ESS

A preliminary report on neutron guide cooling

Conducted for the NBEX design study

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The load on the neutron beam insert has been checked on a model where the upper part is an active insert and the lower part is blocked. The heat load is shown in Figure 1and Figure 2. The total heat load on one active insert is about 200W and for a blocked insert 300W so for this model the total heat load is 250W.

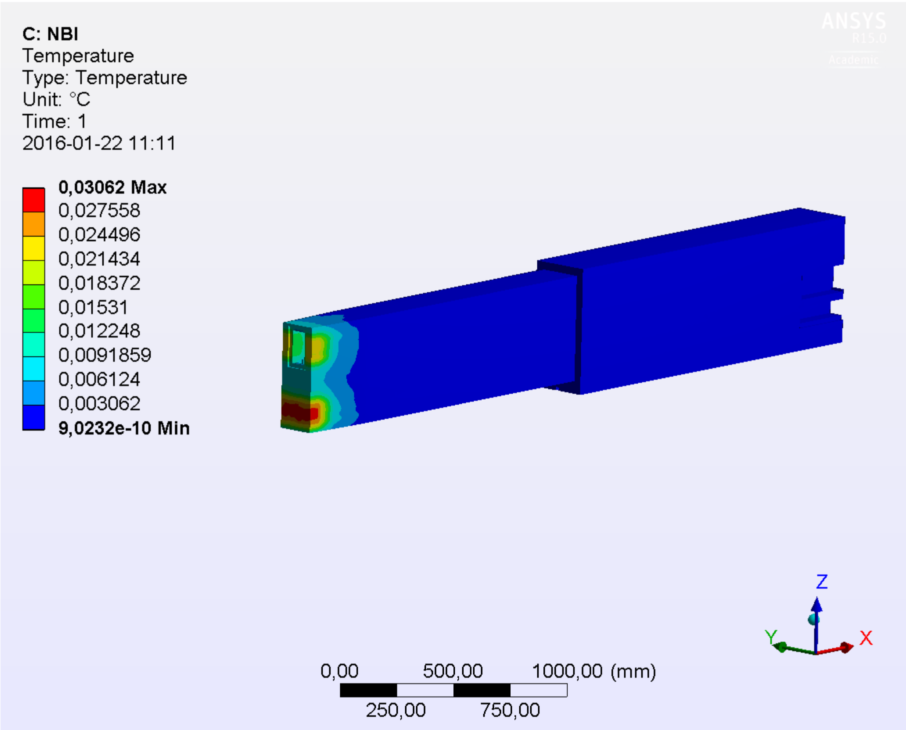

Figure 1 Thermal load on the NBI

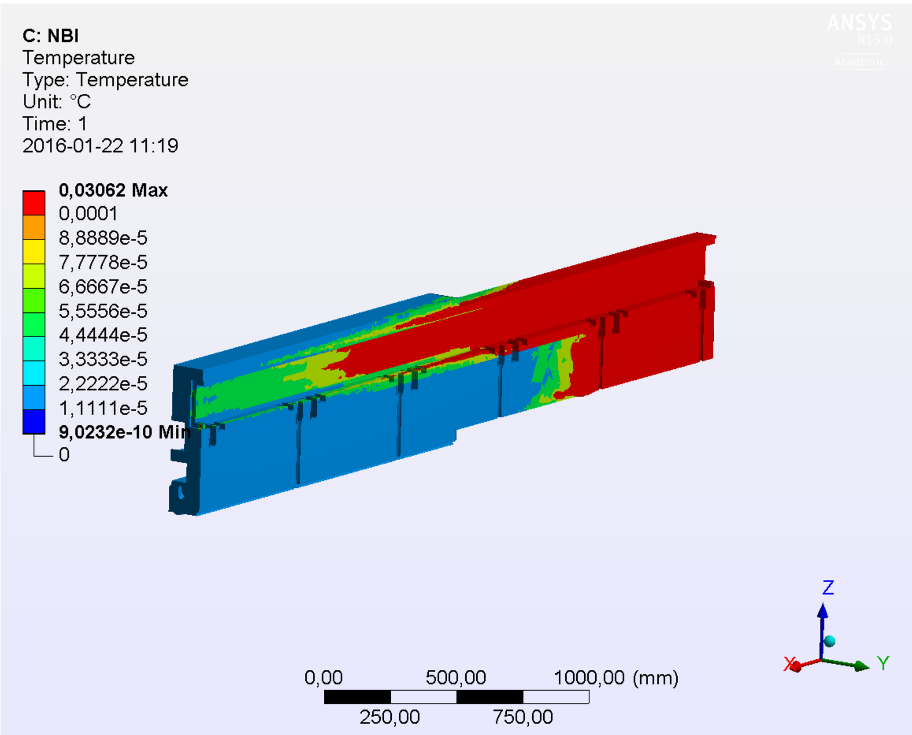

Figure 2 Different scale and cut in half.

