



**High  
Luminosity  
LHC**

# Analysis of Niobium Material

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The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.



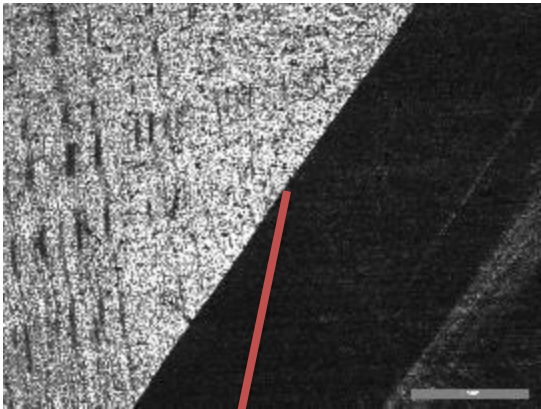
# Niobium rod from Heraeus

- $\text{Ø}133 \times 635 \text{ mm}$
- Ductility between 1 and 6%
- Typical values for tensile strength and hardness
- Yield strength very close to tensile strength
- Very large grain sizes (on the cm scale)

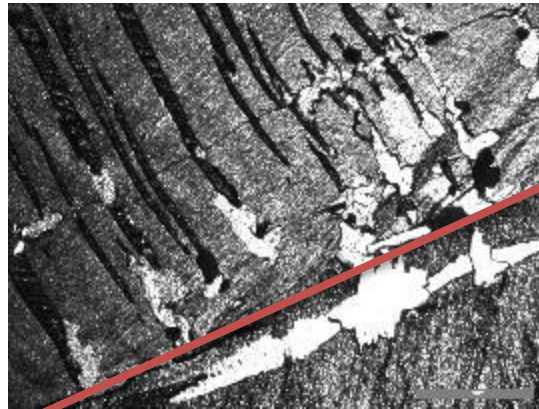


# Niobium rod from Heraeus

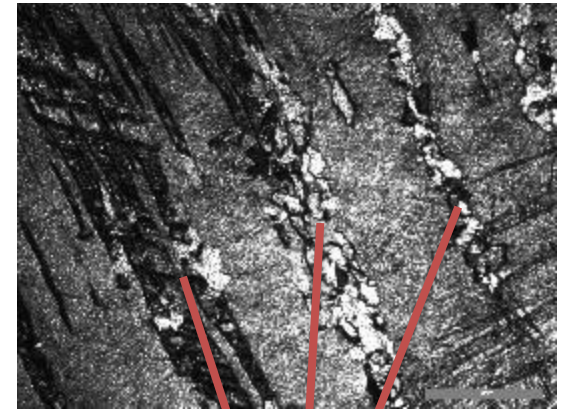
- Material processed by EBM [1]
- Deformation bands visible after etching
- Recrystallised grains in deformation bands and grain boundaries close to the outer radius.



