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Bulk material investigations at cryogenic temperatures

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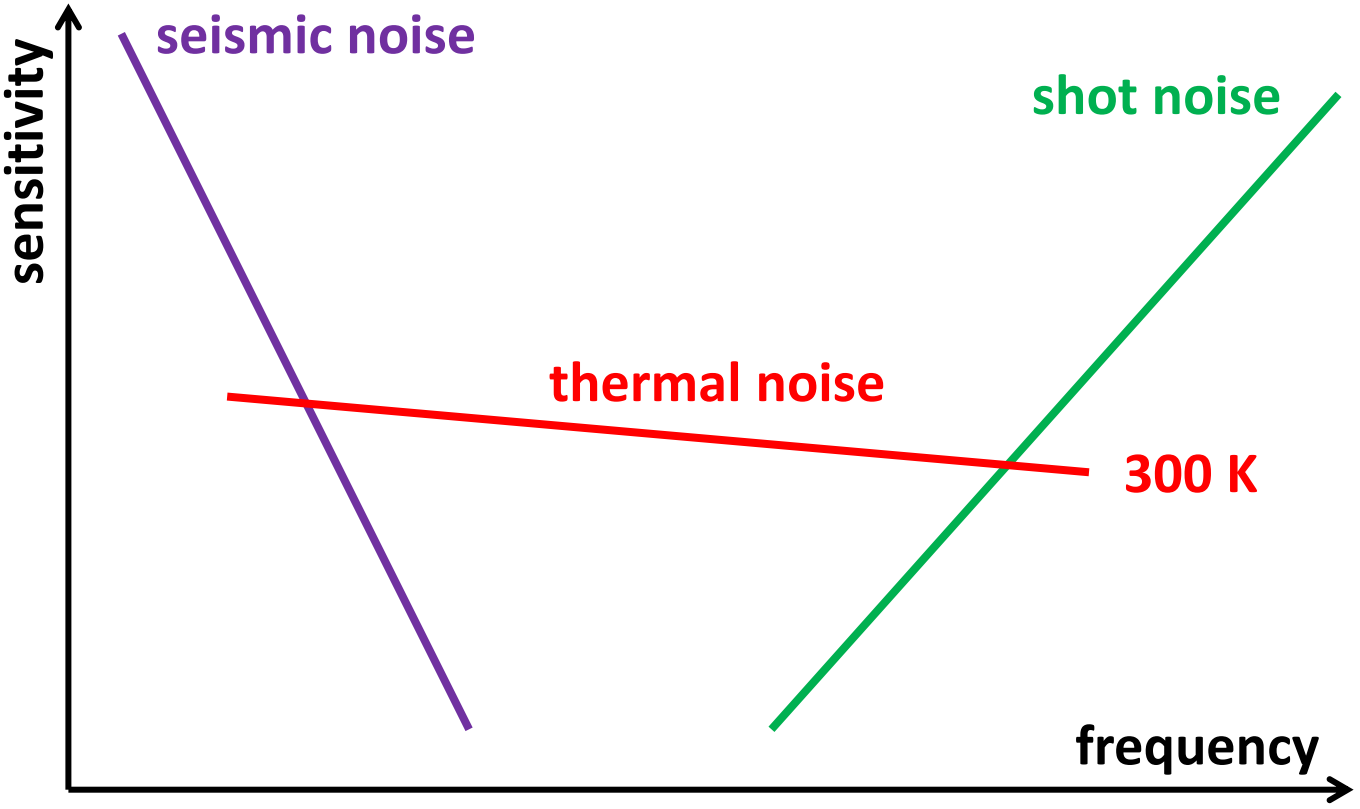
Need for new materials in future GWD

- Current GWDs like Ligo [1], Virgo [2], GEO600 [3] and TAMA300 [4] reached their limits



