LIGO

Glassy metal mirror suspensions:

an update

Riccardo DeSalvo

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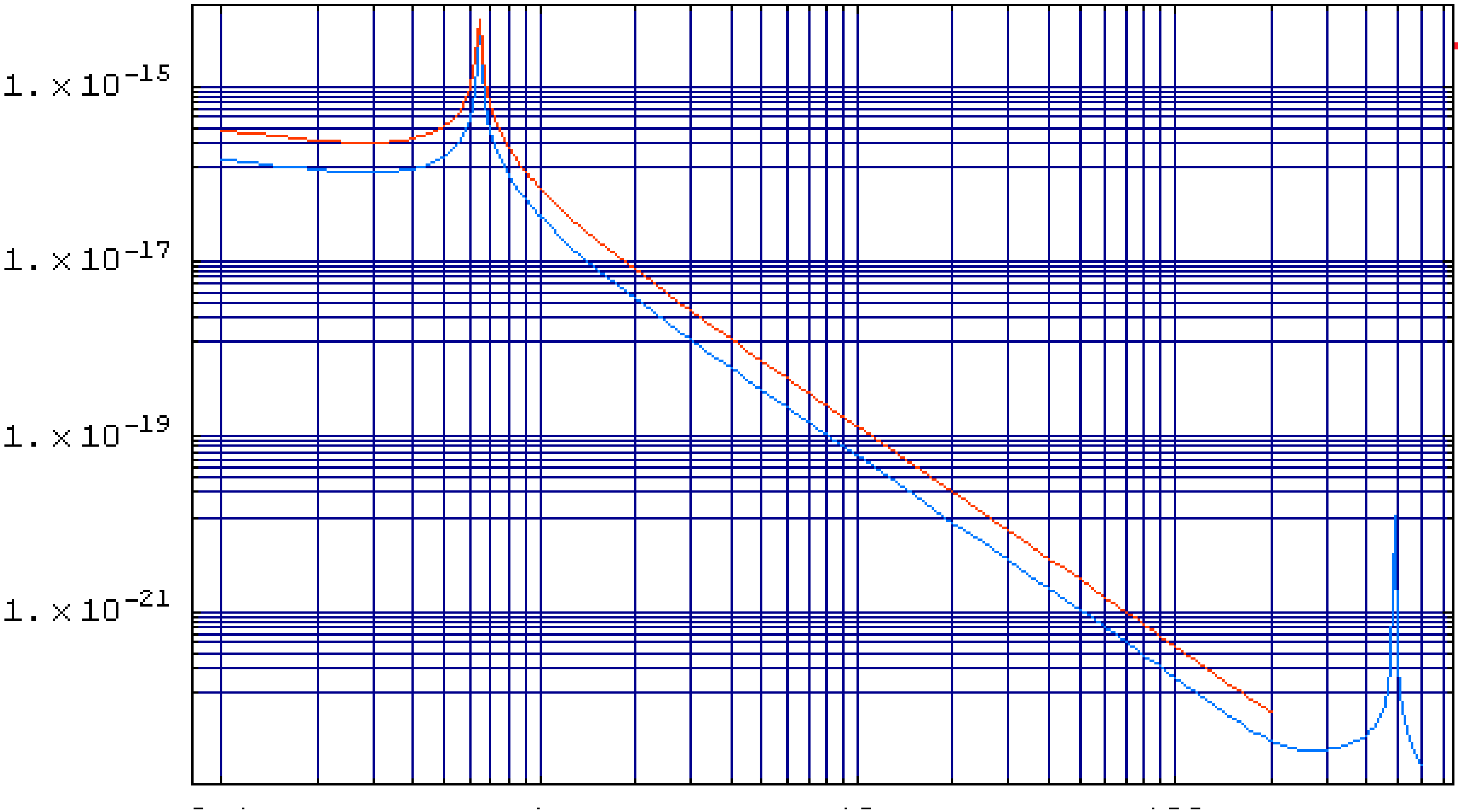
LIGO-G030085-00-D

Estimated MoRuB glass properties

- Mo49Ru33B18 in atomic percent.
- density, 9.5 g/cc
- heat conductivity, 10 Watts/m-K
- heat capacitance, 30 J/mole-K
- linear thermal expansion coeff., 5-6 x 10^{-6} (K^{-1})
- elastic modulus, 250 GPa
- Poisson modulus, 0.36-0.38
- breaking point ~5 GPa

- - These numbers should be accurate to +/- ~20%

Thermal noise of MoRuB flex joints



Glassy metal Q=10^4, Fused SiO_2 dumb bell shaped fiber Q=8.4*10^8,

10*3000 = 30,000 μm², 357 μm diameter, 100,000 μm²,

60 Kg mirror, 40 Kg mirror

Measurements of Q measurement on vitrelloy

Vitrelloy has T_g of 650^{o}C
while
MoruB T_g 1050^{o}C

MoRuB does not
accept hydrogen

MoRuB should have
Less important
loss mechanisms

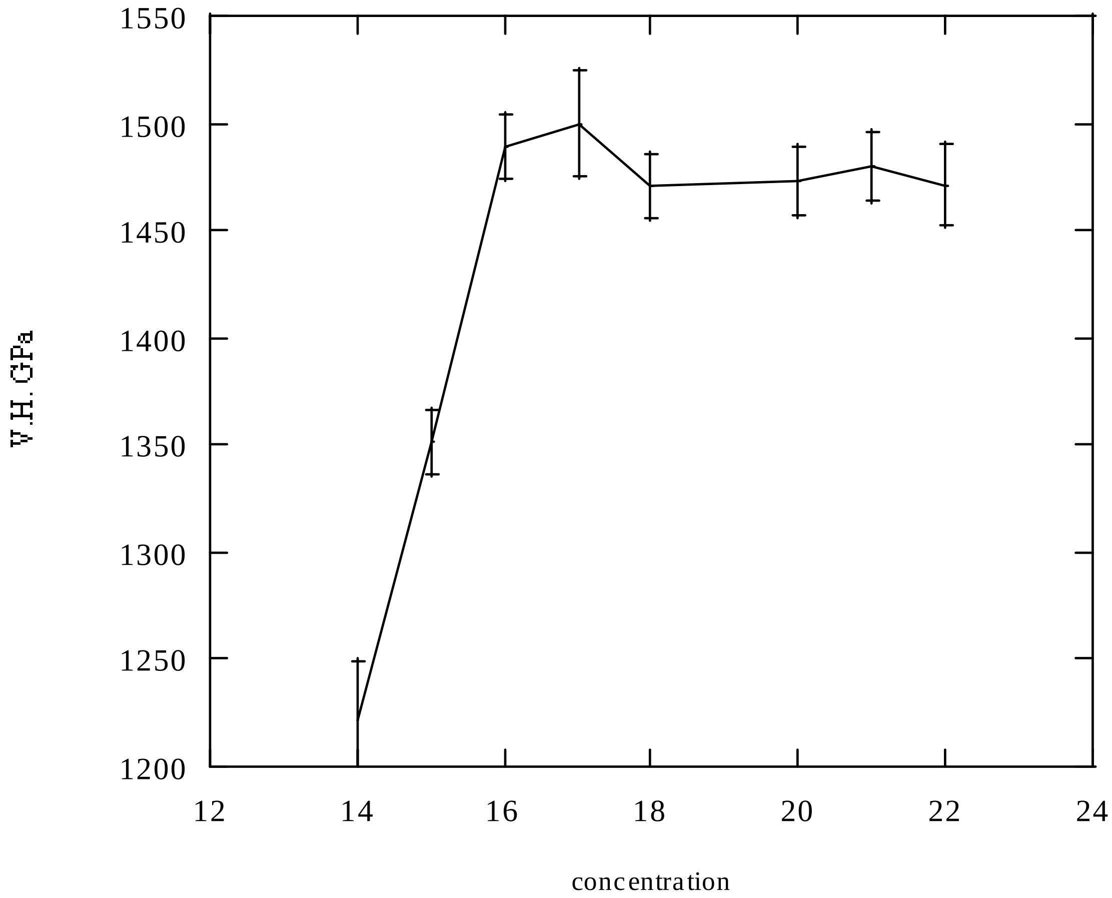
Measurements on MoRuB

- On thick vitrelloy used modal suspension technique
- MoRuB cannot yet be manufactured in thick slabs
- Need diving board measurements
- So far with MoRuB found erratic results
- Different for each mode
- Indicating problems on the clamping point

