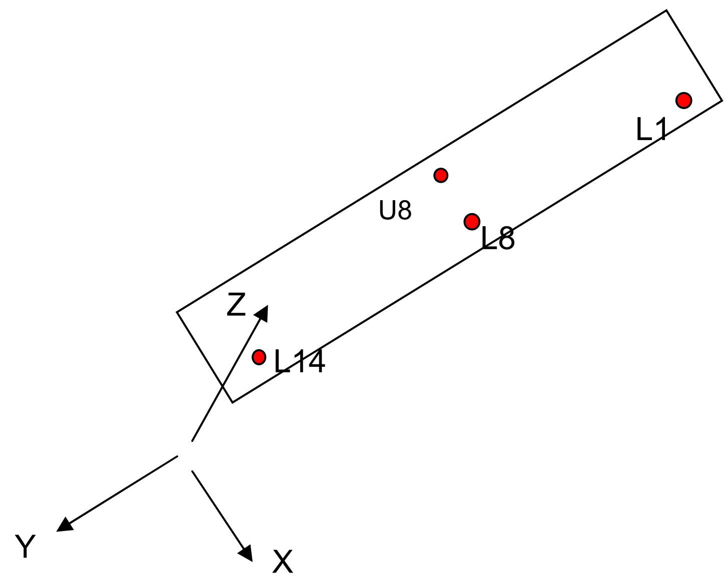


GYZ-direction



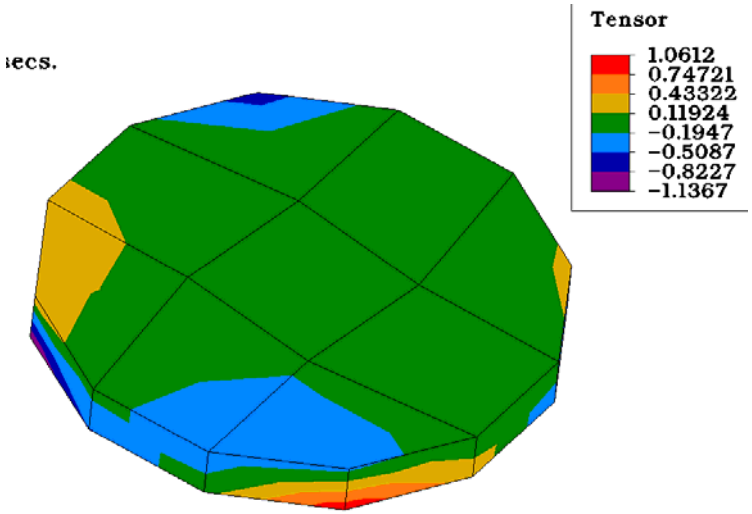
GXY-direction



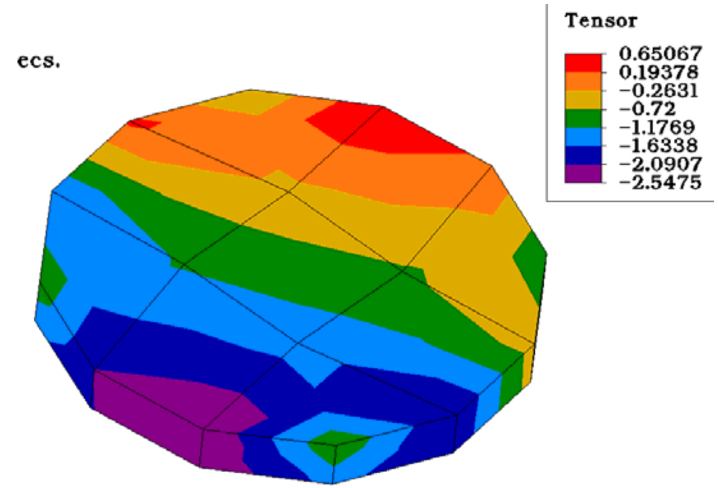


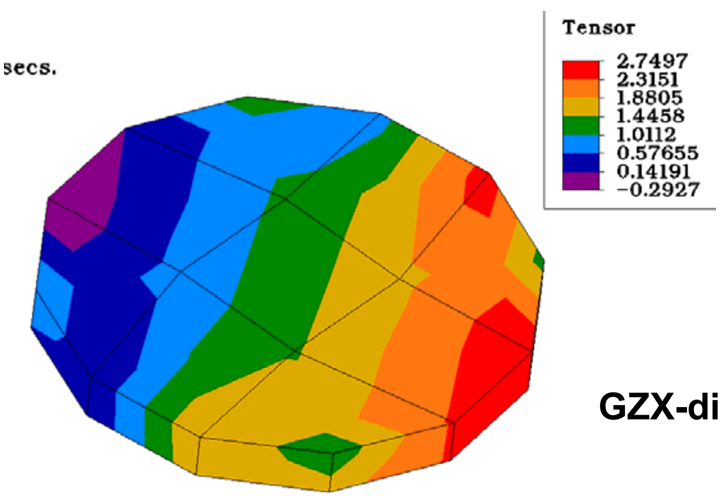
Max. shear stress between glue and silicon

