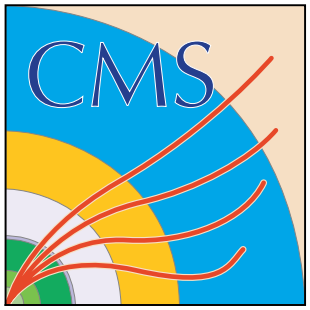
Thoughts on Thermal Contact Resistance



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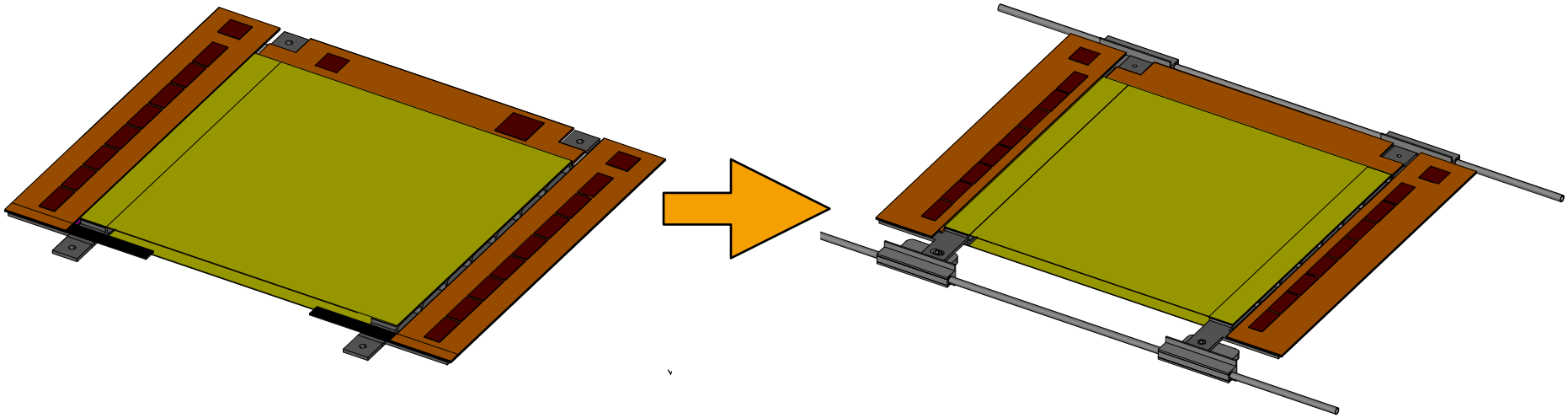
Tracker Upgrade Meeting
26/04/2013

HELMHOLTZ ASSOCIATION

DESY

Introduction

- so far only the actual module was modeled in FEA
- heat transfer from module to cooling blocks needs to be added
  - optimization of bridge and module side cooling contact alone might lead to the wrong conclusions
  - what is the best geometry when looking at the full picture
  - what heat transfer coefficient should be assumed / is achievable



Thermal Contact Resistance

- thermal contact conductance can be approximated by (Yovanovich and others)

$$h_j = h_c + h_g$$

contact

$$h_c = 1.25\lambda_s \frac{m}{\sigma}(p/H_c)^{0.95}$$

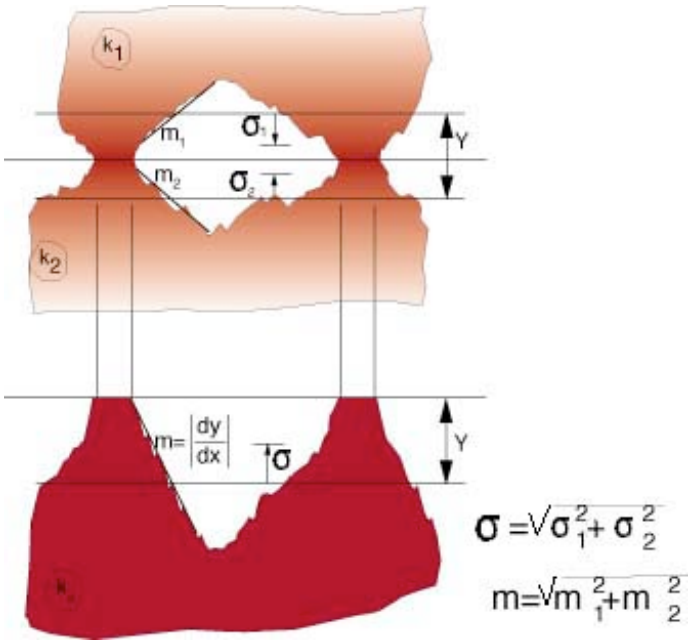
$$\lambda_s = 2\lambda_1\lambda_2/(\lambda_1 + \lambda_2)$$