Identified problem with the AuSn braze

- Found that AuSn braze, unlike standard brazes, it wets without sticking, elastic oscillations or strain detach the edge point
- S-bond, a commercial braze based on (AgSn)TiCd wets and sticks.
- But softer
- Converting to S-bond
- Discussion later

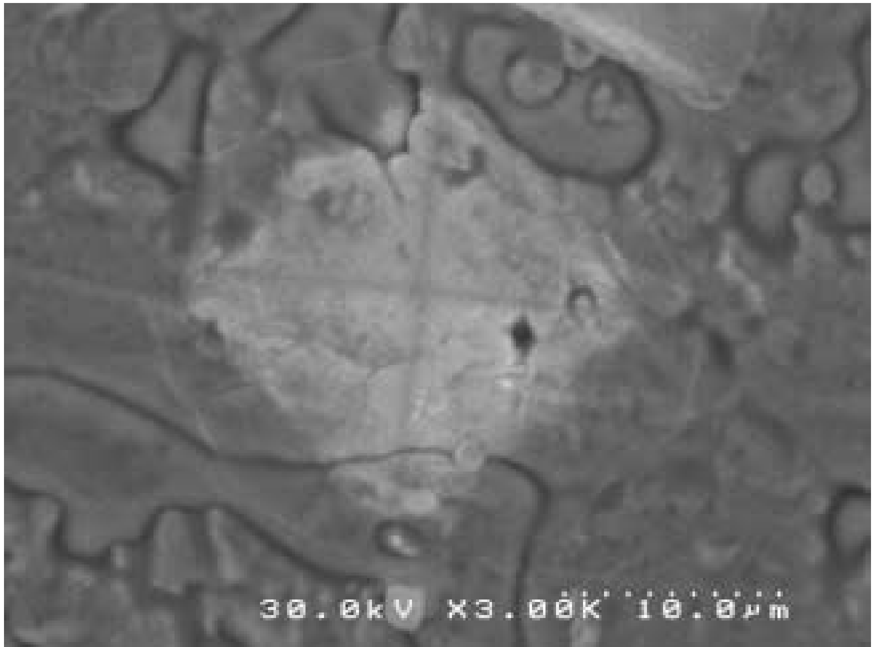
Vicker Hardness behaviour
old measurements

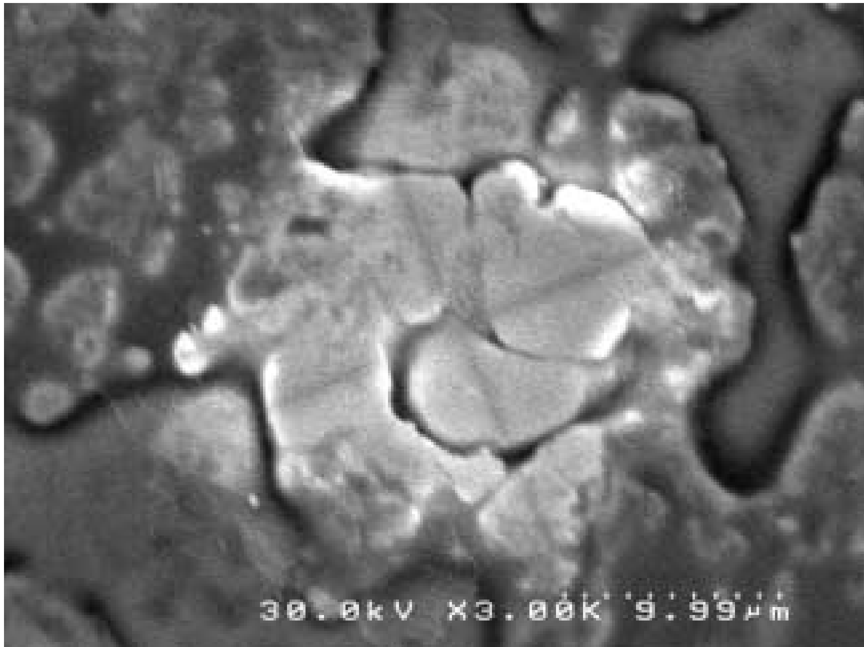


- **from 14% to 16%B** **linear behaviour**
- **from 16% to 22%B** **almost constant**

Vicker Hardness behaviour
old/new measurements

Measurements of hardness based on optical measurements of the size of indentations (see below)
Quite subjective (different people's eyes have different judgments) leading to large systematics
Large fluctuations of errors => large error bars