GXY-direction: 0.31

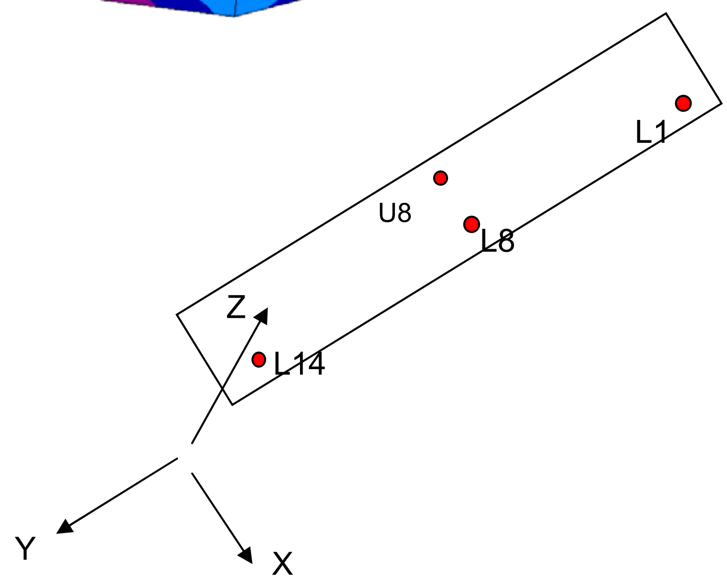


GYZ-direction: 0.65





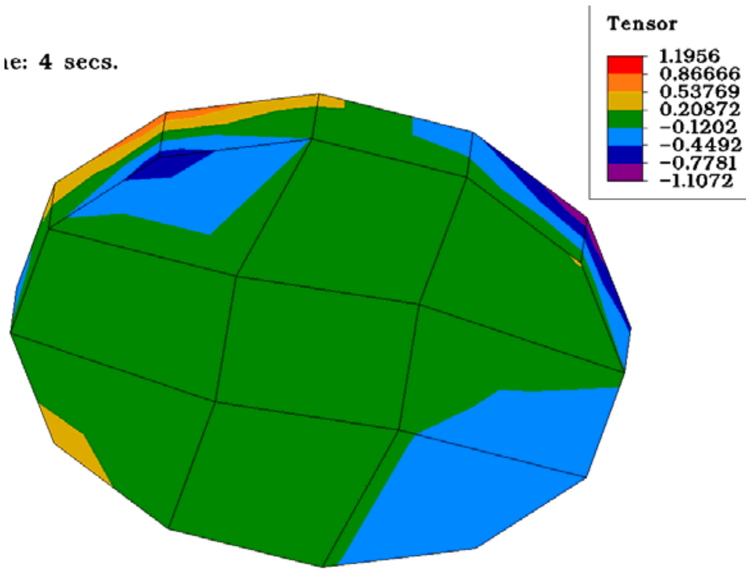
GZX-direction: 2.73



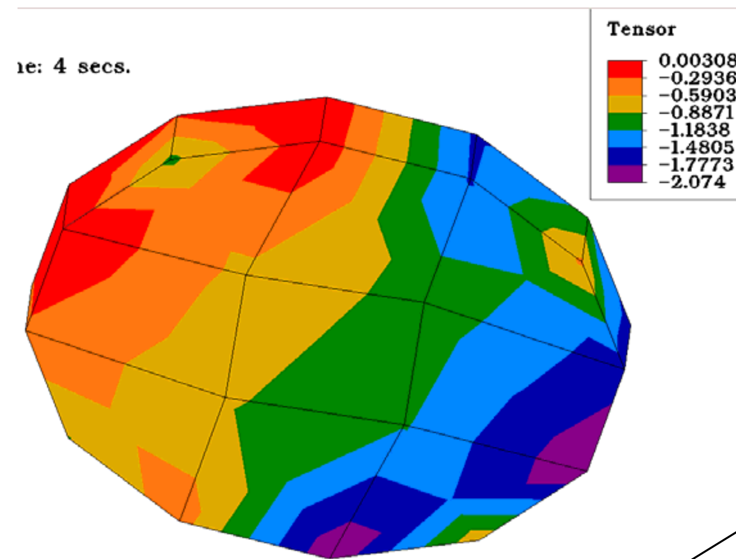
L14

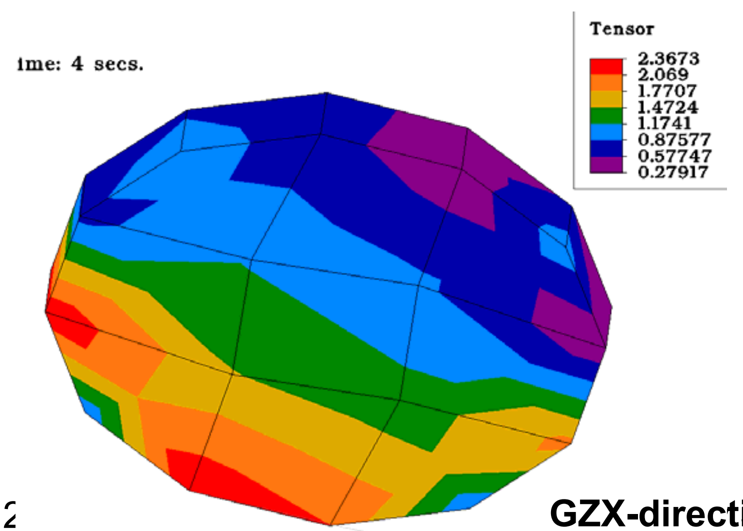
Max. shear stress between glue and beryllium