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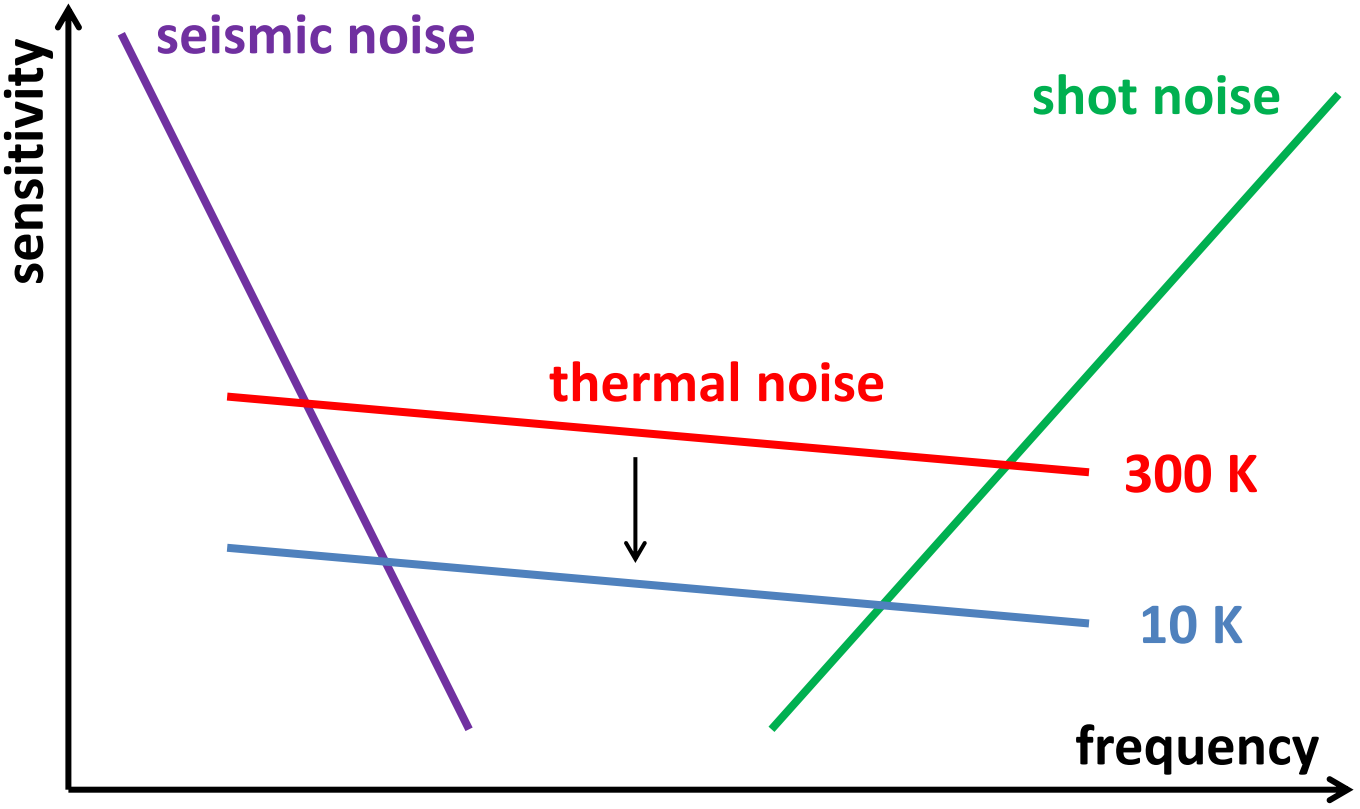
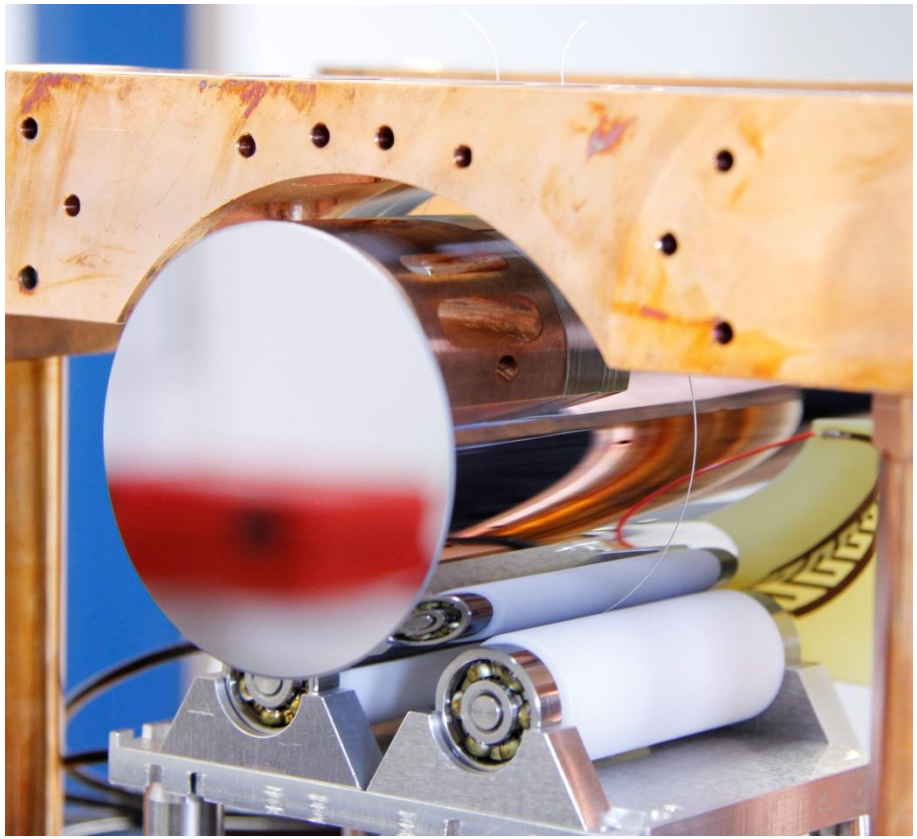