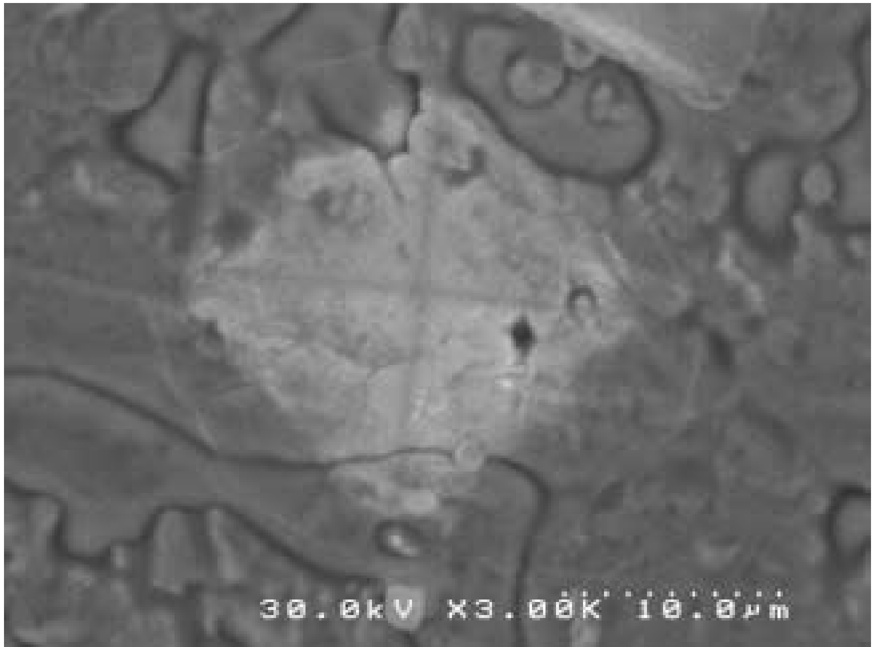


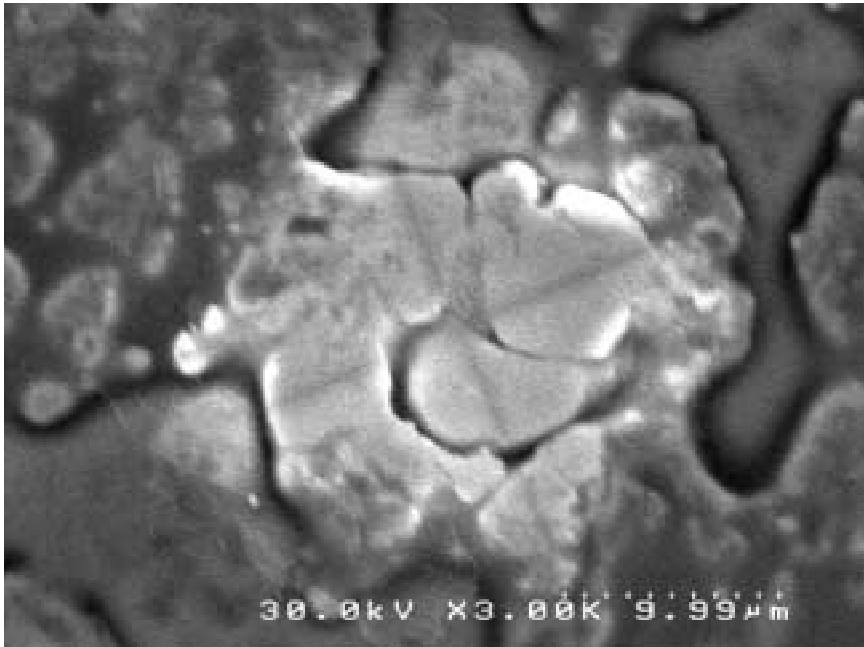


Vicker Hardness behaviour
old/ new measurements

In SEM it is obvious that the optical measurement did not even “see” the surface imperfections
⇒Polished samples before indentation
⇒Use SEM for evaluating indentation size