GXY-direction: 0.33

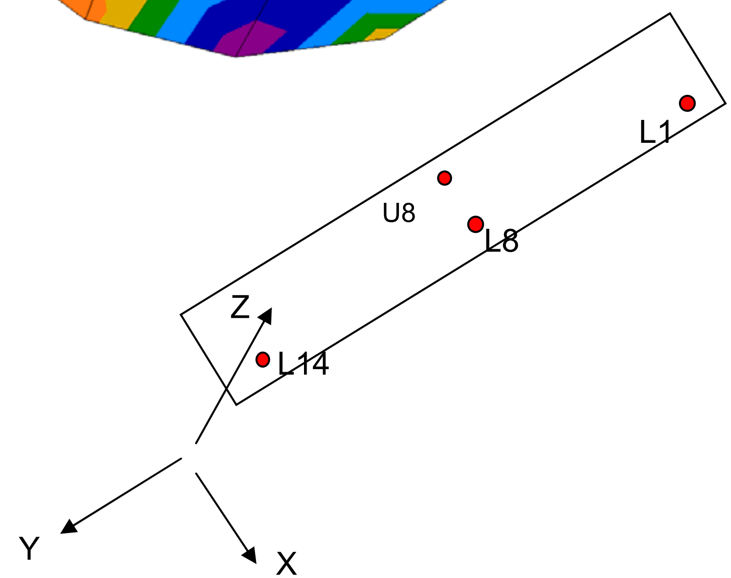


GYZ-direction: -0.0179



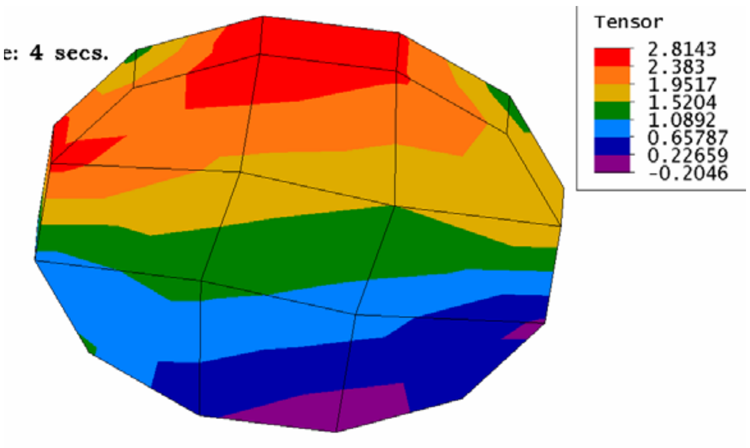


GZX-direction: 2.32

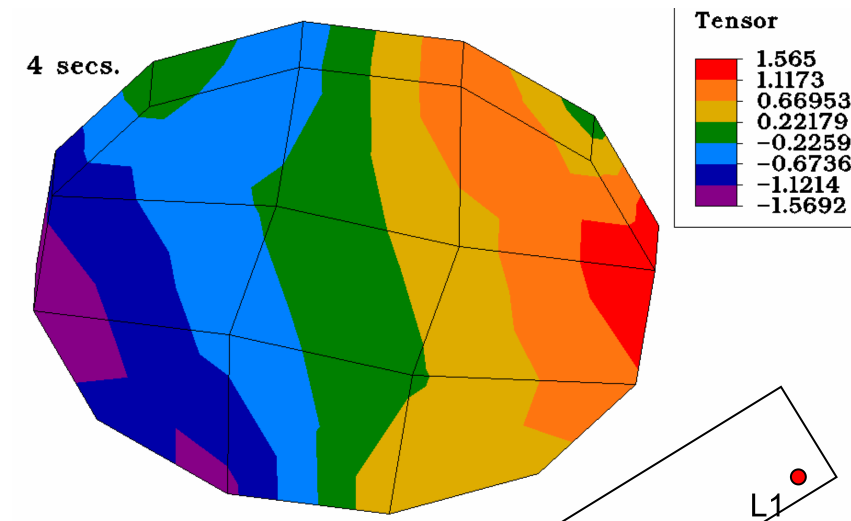