grain boundary at inner radius



grain boundary with recrystallised grains



deformation bands, recrystallised grains

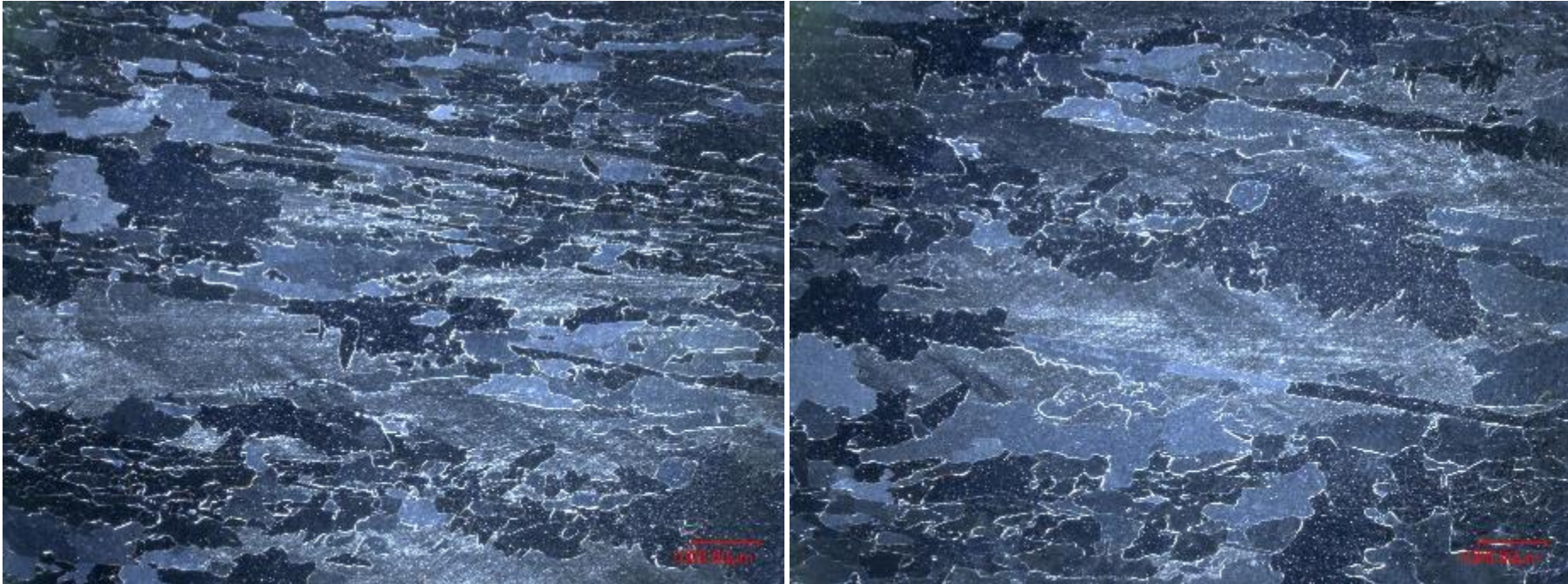
# Niobium rod – tensile tests

- Ductile fracture
- Failure not necessarily at grain boundary



# Niobium in beam tube (Niowave)

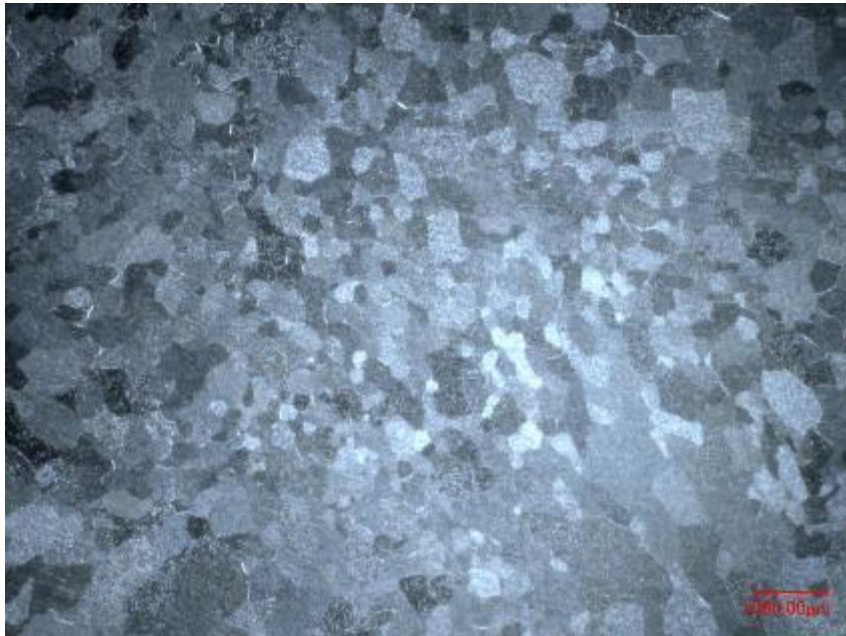
- Recrystallised and deformed structure
- Large grains in mm range remain
- HV10 ranging from 80 to 125