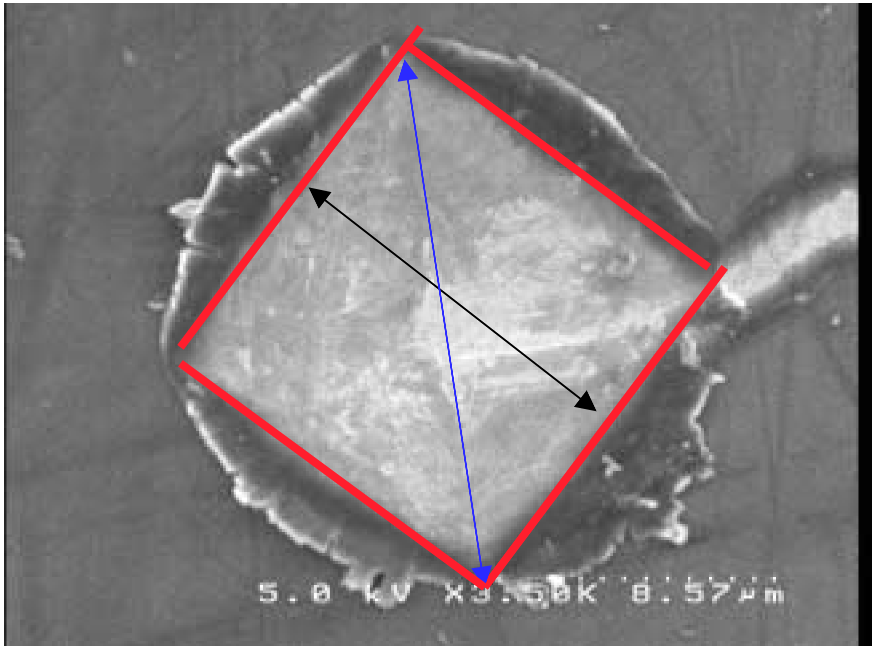
Allyson Feeney

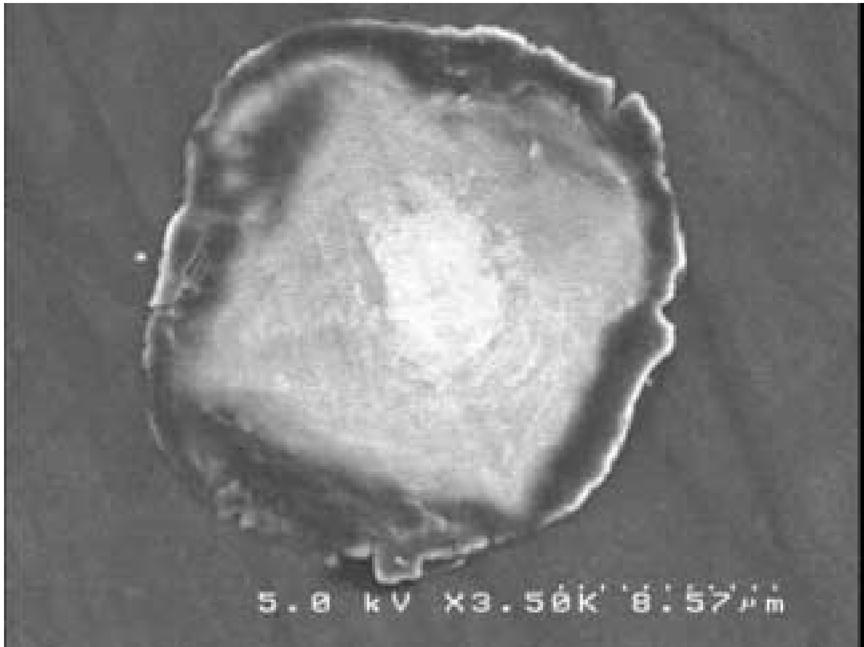




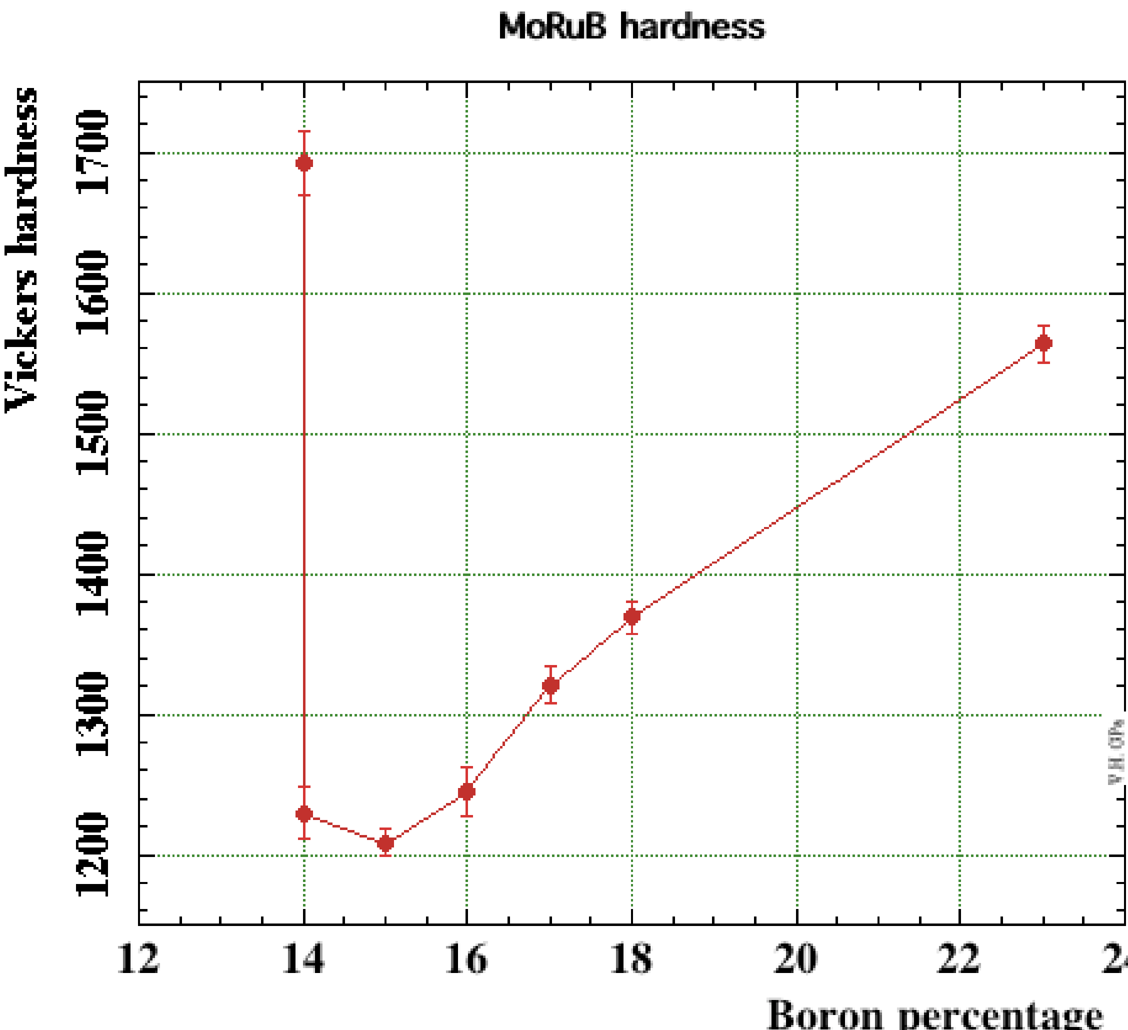
Vicker Hardness behaviour
new measurements

Now easier to measure on SEM images (less subjective)
Can measure both side to side and diagonal
View an plastic outflowing (shear bands) that was previously completely unsuspected and characteristic of different B concentrations

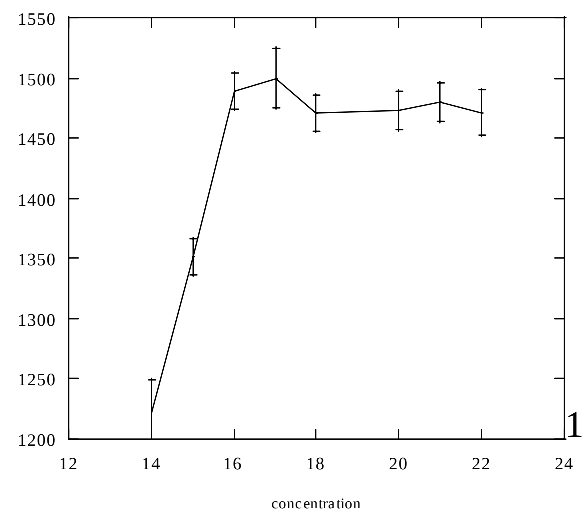




Vicker Hardness behaviour
new measurements



Different behavior
Dual phase for B14
More repetitive
Smaller errors



The braze problem

- Initially thinking of sputtering because of oxyde layer problem
- Found that with aggressive attack and immediate braze coating could avoid the effort (possibly a dead alley)
- Made an oxygen free glove box

QuickTime™ and a Photo - JPEG decompressor are needed to see this picture.

AuSn problems

- Found that despite oxygen free box
- AuSn wets well but peels off
- Checked that AuSnTi wets very well, but also peel off!!!

- Lots of wasted time
- But will be faster to reconfigure to AgSnTi

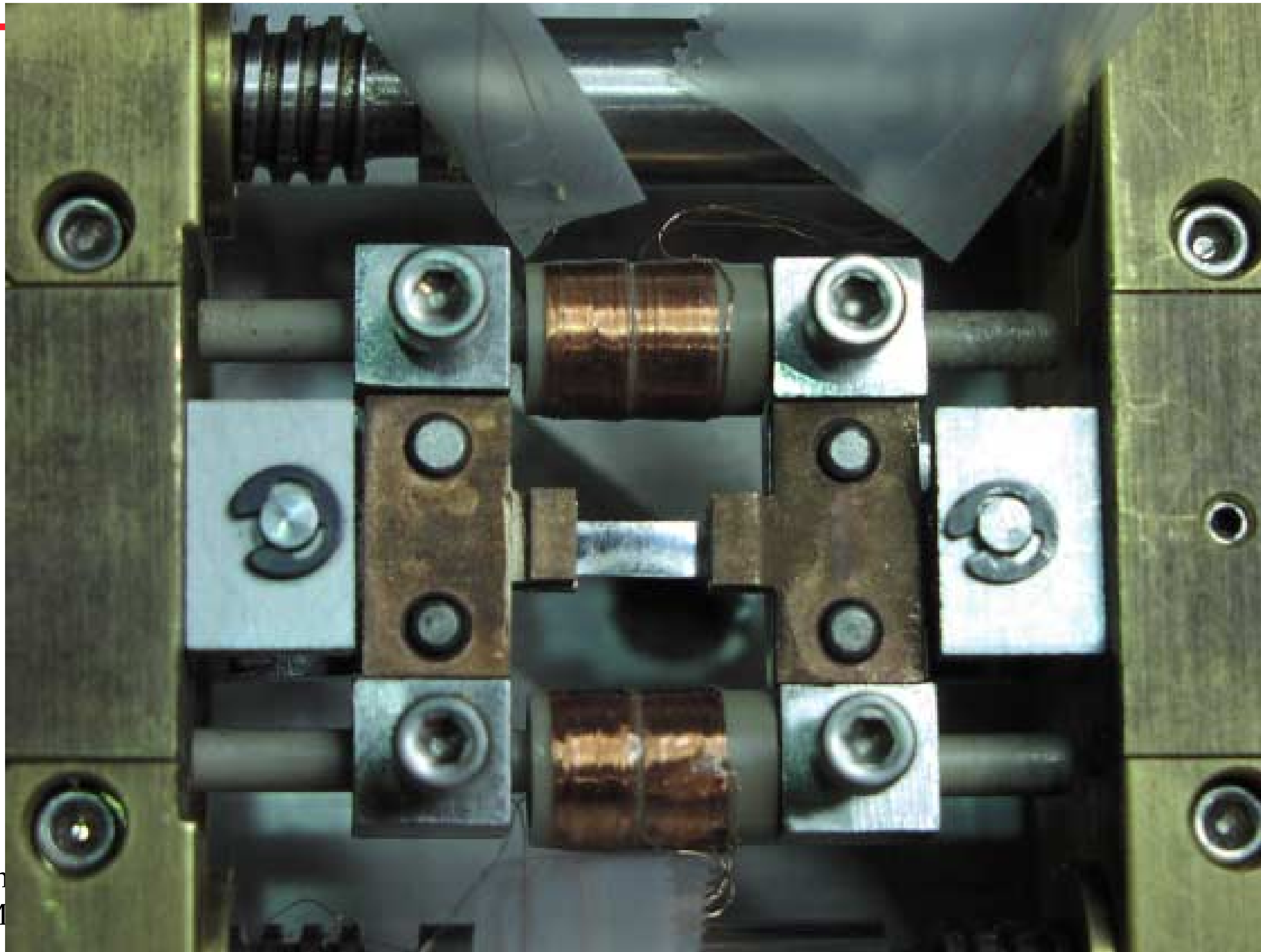
AgSnTi problems/advantages

- AgSnTi wets well and STICKS TO IT
- More subject to impurities and pollution
- Softer, will need better control of thickness