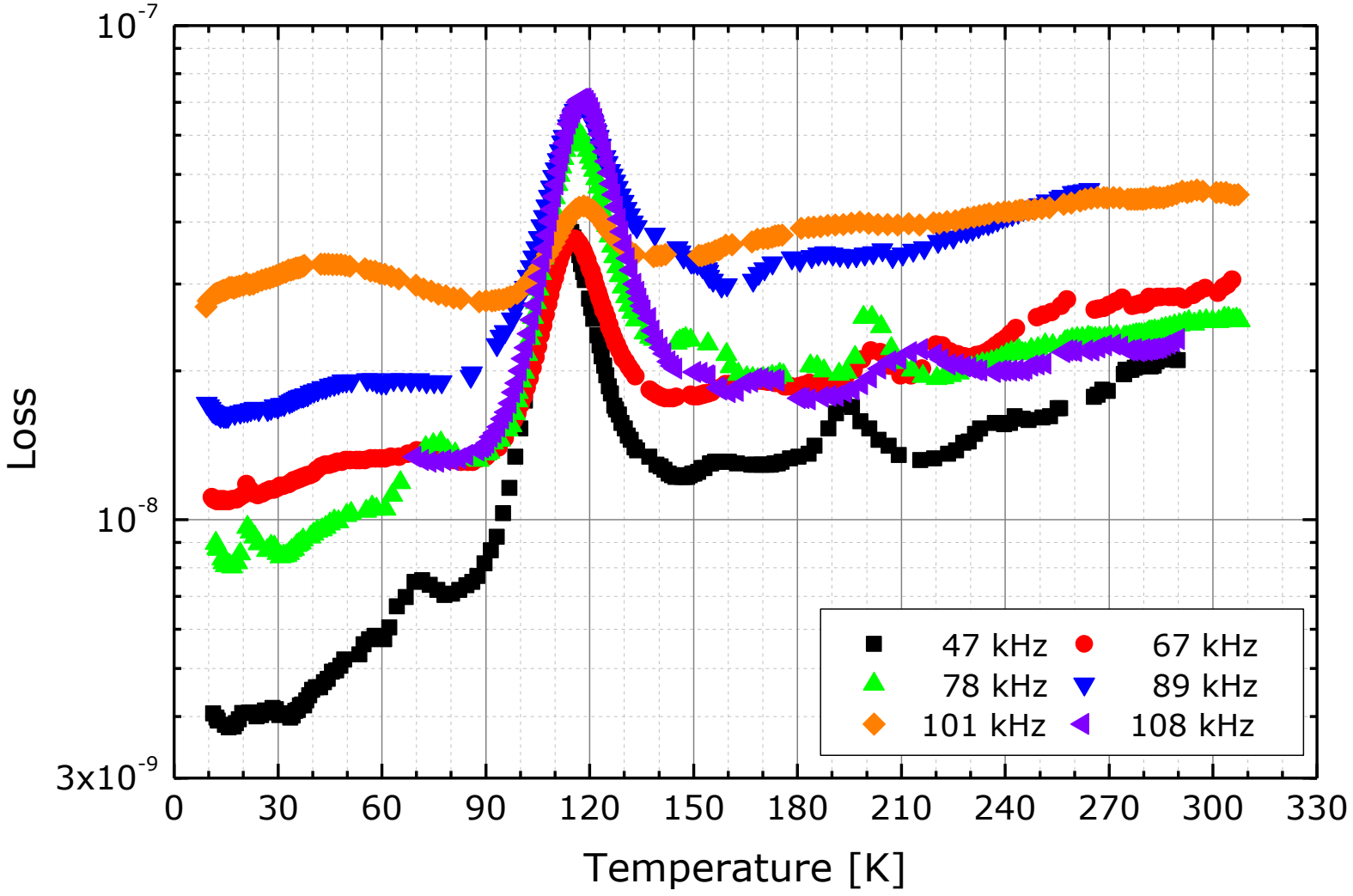
Investigation of bulk silicon samples

- Samples of different geometry but same crystal orientation and
- Samples of different crystal orientation but same geometry
- Ring down measurement

Diameter	Height	Orientation
65 mm	50 mm	(111)
65 mm	70 mm	(111)
65 mm	120 mm	(111)
3 inch	75 mm	(111)
3 inch	75 mm	(100)
110 mm	200 mm	(111)



Silicon (111) Ø 65 mm x 50 mm



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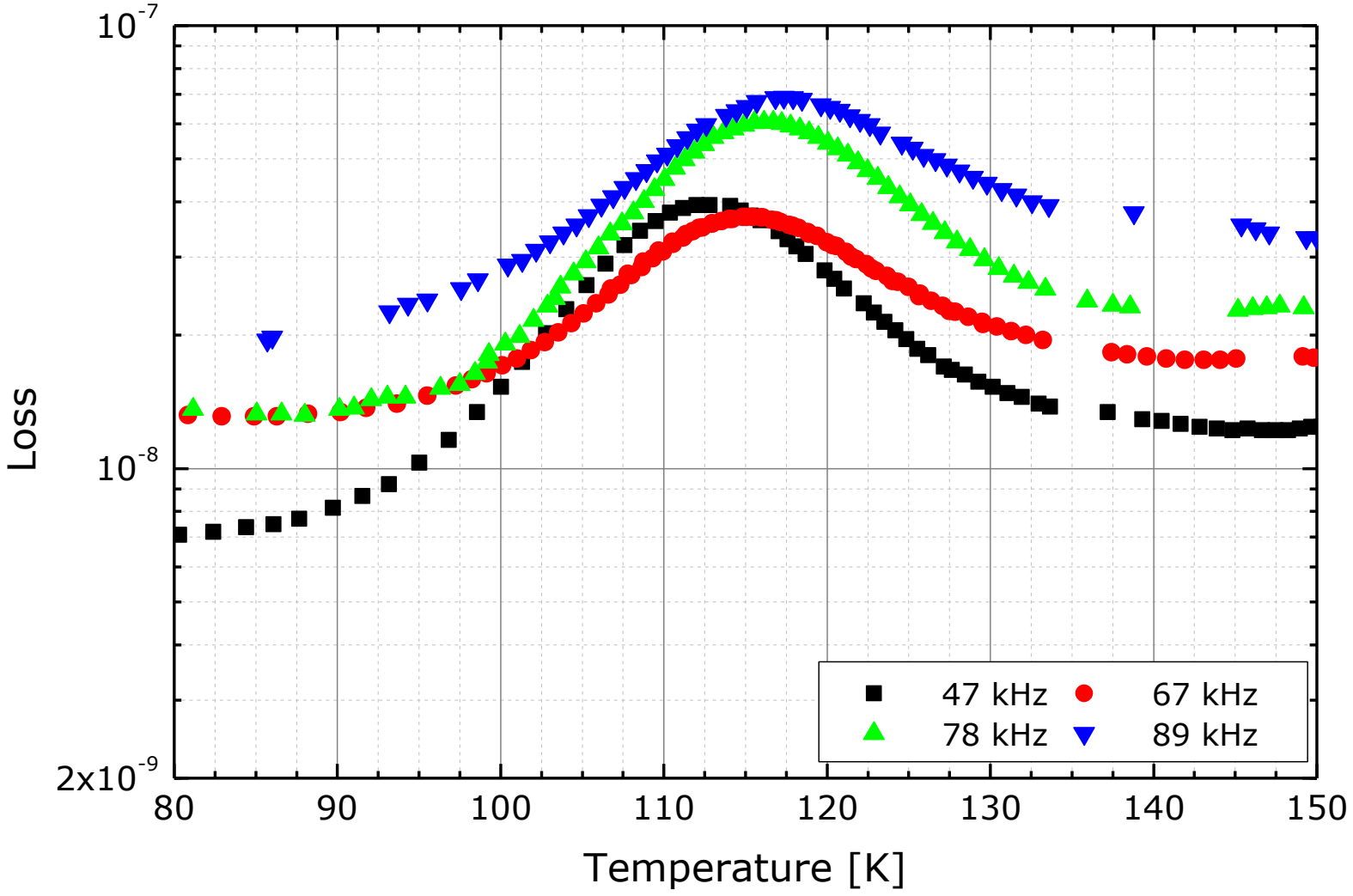