Most of the part is located outside the monolith vessel where the cooling needs is negligible but about 0.7 m of the guide is located inside the vessel and surrounded by cooled blocks. Due to the vacuum atmosphere the only way for the heat to be transported away from the guide (if the contact points are neglected and the guide is not actively cooled) is by heat radiation. The maximum temperature will then be somewhat above 100 °C, the maximum deformation is almost 2 mm and the vertical deformation 0.6 mm, see below. The conclusion is therefore that the insert has to be actively cooled.

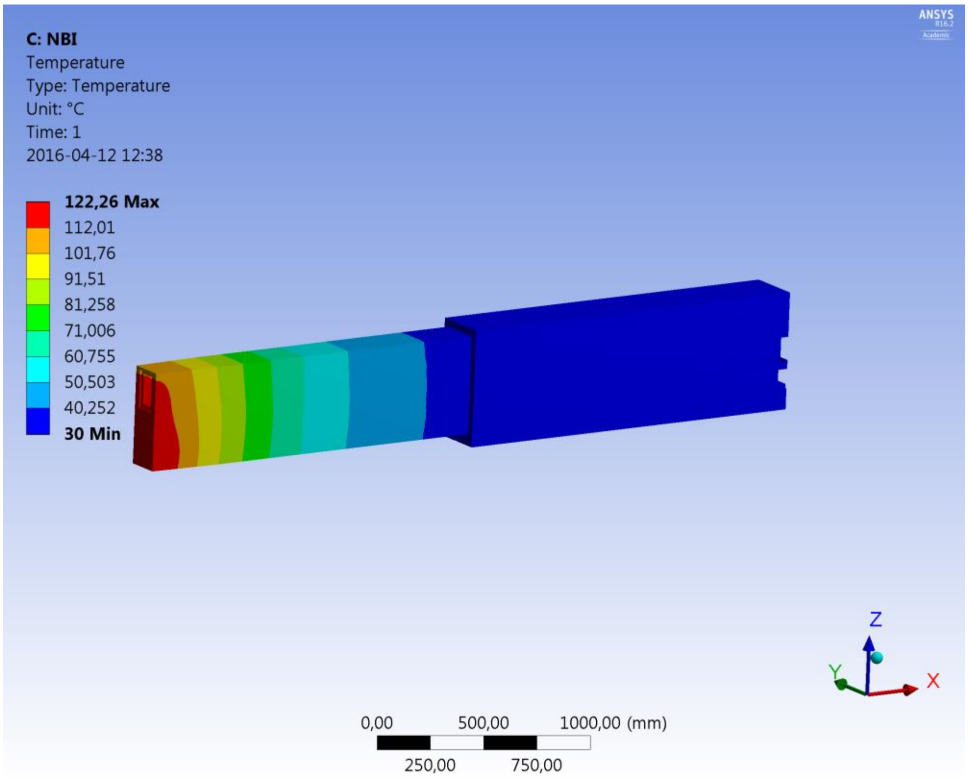

Figure 3 Maximum temperature if only radiation is taken into account.