Max. shear stress on the glue itself

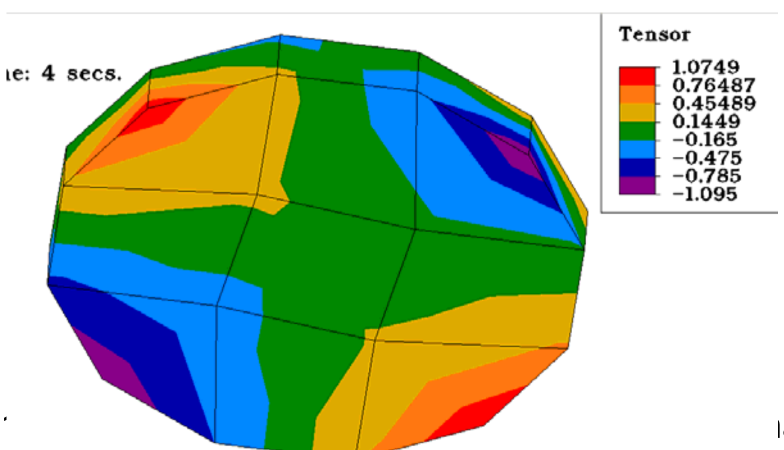
GZX-direction

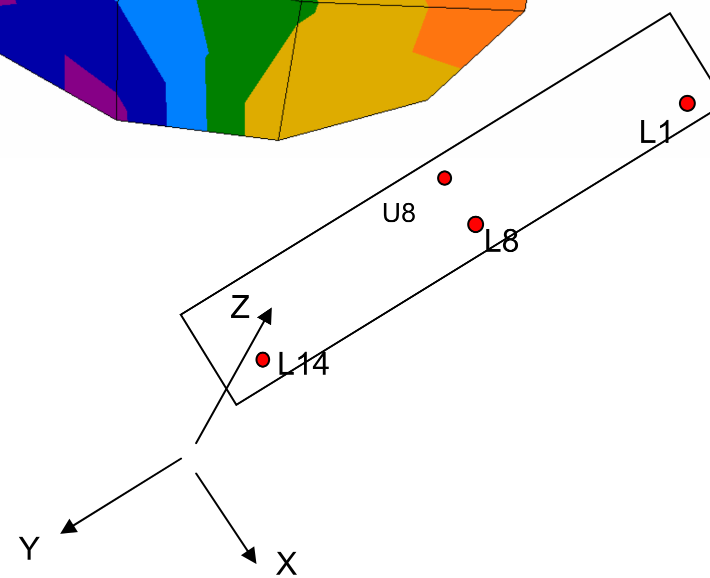


GYZ-direction



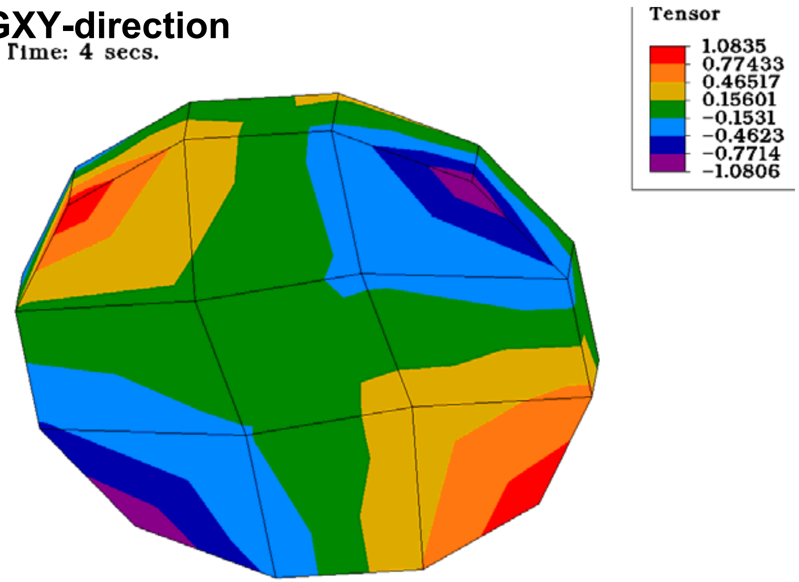
GXY-direction