- If everything fails may need to revert to sputtering

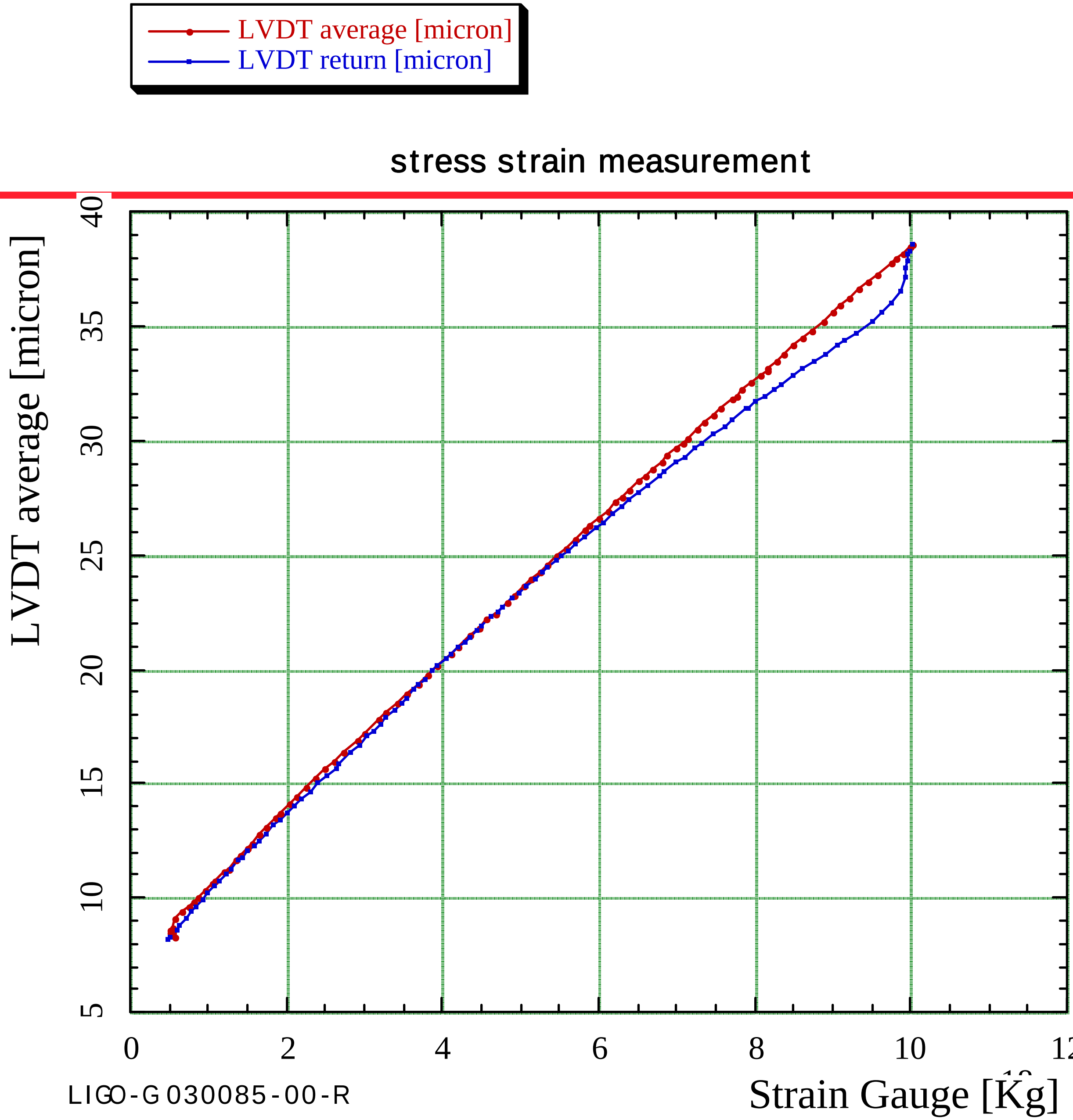
Stress Strain tests

- Made tests on MoRuB even if often the braze slipped off cleanly or cracked



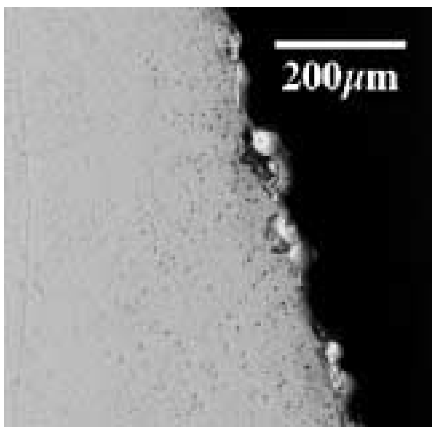
So far achieved >2.2 GPa yield While expecting 5.2 GPa

Sample either slipping or cracking

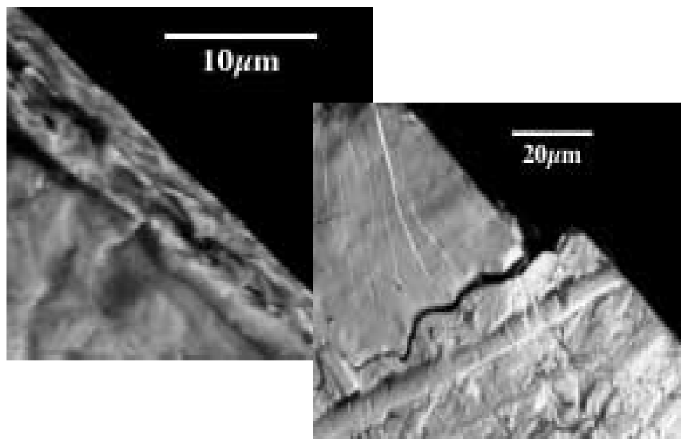


Why low values for yield point?

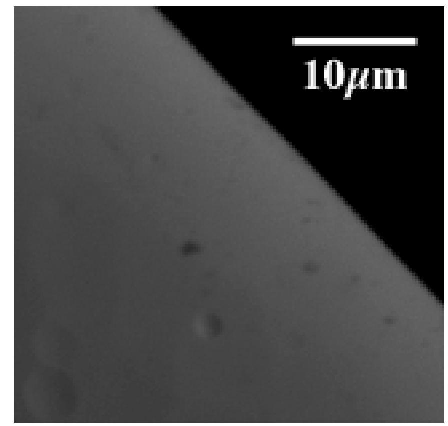
Nucleation of cracks. To take good measurements we need regular borders without weak point for crack nucleation:



EDM Cut
Local melting
Possible formation
Of crystals on edges



Scissor cut:
Very irregular and unreliable!



Electropolished cut:
The best!

Nucleation of cracks causes premature failure of the material!