Arrhenius plot

- Mechanical loss ϕ in an anelastic solid is described by:

$$\phi(\omega) = \Delta \frac{\omega\tau}{1 + \omega^2\tau^2}$$

- Relaxation time τ of the loss process follows the Arrhenius law:

$$\tau = \tau_0 \exp \frac{E_A}{k_B T}$$

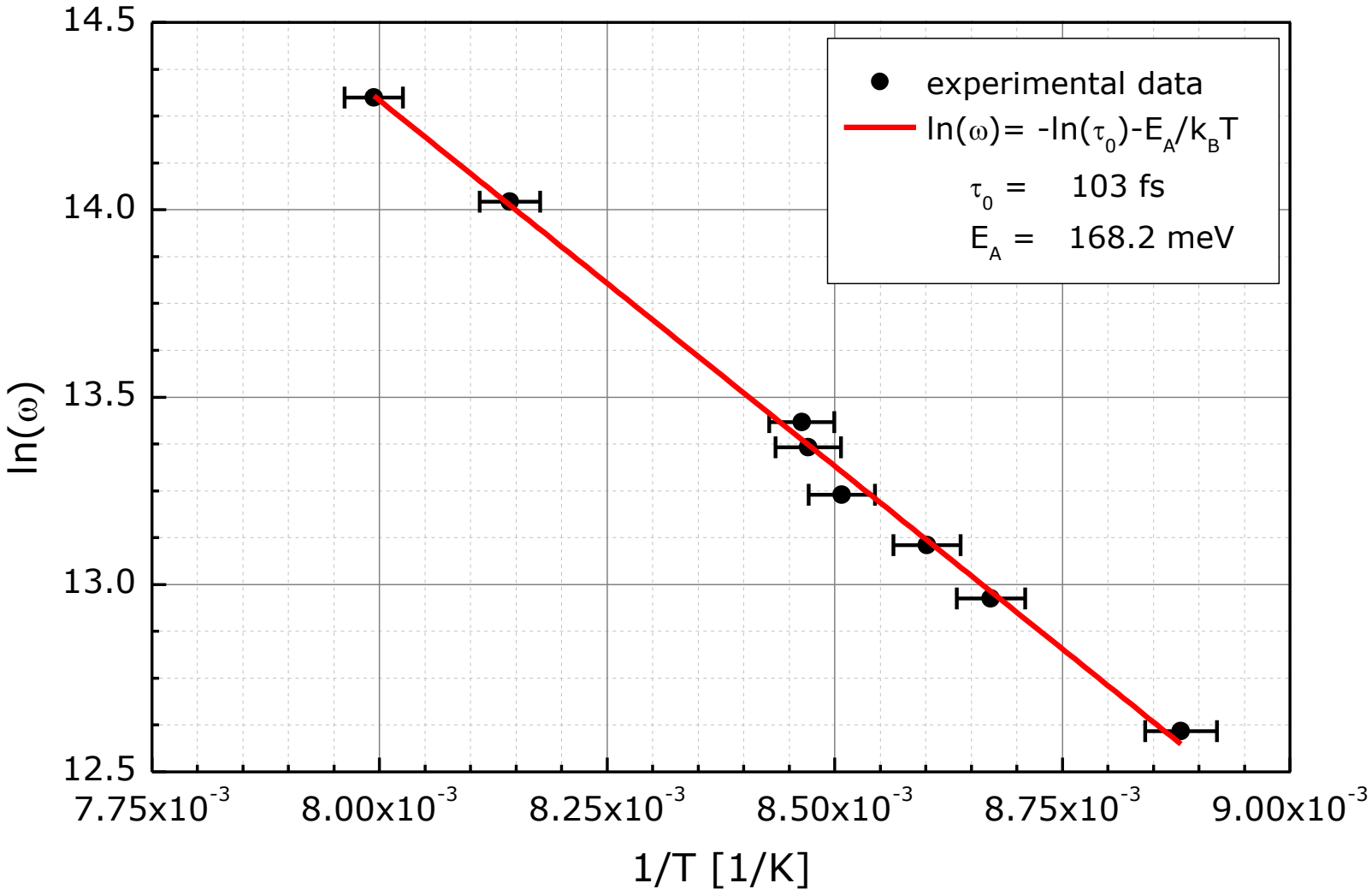
- Thus one gets the Arrhenius plot:

$$\ln \omega = -\ln \tau_0 - \frac{E_A}{k_B} \times \frac{1}{T}$$

$$y = y_0 + m \times x$$

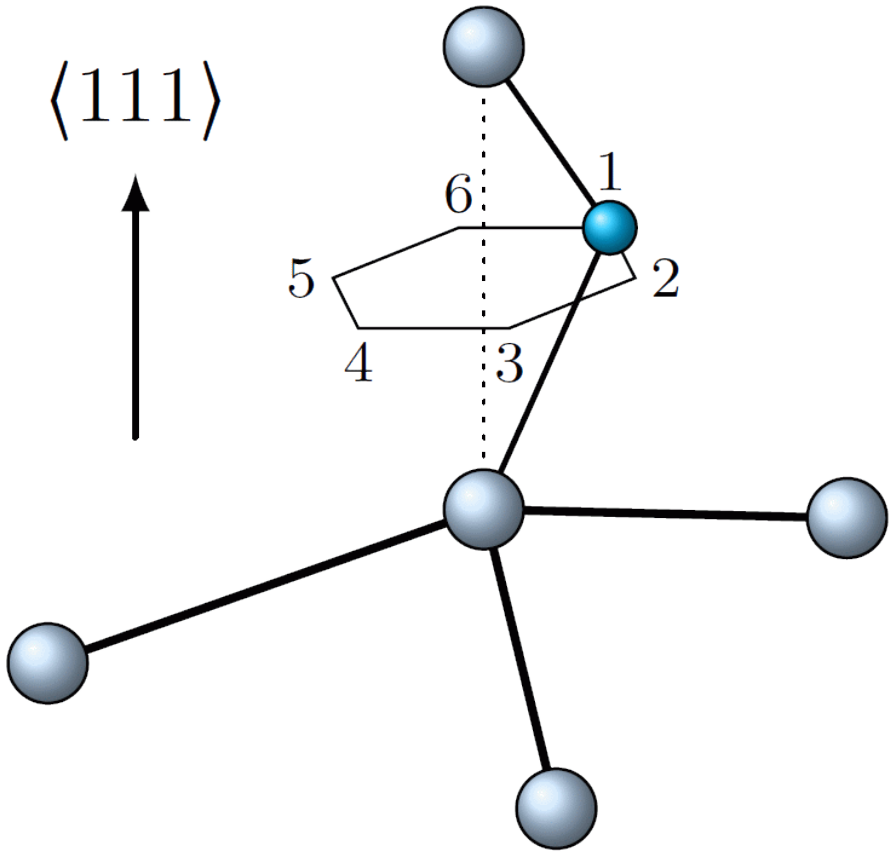
Nowick & Berry [5], Gottstein[6]

Arrhenius plot for Ø 65 mm x 50 mm sample



Interstitial oxygen in silicon

- Czochralski grown crystals with oxygen impurities
- Oxygen covalently bonded between two silicon atoms
- Potential loss mechanisms:
  - Rotation due to six-fold symmetry
  - Diffusion by hoping
- Annealing did not change the loss peak – exclusion of kinks and dislocations