gap

$$h_g = \lambda_g/(Y + M)$$

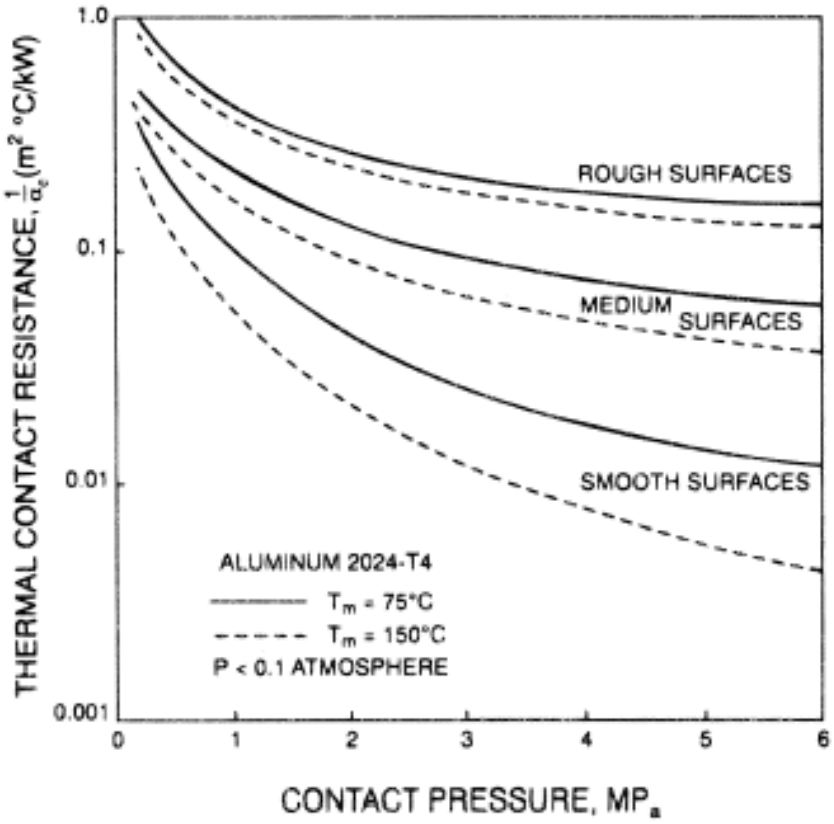
$$Y = 1.53\sigma(p/H_c)^{-0.097}$$

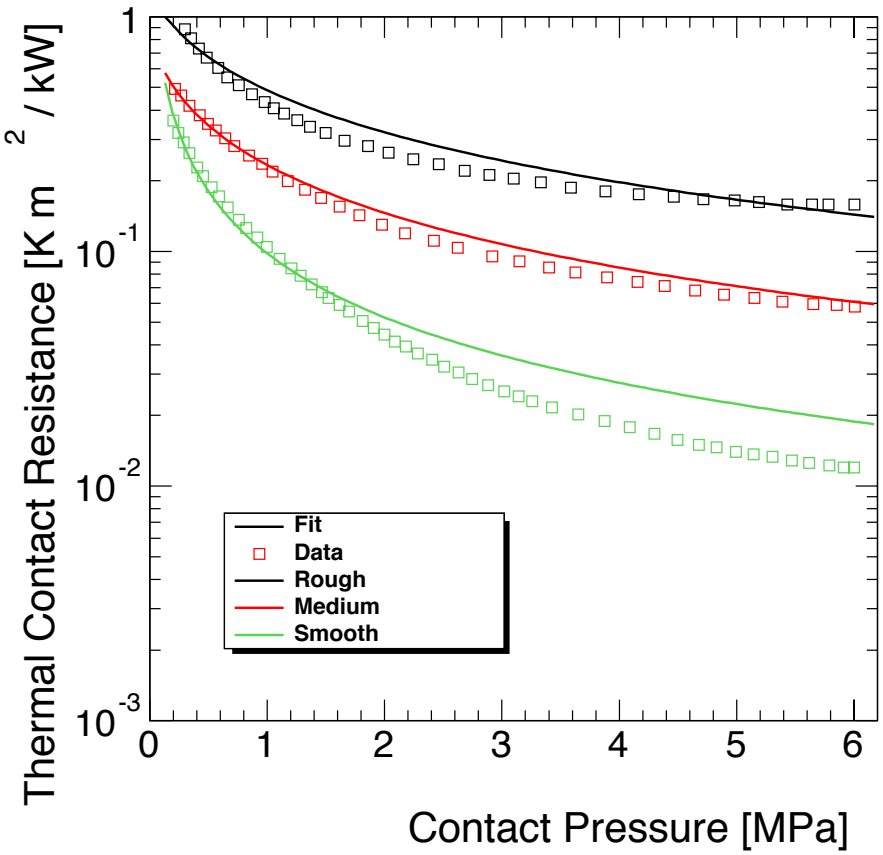
$$M = M_0 \frac{T}{T_0}\frac{p_{g,0}}{p_g}$$



p	pressure
σ	effective RMS surface roughness
m	effective mean absolute asperity slope
H_c	surface microhardness
λ_s	harmonic mean thermal conductivity of interface
Y	effective gap thickness
M	gas parameter

Thermal Contact Resistance - Al-Al-Interface