•Engineering studies

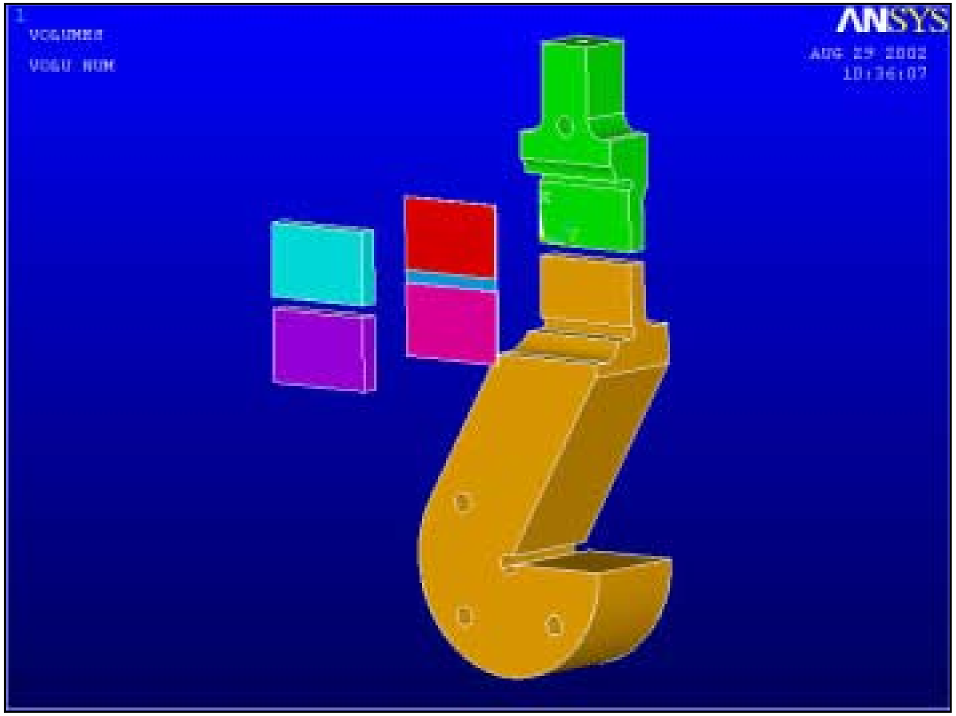
of suspension structures

QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

Finite Element Analysis of MoRuB flex joint

Monoflex Assembly:

- Hook
- MoRuB Membrane
- Cavaliers

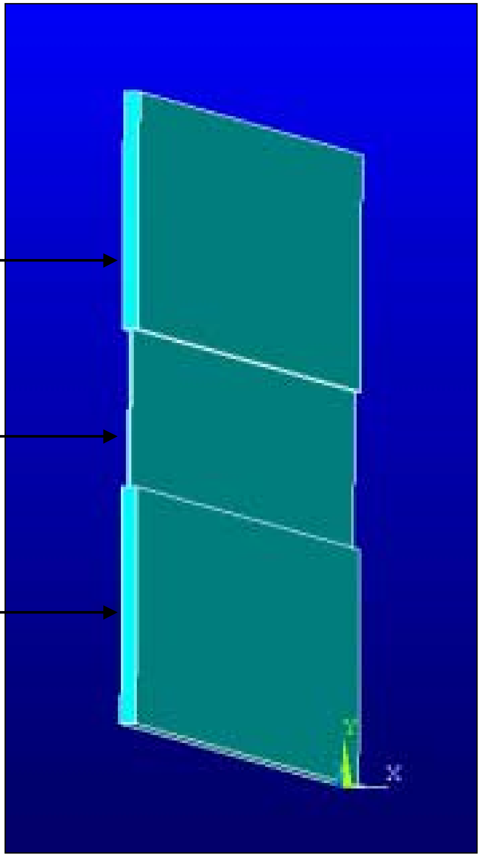


Finite Element Analysis of MoRuB membrane

Initial Membrane Geometry:

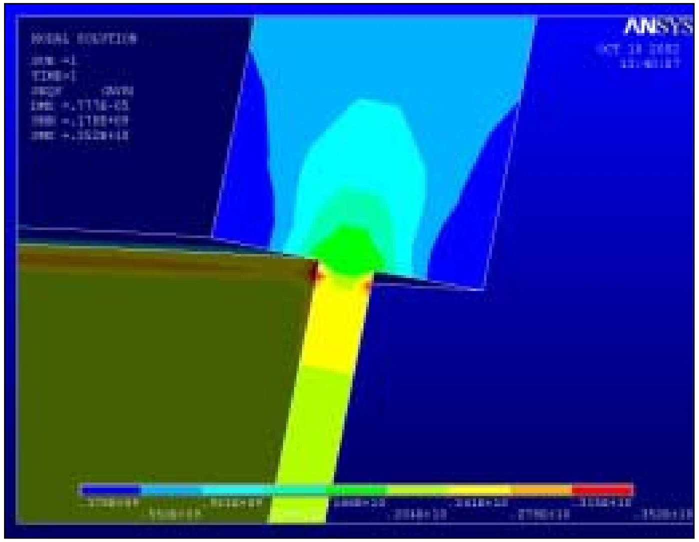
- Height: 6mm
- Width: 3mm
- Thickness: 50µm
  <10µm
  50µm

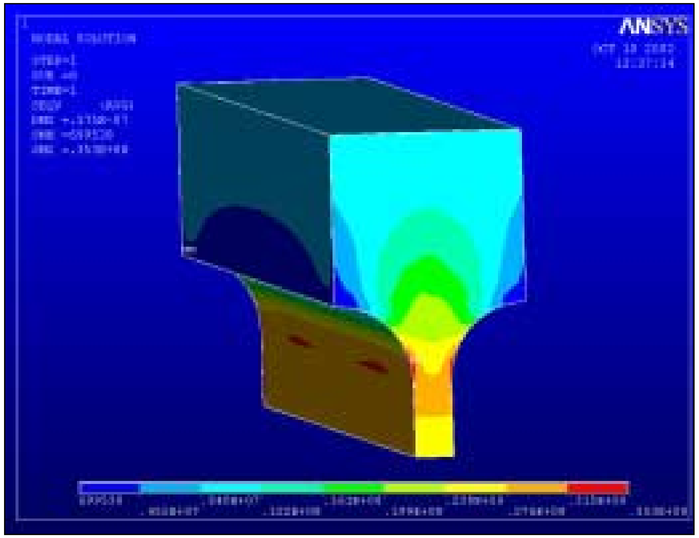
- With and without fillet radius



Filllet radius effects

In order to minimize the stress concentration in the transition zone a 20µm fillet radius was chosen.