# Niobium rods $\varnothing 50$ mm - comparison

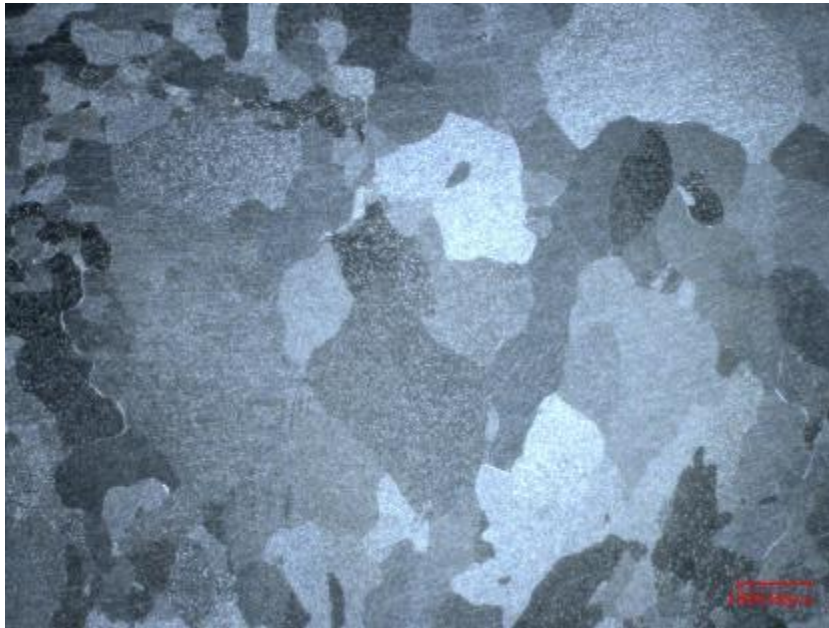
Heraeus

Ningxia



# Niobium rods $\varnothing 50$ mm Heraeus

- Inhomogeneous grain size distribution
- Grain size up to several millimetres
- Visibility of deformation bands



# Niobium Heraeus – conclusions

- Initial annealing of the rod insufficient for the high diameter
- Further annealing led to increased recrystallization, but larger grains remain
- Low ductility of tensile specimens may be due to adverse orientation of a grain boundary, or high misorientation, statistic is not sufficient
- Recrystallisation of this material is not uniform and results in final, inhomogeneous grain size distribution [2]



# Actions

- Discuss reclamation of rod material from Heraeus
- Request improved heat treatment: better adjustment to diameter
- Ask Niowave or Heraeus for the heat treatment that has finally been implemented

# References

[1] B. Spaniol and U. Weitzel-Hoefler, *Mass Production of High Purity Niobium*. Proceedings of the 1999 Workshop on RF Superconductivity, pp. 96-99.

(<https://accelconf.web.cern.ch/accelconf/SRF99/papers/tua006a.pdf>)

[2] H.R.Z. Sandim et al., *Recrystallization behavior of a cold-rolled niobium bicrystal*. Mat. Sci. Eng., A354:217-228, 2003.

(<http://www.sciencedirect.com/science/article/pii/S092150930300011X>)