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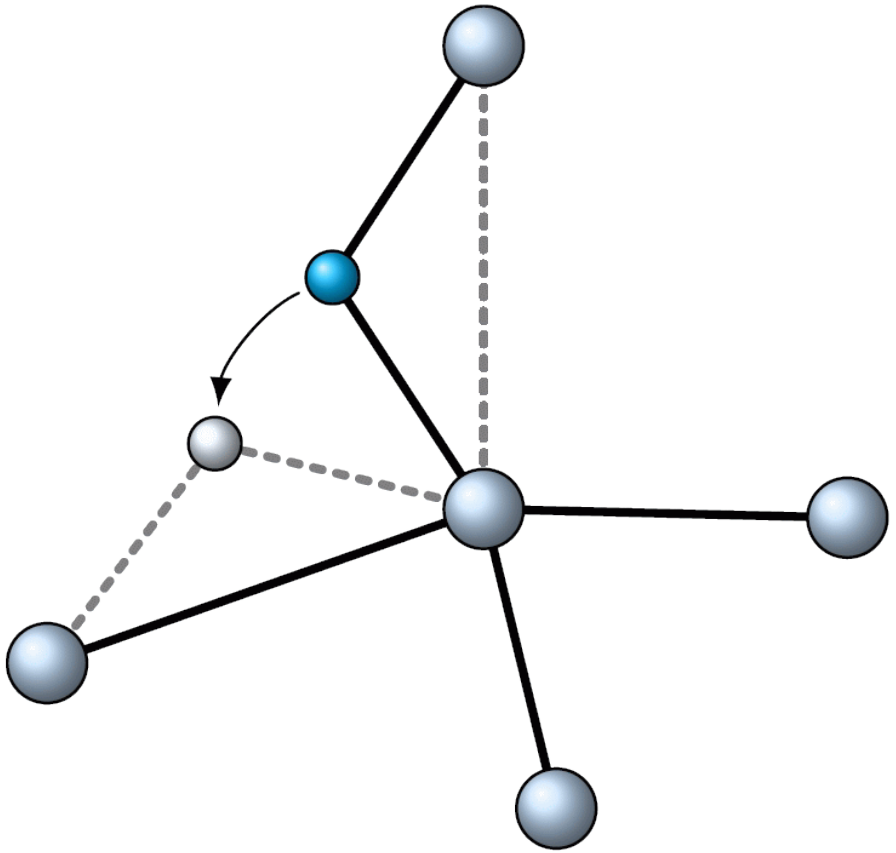
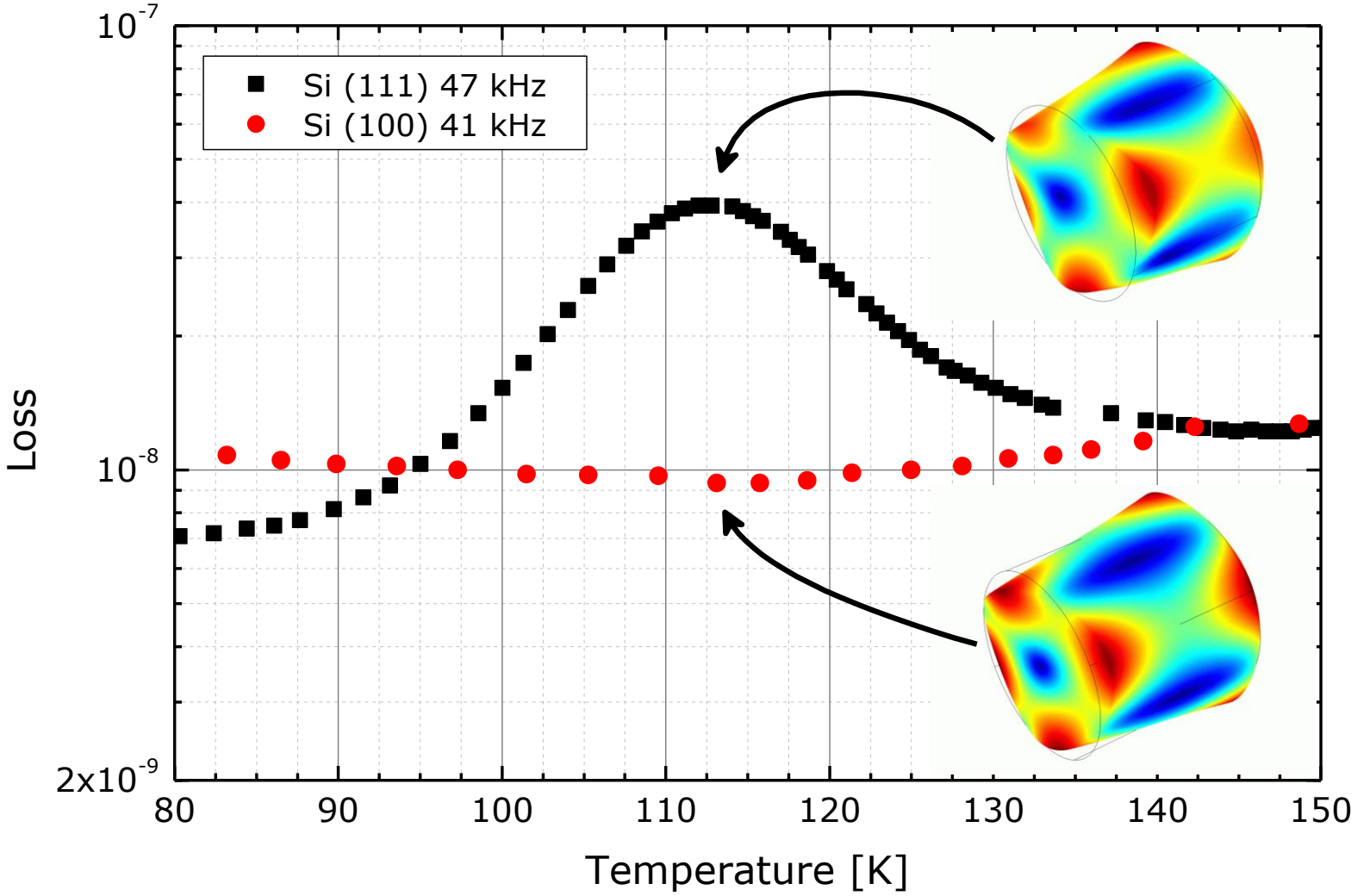
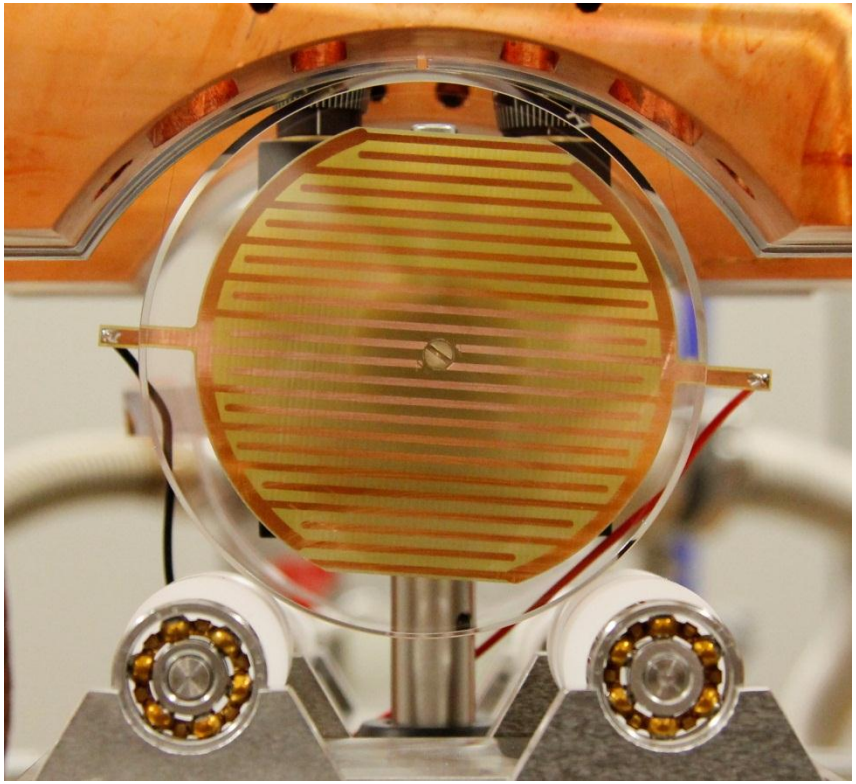