Sharp transition model

Stress maximum (Von Mises)=3,52e9Pa

20 µm fillet radius

Stress maximum (Von Mises)=2,7e9Pa

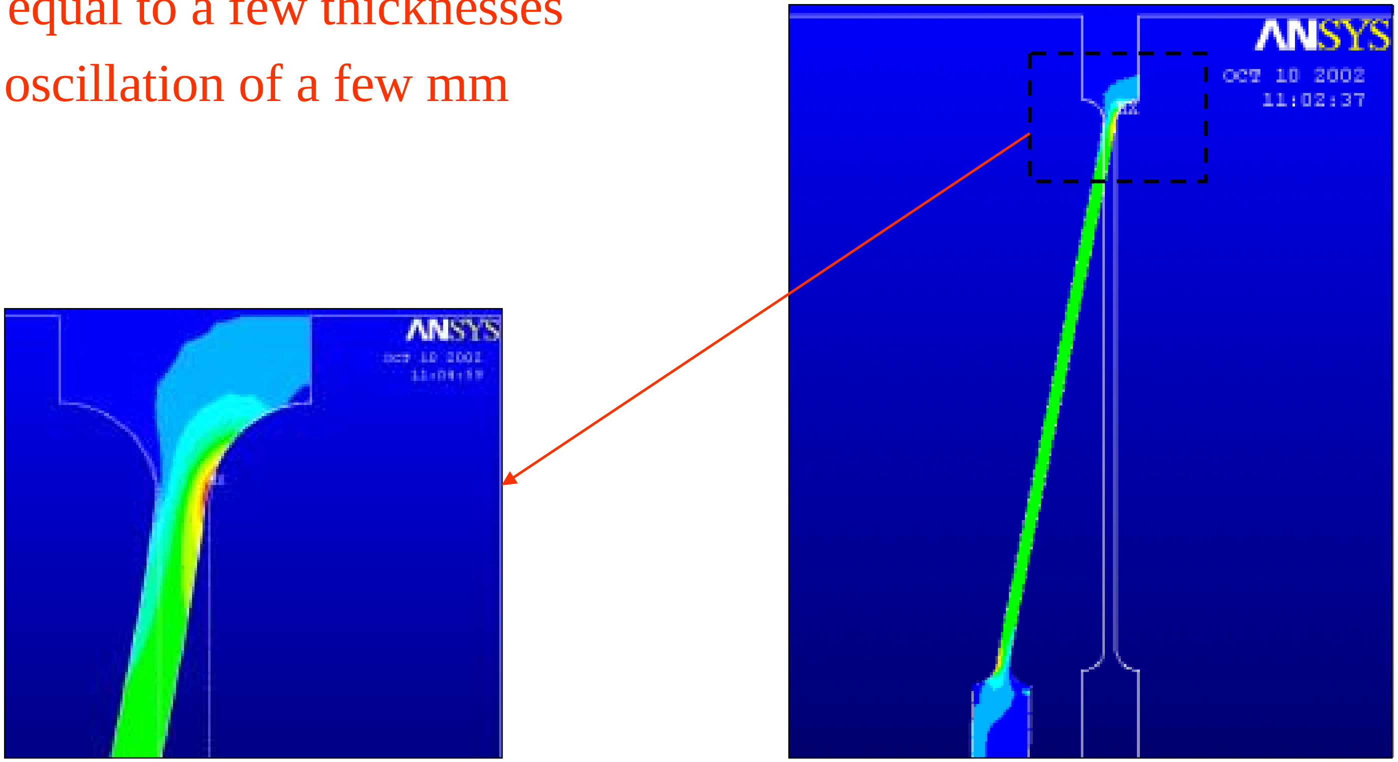
Finite Element Analysis of MoRuB membrane