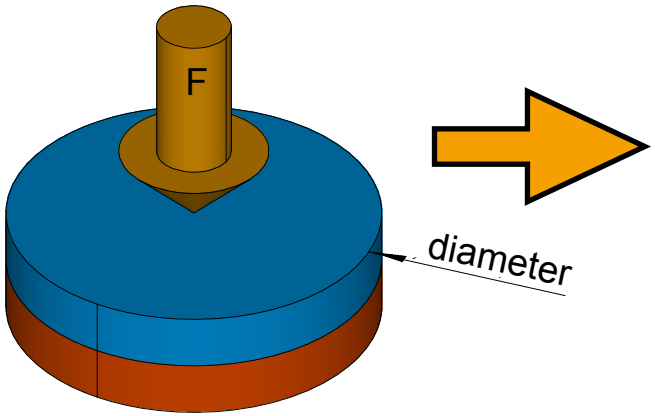
- effective RMS surface roughness σ and surface microhardness H_c are fit parameters
- fit is not really good ➟ will use fit and interpolation in the following

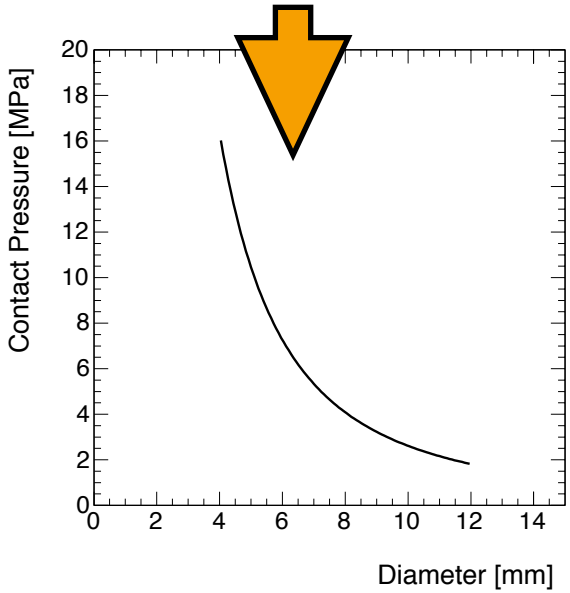
Estimates for Module to Cooling Block Heat Transfer

- module is mounted with a M1.4 screw
  - slope 0.3mm per turn
- screw is tightened with 1000 g x cm torque
  - 90% of torque is lost due to friction (40% in thread, 50% under head)