Comparison of 111 and 100 orientation

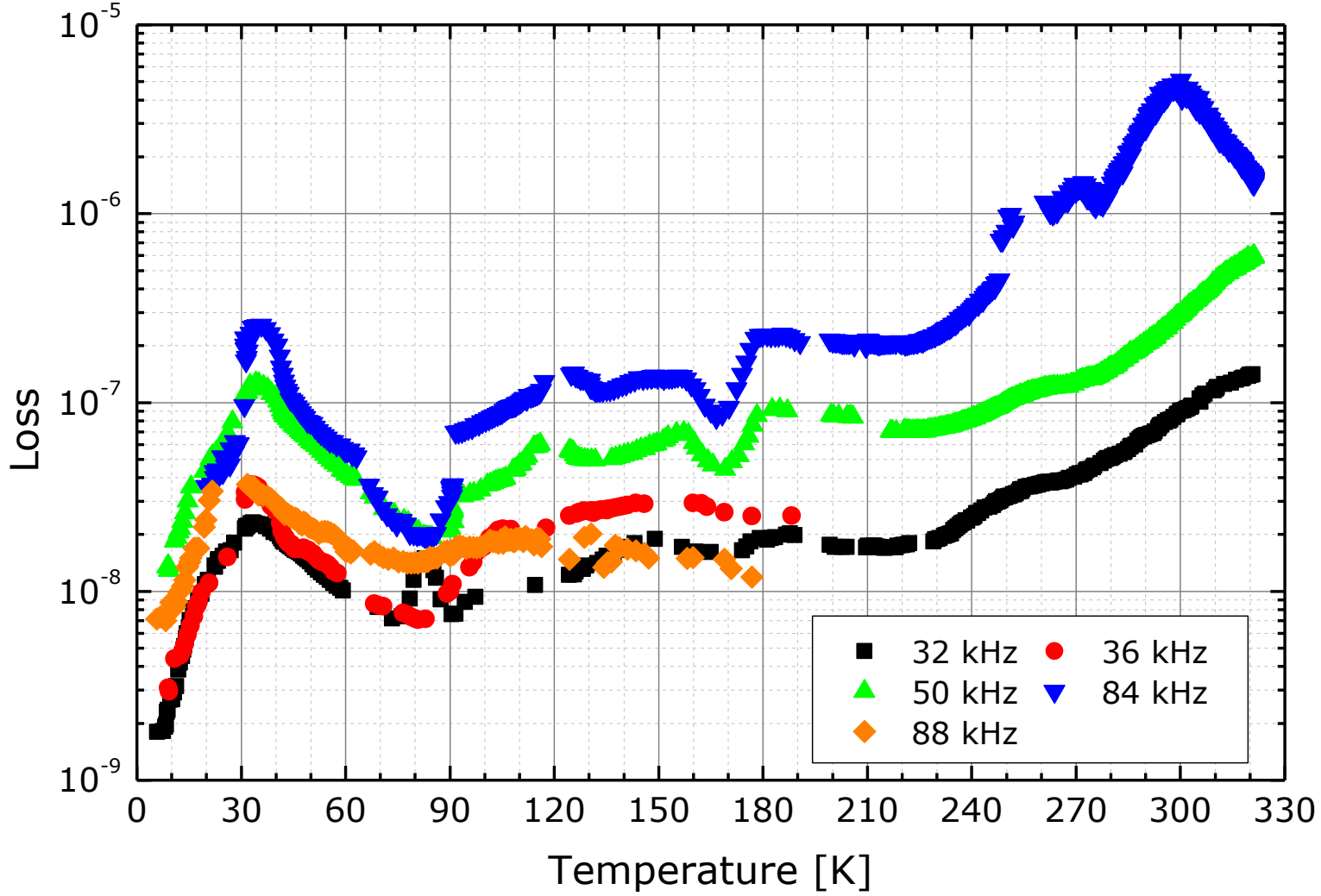


Bulk sapphire

- Choice for KAGRA [8]
- Low absorption for 1064 nm compared to silicon