Effective bending length simulation

Most oscillation energy stored

in a length equal to a few thicknesses

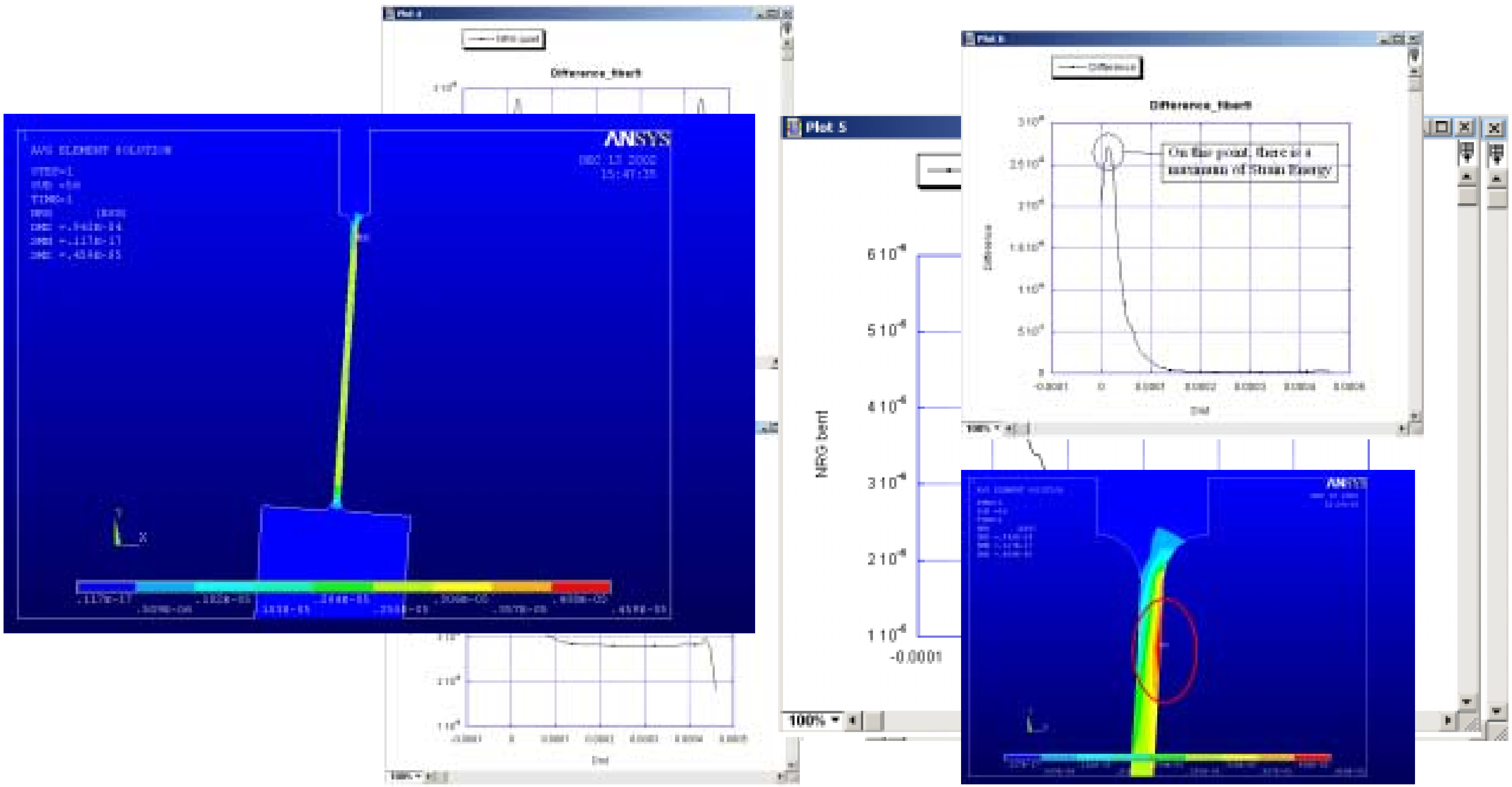
Allowable oscillation of a few mm



* Von Mises equivalent stress plot

Location of Strain Energy

The principle



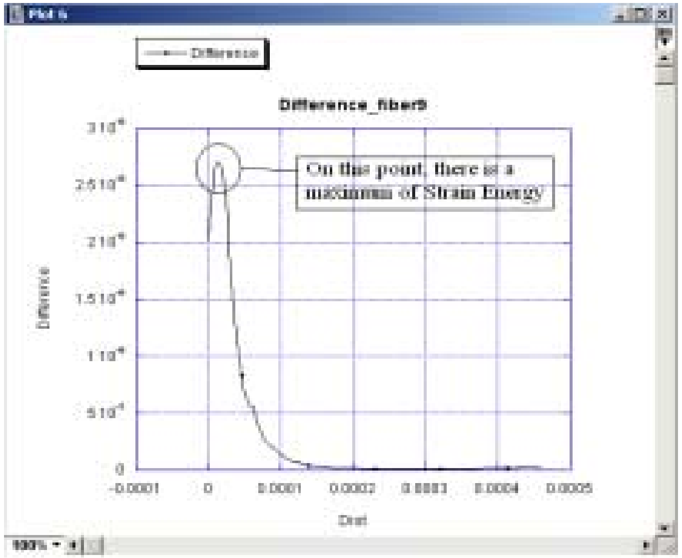
“Bent” position

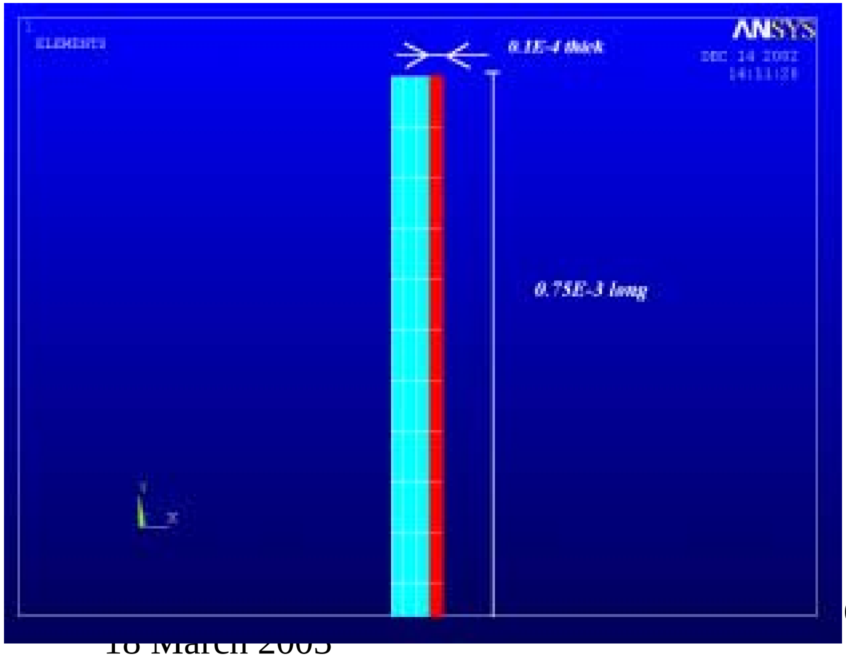
Braze effects

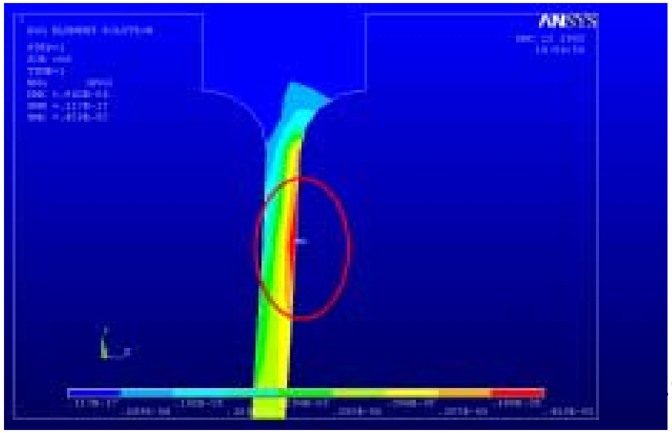
Compare the oscillation strain energy stored in the braze and in the F-joint (Q-normalized)

Effects on overall Q-factor

Thin and wide constrained braze irrelevant



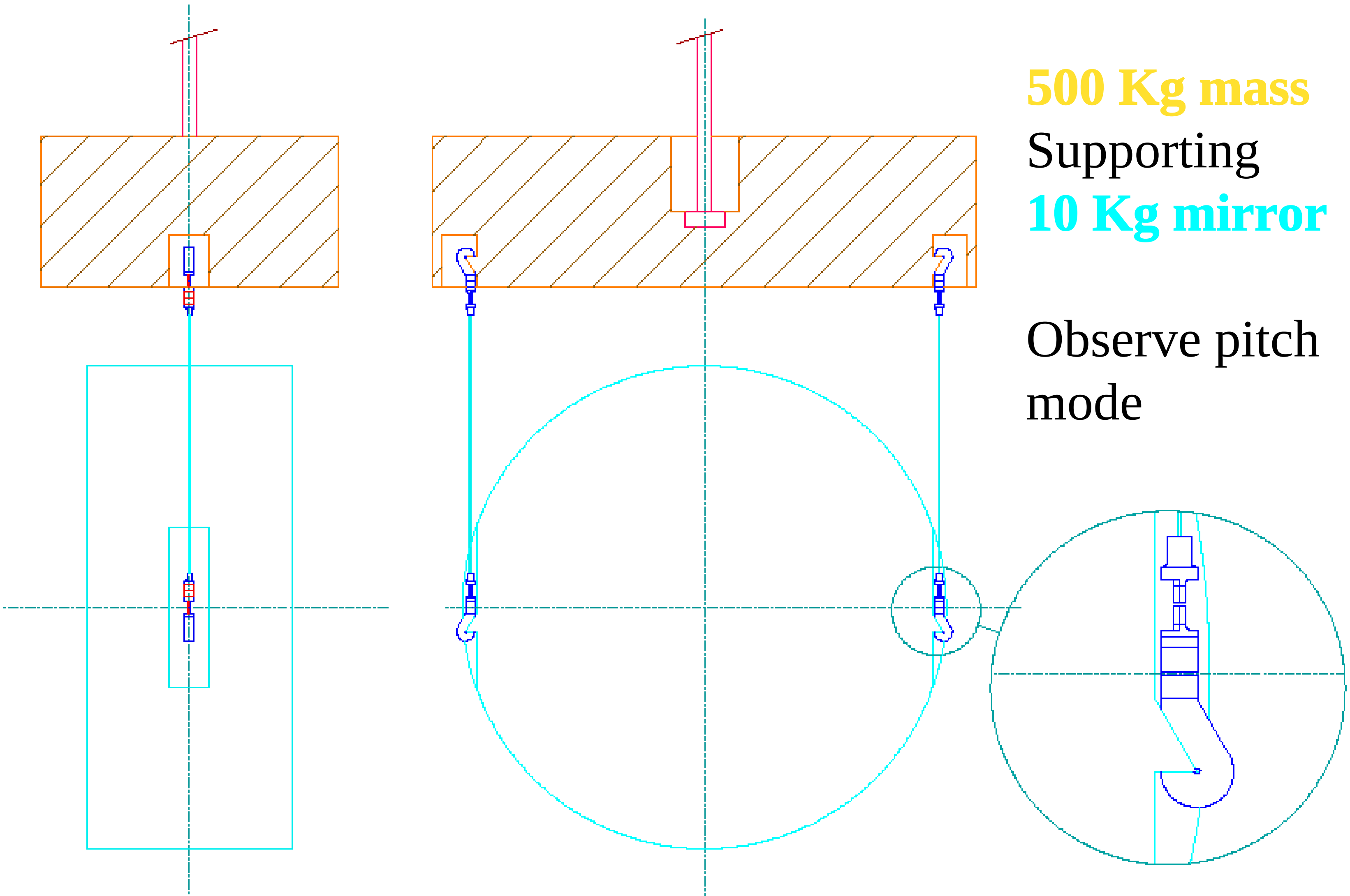




Conclusions

- Glassy metals are a promising technology for fully engineer-able mirror suspensions
- Brazeability has still to be fully tested
- Substantially development necessary before being able to consider it a real and advantageous alternative to FS

Testing jig



500 Kg mass

Supporting

10 Kg mirror

Observe pitch mode