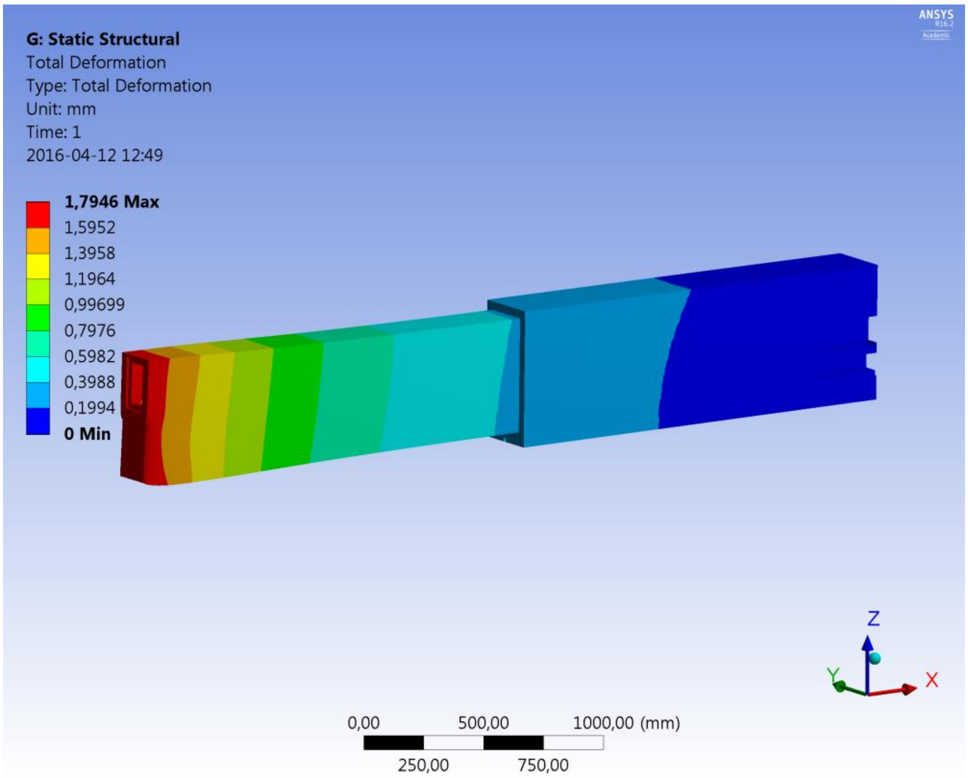

Figure 4 Total deformation.

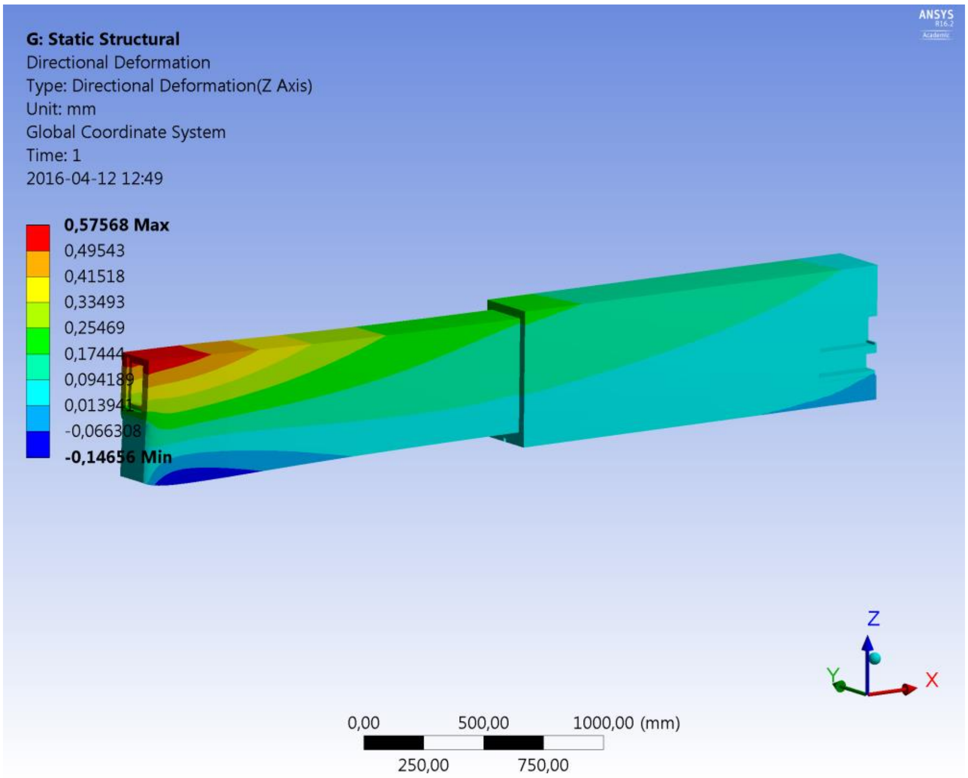

Figure 5 Vertical deformation.

One way to achieve an efficient cooling is to mount the substrate in an insert guide that is actively cooled by water. Outside this guide there is steel for radiation shielding. The substrate is passively cooled by the insert guide by conduction thru the adjustment screws. Normally the substrate has a spring on one side and an adjustment screw on the other but in order to increase the cooling it is proposed to use screws on both sides, at least the first row near the target.