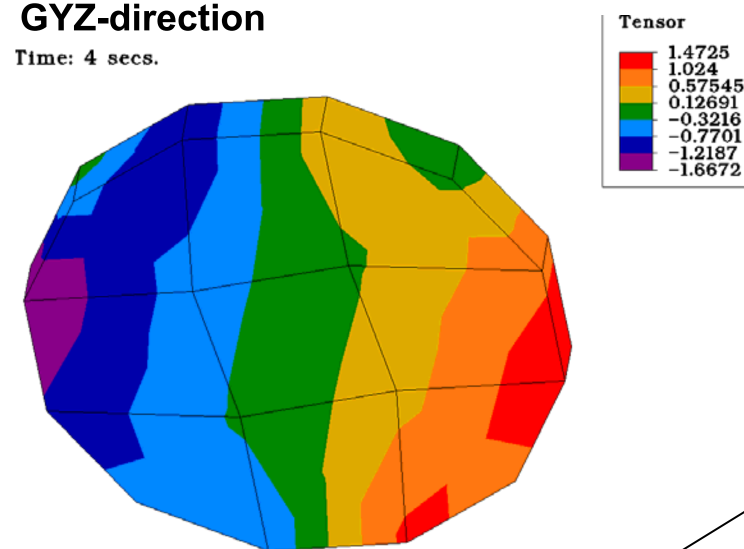


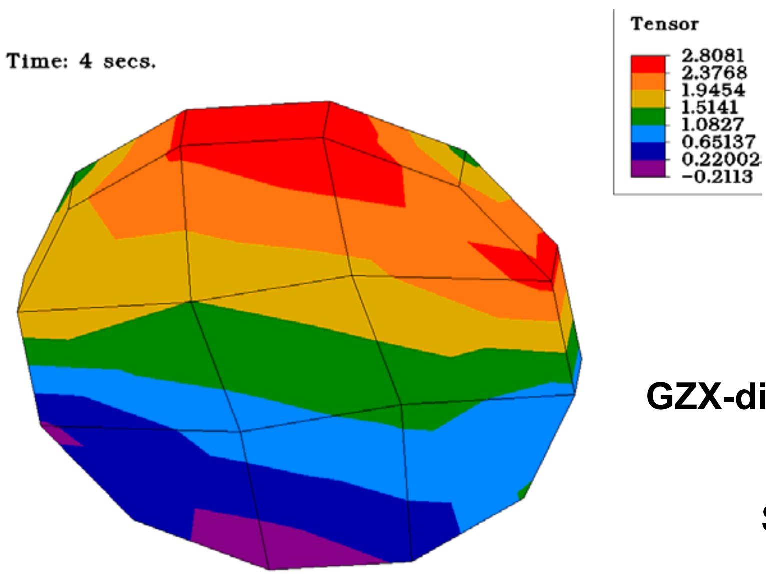
Max. shear stress on the glue itself

GXY-direction

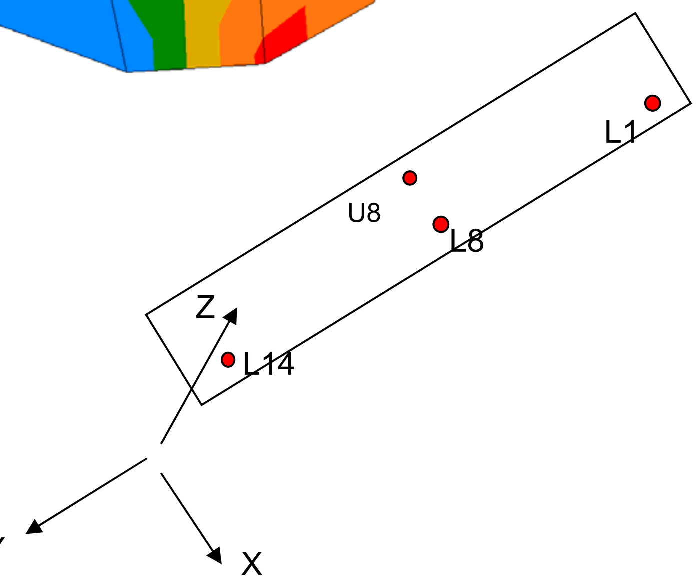


GYZ-direction