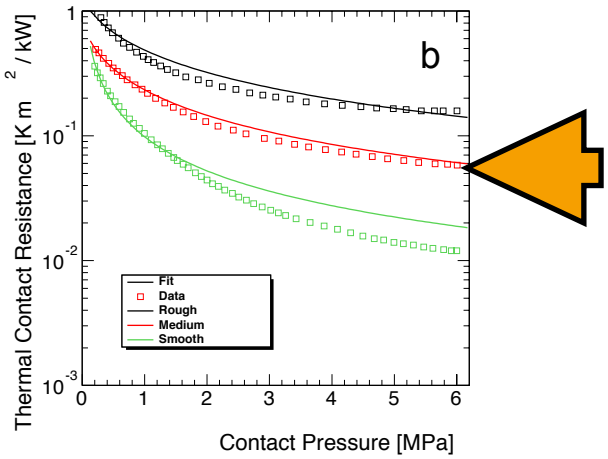
$$\tau \cdot 2\pi \cdot 0.1 = F \cdot 0.3\ \mathrm{mm} \qquad F = \frac{\tau \cdot 2\pi \cdot 0.1}{0.3\ \mathrm{mm}} = 205\ \mathrm{N}$$

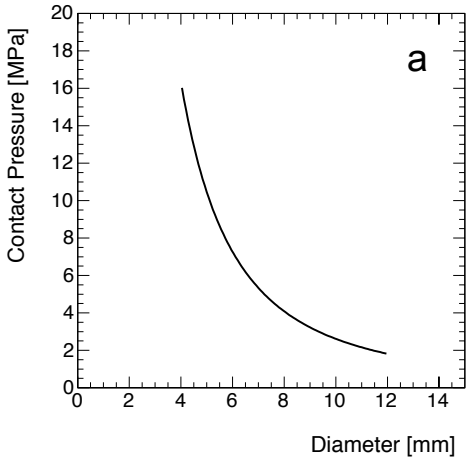
- module is mounted with a assumption: force is applied homogeneously to contact surface (circular shape)
  - has to be ensured by spring washer etc.

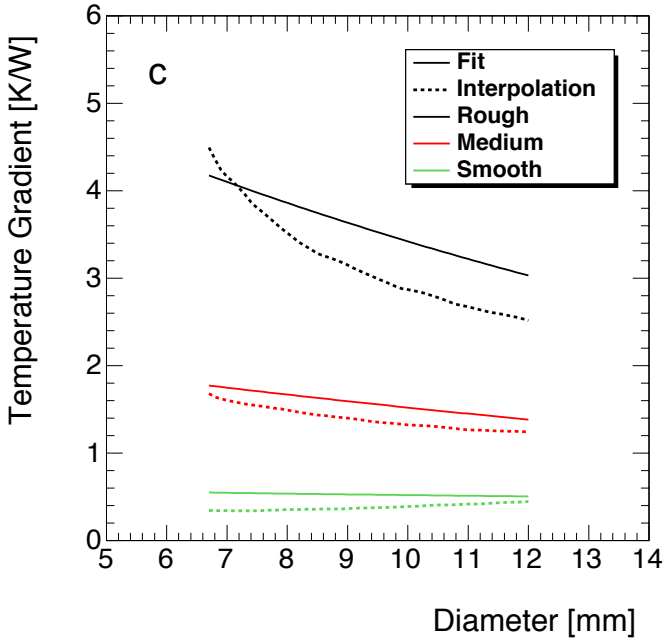




Estimates for Module to Cooling Block Heat Transfer







(a) for a given torque/force contact pressure is calculated

(b) thermal contact resistance R is taken from fit and interpolation for calculated contact pressure

(c) temperature gradient of interface is calculated from R and contact area $\Delta T = R / A$

- only weak dependence of ΔT on contact diameter/area present
- benefit of increasing the contact surface is negligible (for medium and smooth surface)

Summary

- when looking at the module alone a large cooling contact seems to be the best choice
- with respect to the heat transfer we do not benefit from the larger surface
  - in fact, ensuring an efficient usage of the contact surface will be become tricky for larger contact areas
- increasing the force will not change the result
  - in any case we have to make sure that 3 out of 4 contacts can slide