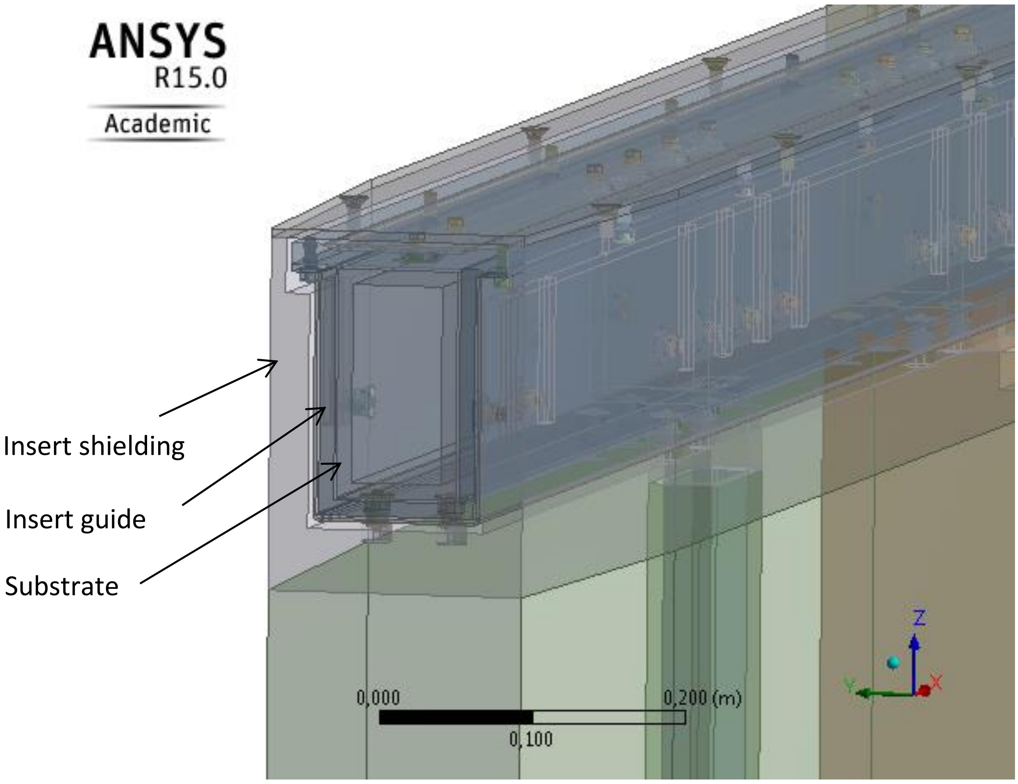

Figure 6 Principal design of the neutron beam insert with the neutron guide and substrate.

In order to analyze this solution a simplified symmetry model has been made and here it is assumed that there are two screws on each side, see Figure 7. Figure 8 shows the applied heat load and Figure 9 the resulting temperature result for the model cut thru the outermost adjustment screw. The stresses are shown Figure 10 and as can be seen they are low and the deformations are negligible. In this case the substrate and adjustment screws are made of copper.