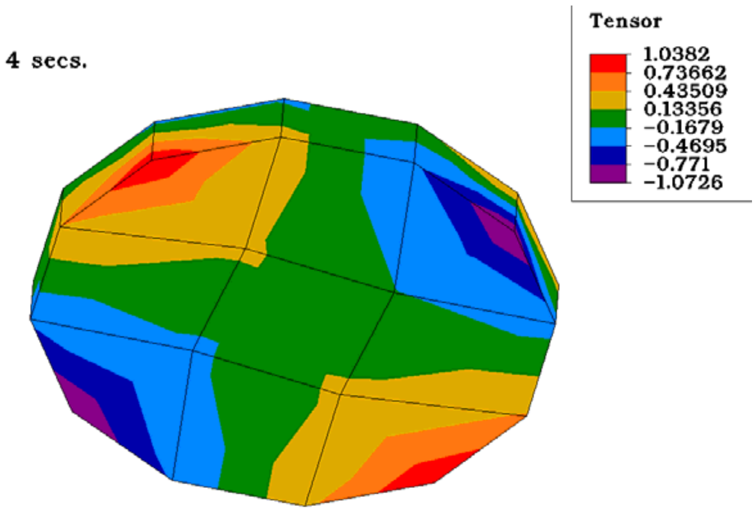
GZX-direction



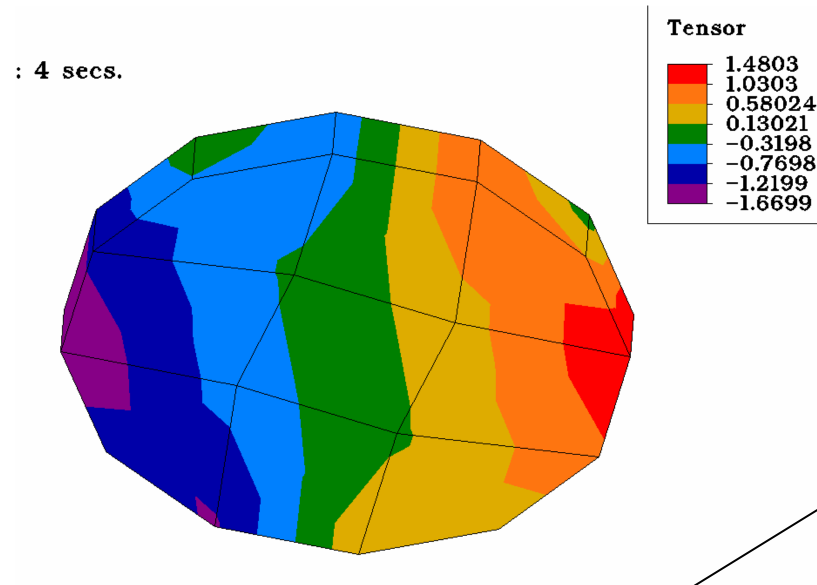
U8

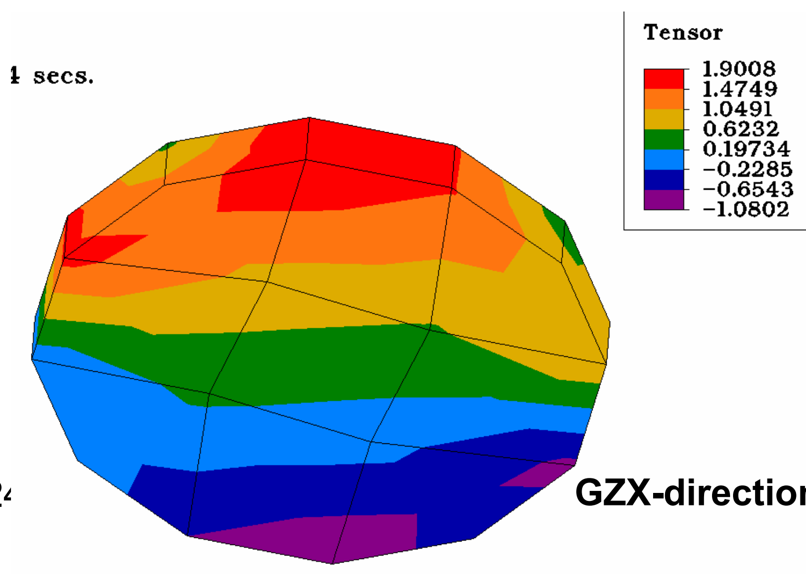
Max. shear stress on the glue itself

GXY-direction:

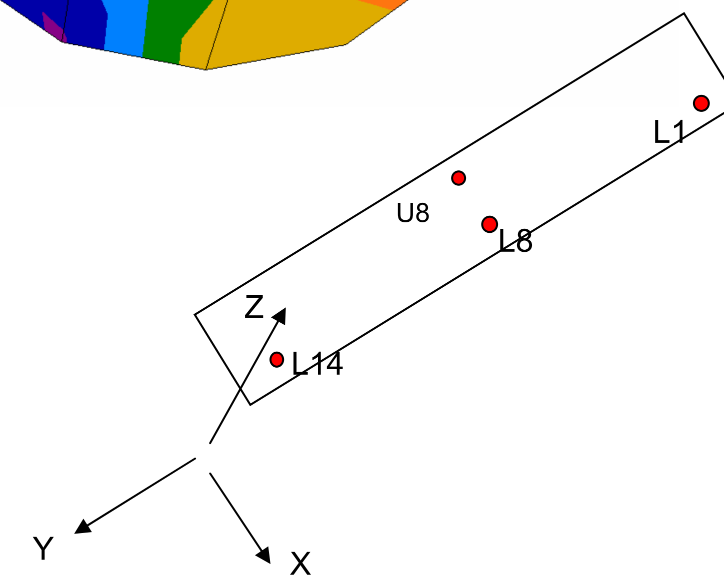


GYZ-direction: 1.4438





GZX-direction: 1.89



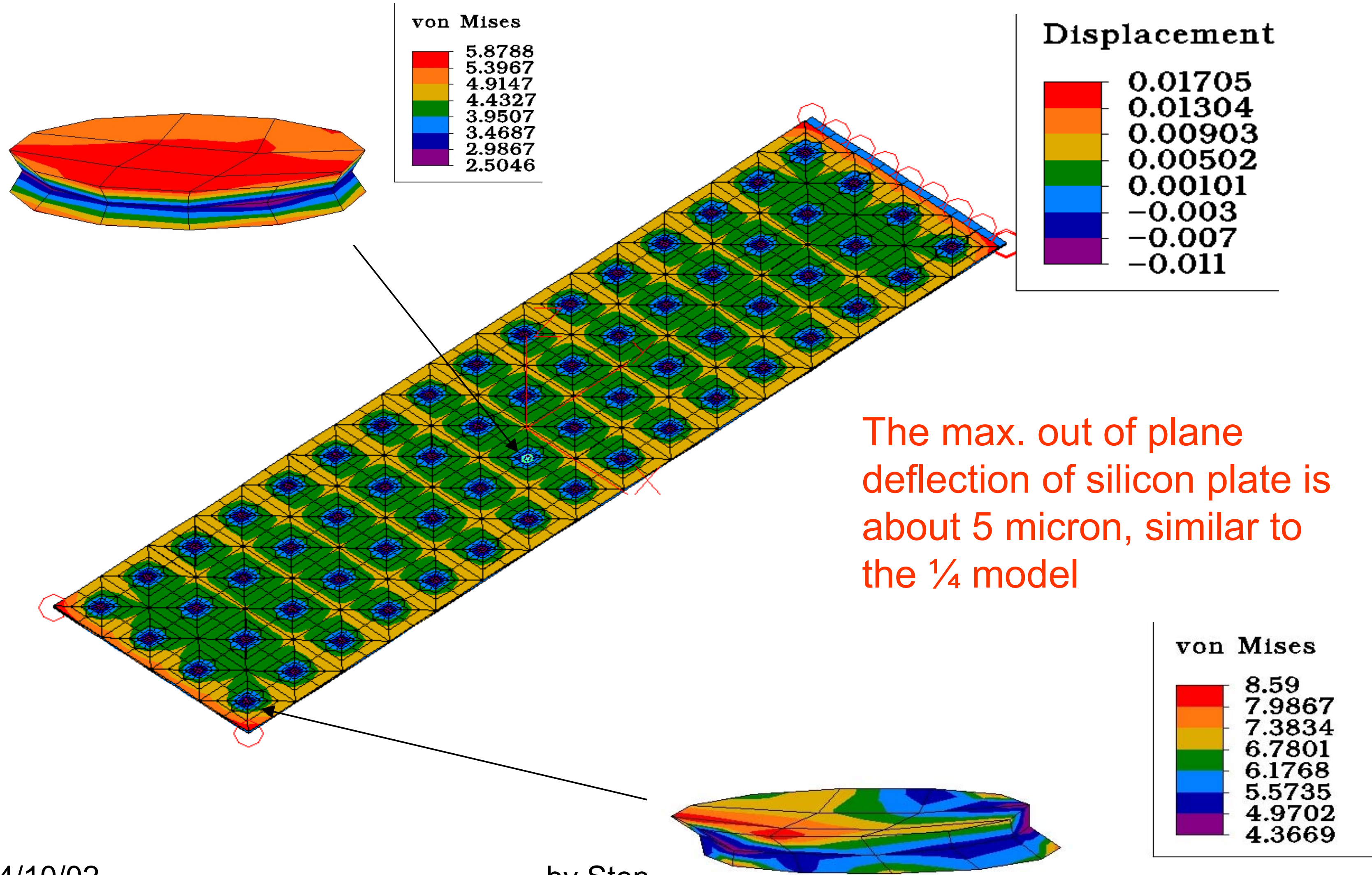
Observations on the glue stresses

The differential in-plane displacements between the silicon and the beryllium are not small (by inspection of the displacement results). However, the shear stresses on the glues are very low. The stresses at the interfaces between the glue and the silicon and the beryllium surfaces are also quite low.

The reason why these stresses are low is because of the extremely low Young's Modulus value of the glue. This shows that by choosing a flexible glue, we can avoid imposing high stresses on the silicon, or the beryllium when the differential in-plane displacements between the silicon and beryllium are significant.

One can say that the meshes in the glue pillar may not be fine enough, and may therefore lead to conservative results. We could set up FE model on the glue pillar alone, and by imposing the boundary displacements on its boundary, we can calculate the more accurate stresses. But since the stresses in the glue are so small, we do not think this is necessary

We also carried out similar analysis on a 1/2 model to see if the symmetry boundary condition along the length of the model has caused any significant change to the deflection at all.