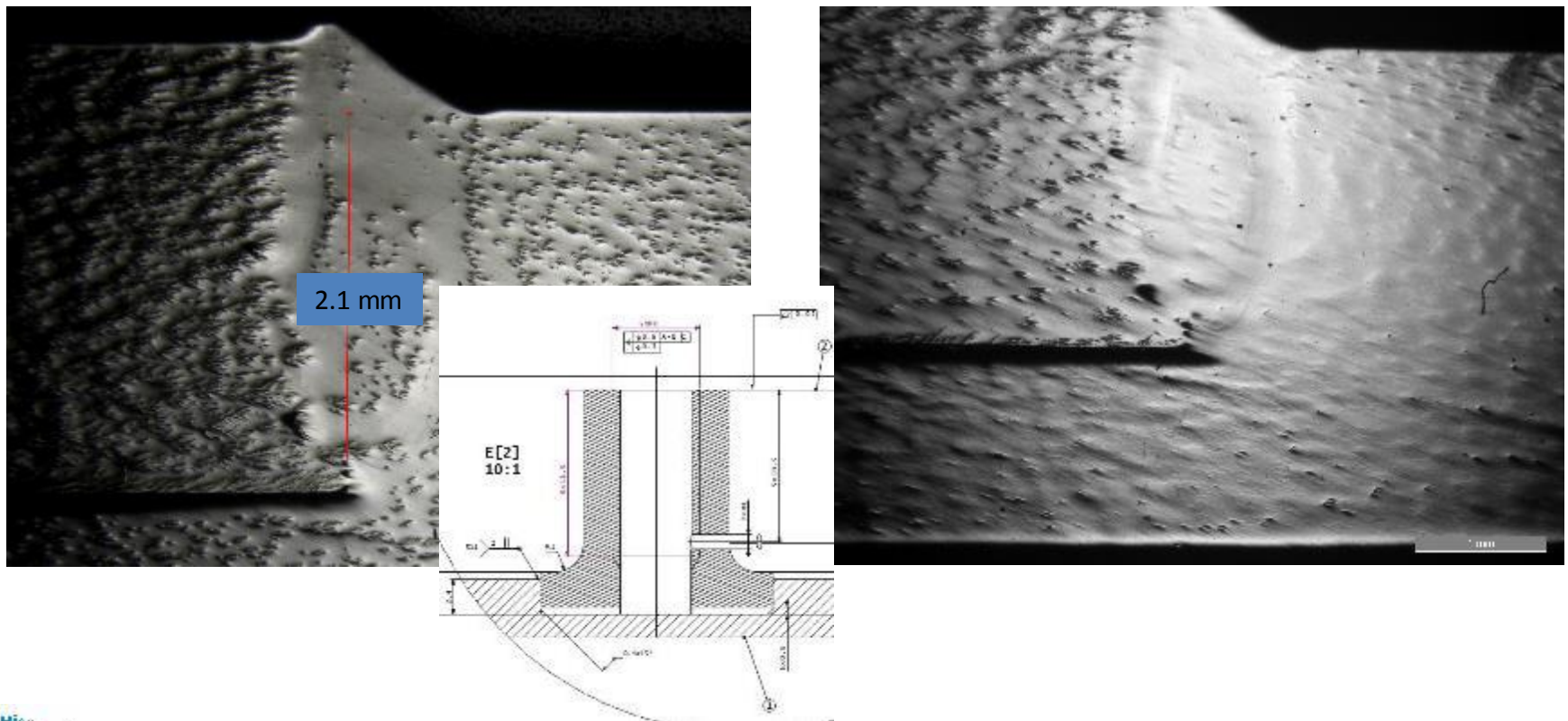
# Nb plate 210x100 by Ningxia

- Uniform, homogeneous microstructure



# Nb/Nb55Ti weld

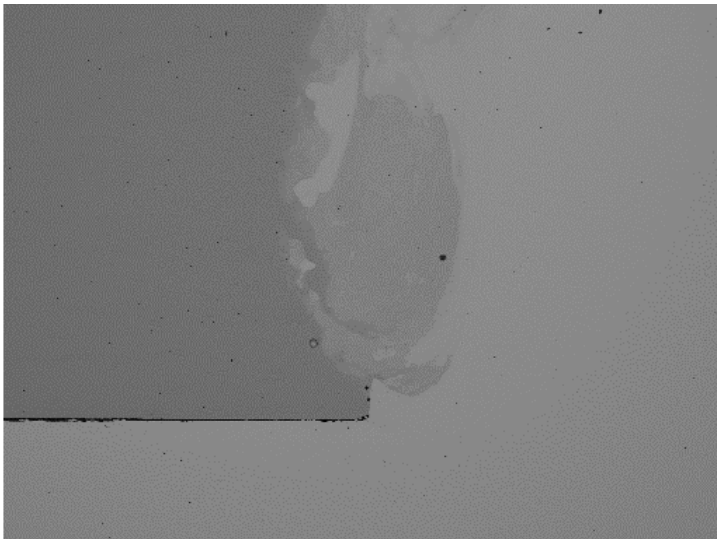
- Penetration depth of  $> 2$  mm achieved
- No apparent contamination of RF surface



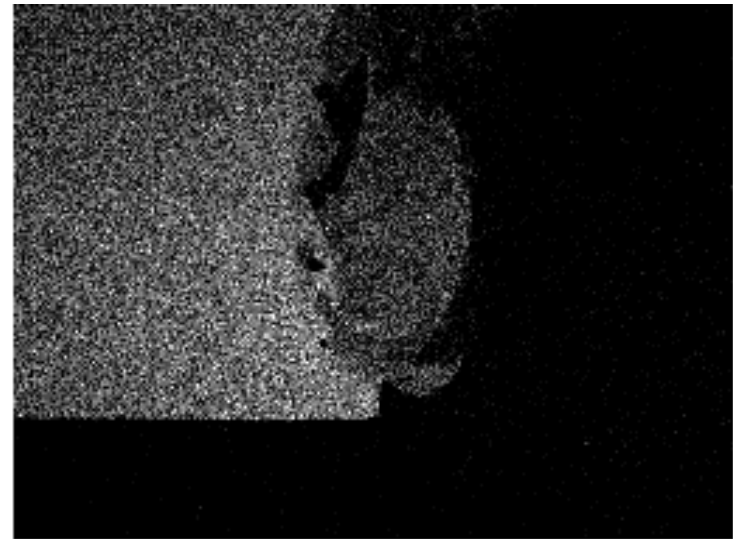
# Nb/Nb55Ti weld

- No evident diffusion of Ti into RF surface

BSE contrast



Ti distribution ( $K_{\alpha 1}$ )





# High Luminosity LHC



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