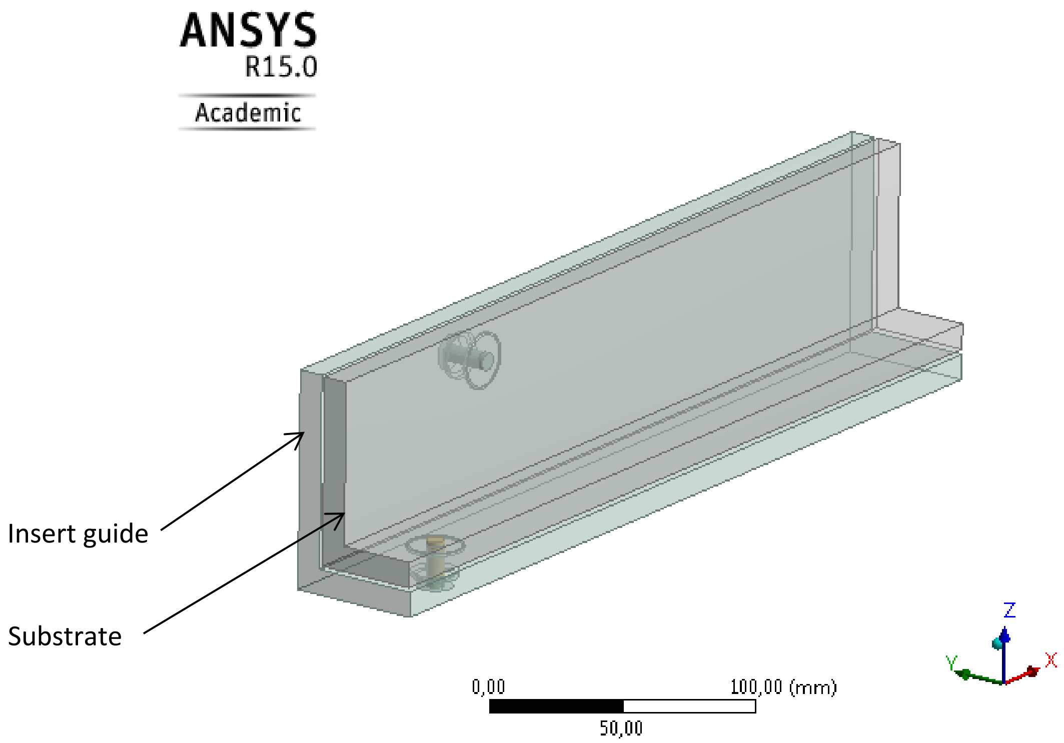

Figure 7 Simplified model of the substrate and the surrounded water cooled tube with adjustment screws.

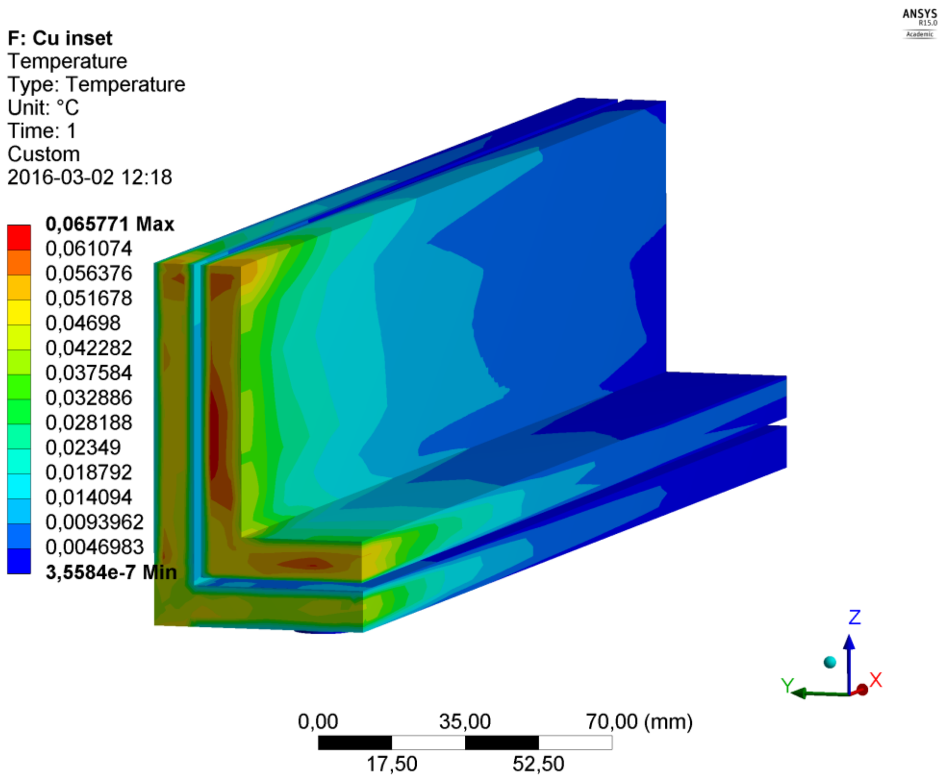

Figure 8 Applied heat load. W/mm^3.