The max. out of plane deflection of silicon plate is about 5 micron, similar to the ¼ model

Observation on the ½ model results

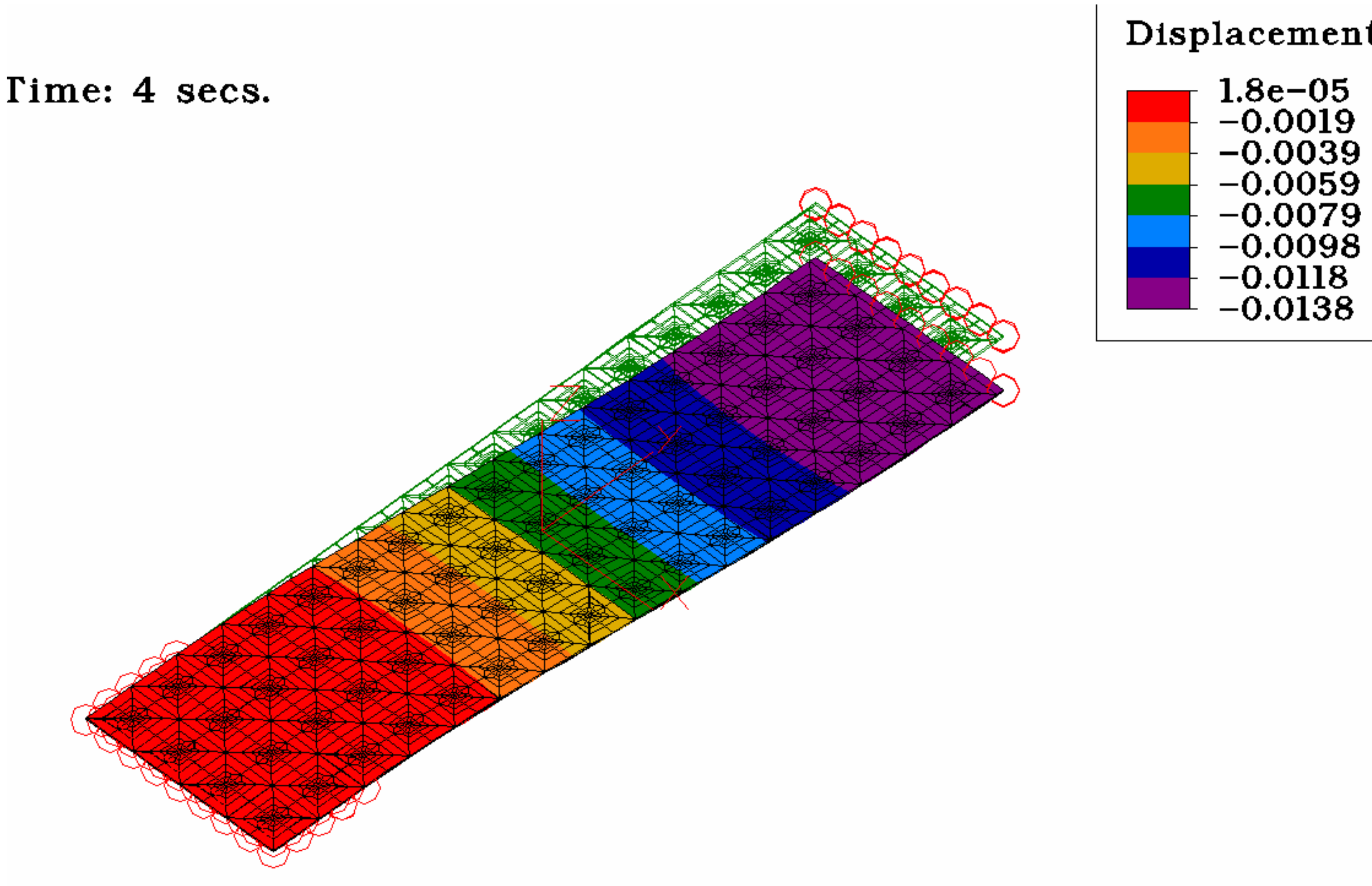
There were doubt if a ¼ model would behave significantly different than a ½ or full model because of the imposed boundary conditions that makes a ¼ model behaves like a ½ or a full model if the loading is predominantly a thermal load and the deformation may not behave exactly symmetrical along the symmetry lines. This prompted our need to set up a ½ model.

This ½ model took nearly 7 hours to complete the run.

Deflections from the ½ model are very similar to the ¼ model, indicating that the ¼ model is sufficient for the purpose of our analysis.

We can conclude that ¼ model is as good as the full model in future analyses. This would save up enormous CPU and turn around time.

Deflection due to gravity load only (no thermal load)



Discussion on gravity load

The maximum deflection caused by the self-weight load of the structure is about 13 micron. Superimposing the deflection due to thermal shrinkage, it could have a max. 24 microns (13 + 11 microns) downward deflection.

It is not known if this deflection is acceptable. If not, we need to apply pre-tension forces at the beryllium ends to reduce this deflection.