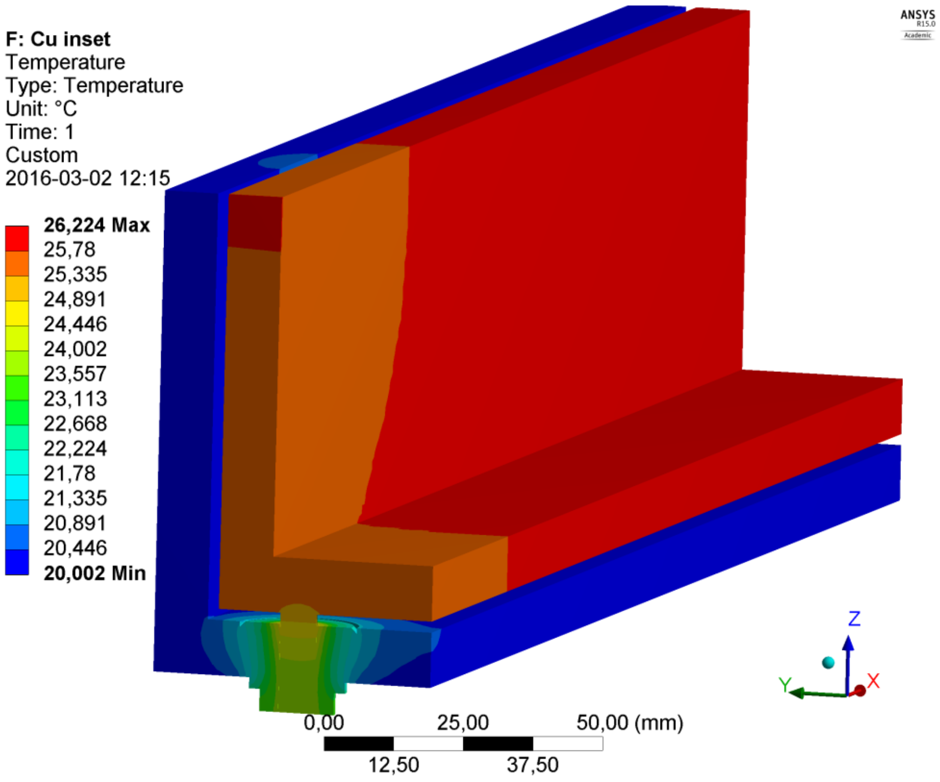

Figure 9 Resulting temperature.

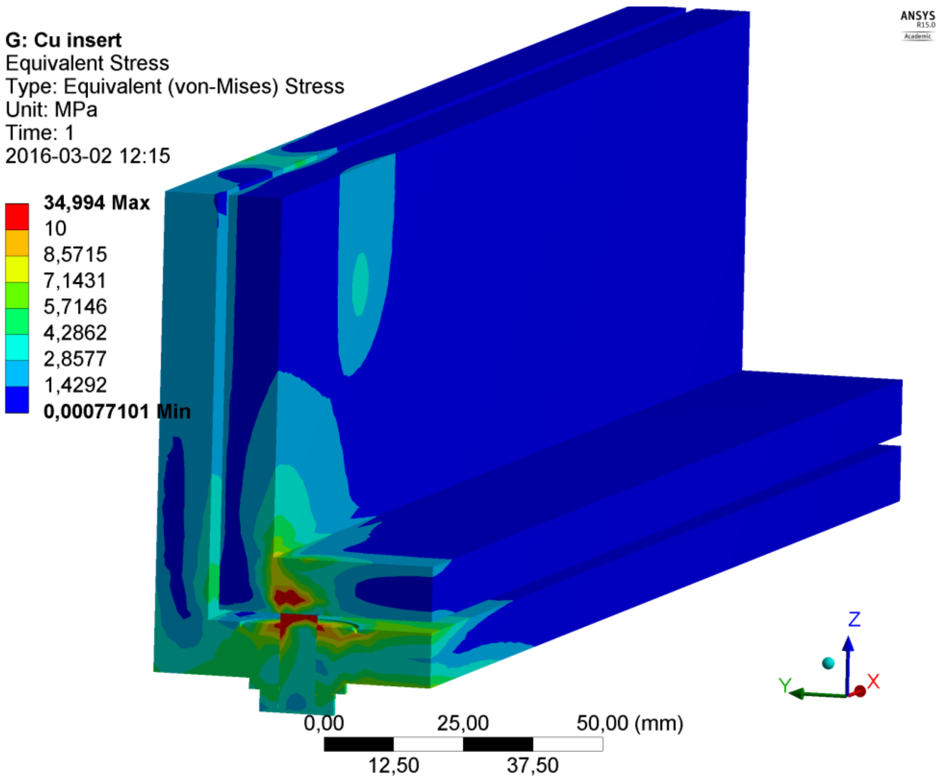

Figure 10 Resulting stress.

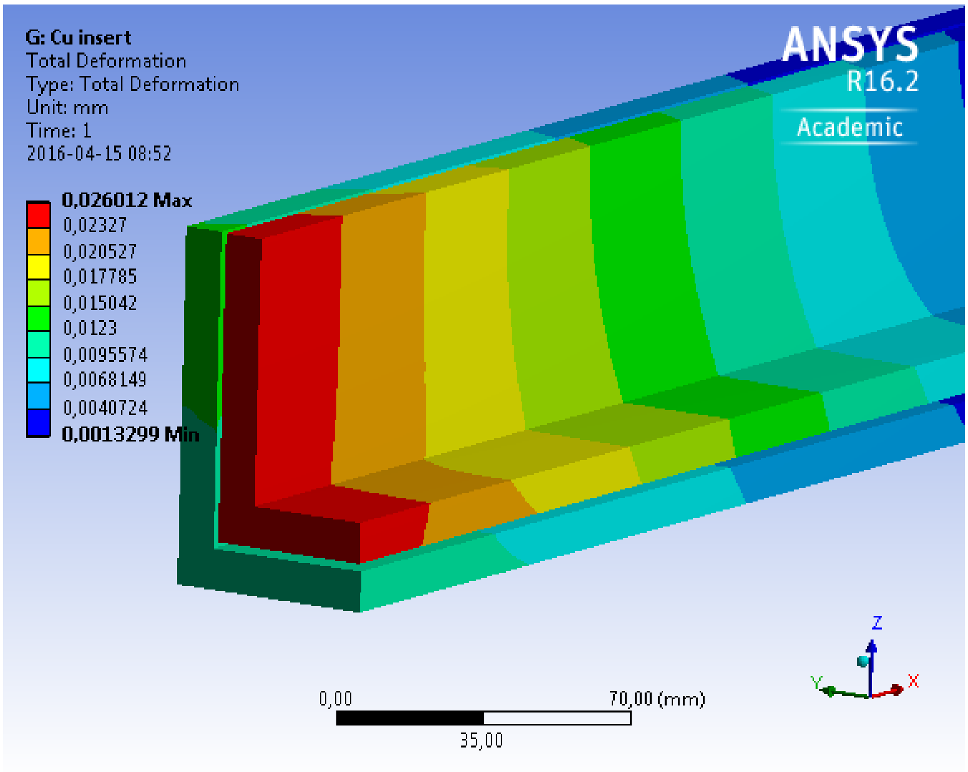

Figure 11 Total deformation, 26µm. Mainly axial.

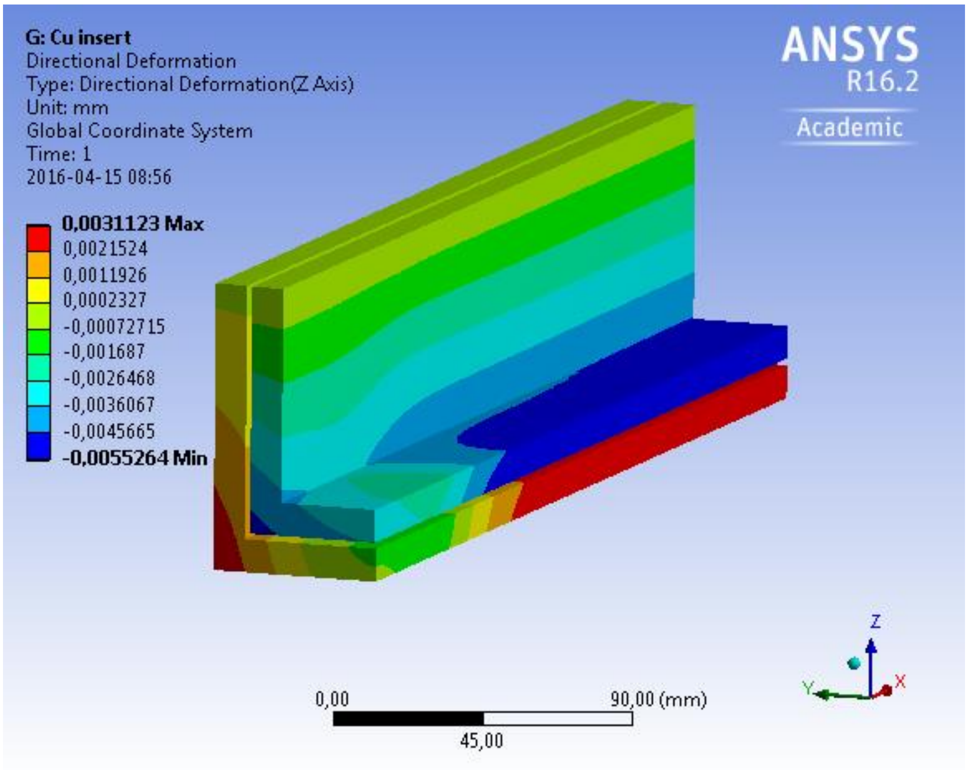

Figure 12 Vertical deformation, 3µm.

The same analysis has been performed for an aluminum substrate and the result is presented below. The thermal conductivity is lower in aluminum but the heat load is also lower so in total the temperature in aluminum is lower than in copper. In the analysis adjustments screws in copper has been assumed.

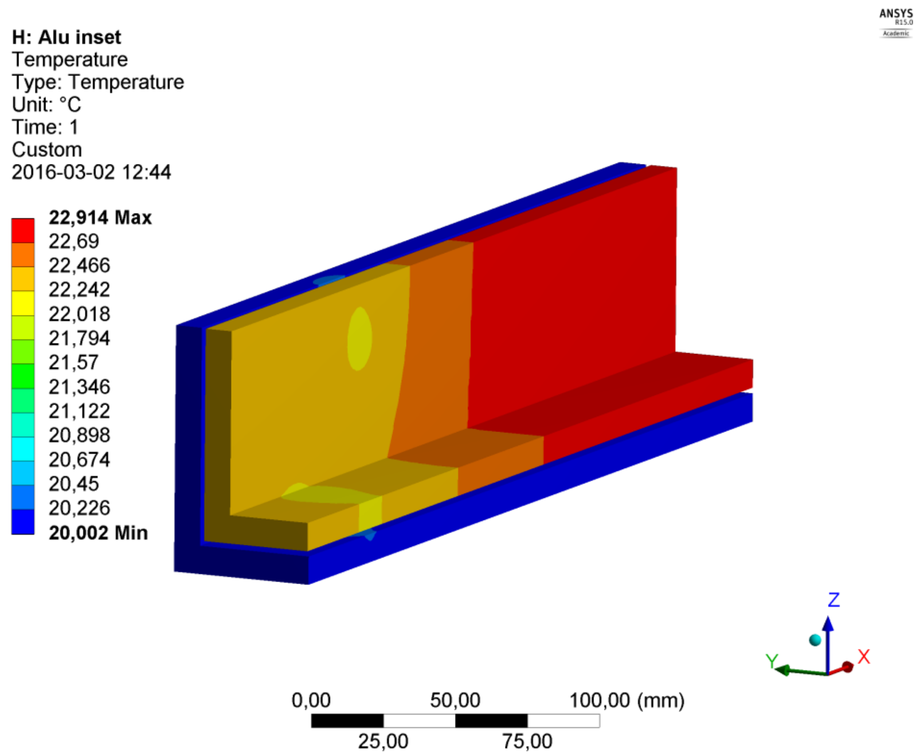

Figure 13 Temperature in Aluminum

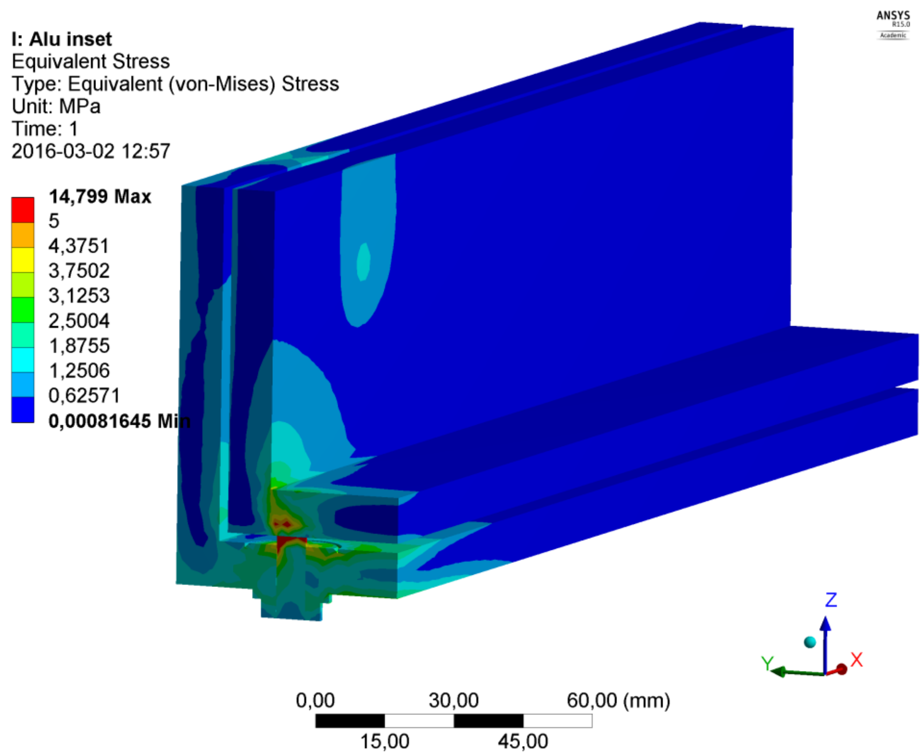

Figure 14 Stresses in Aluminum

The conclusion is that with this solution the thermal deformation of the substrate is almost negligible but the solution is rather complicated so therefore we will test a solution where the substrate is attached directly to the insert where the insert is cooled by cooling channels. That was our first approach but at that time we did not have detailed heat load so we did some conservative assumptions and we also thought that the restriction on displacement was 50μm.