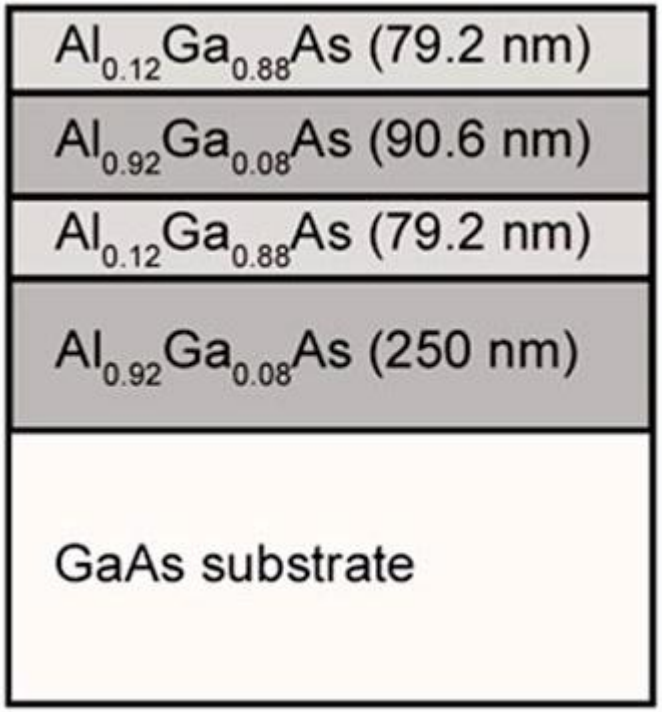


Loss measurement of bulk sapphire samples



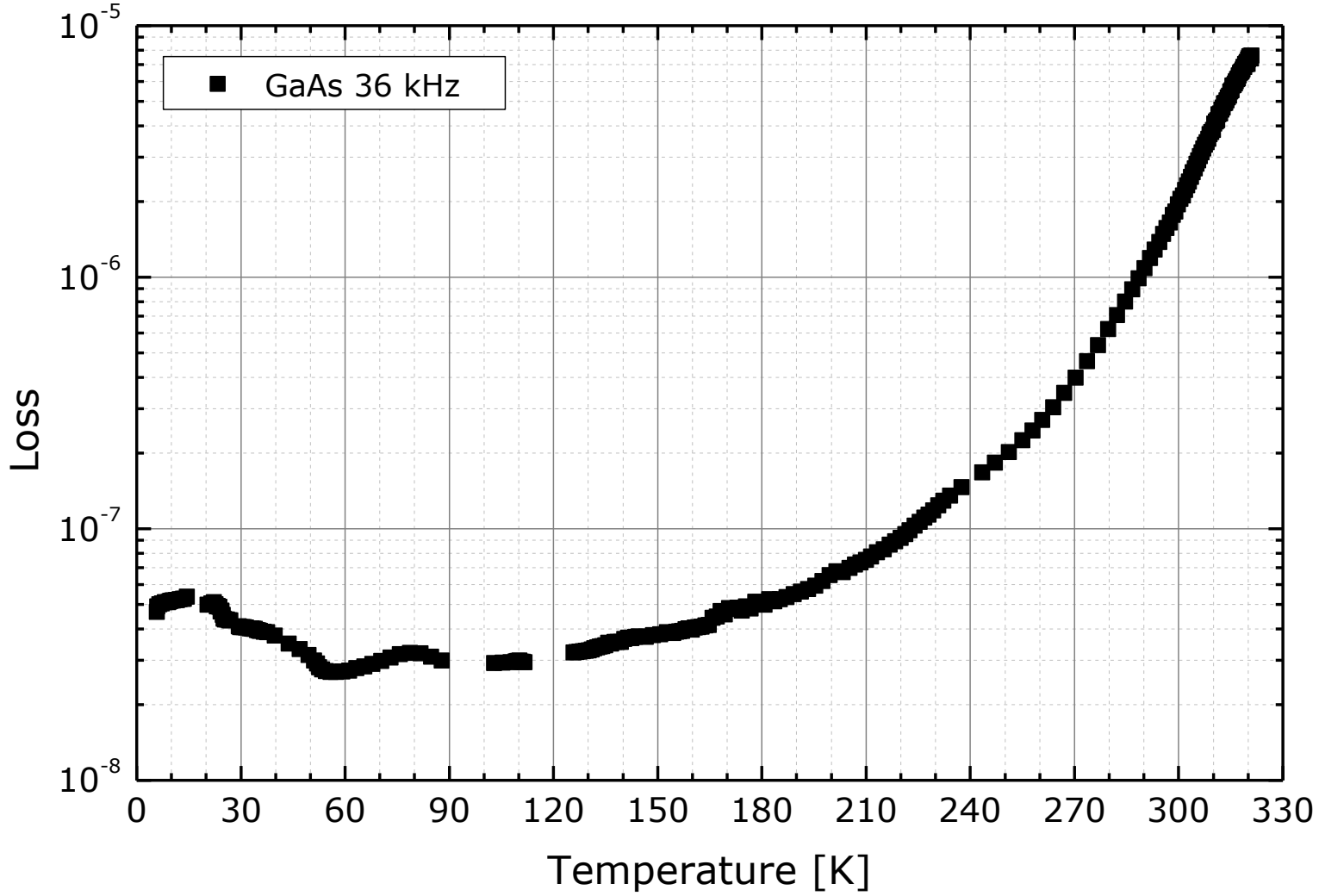
Bulk gallium arsenide

- Epitaxial growth of crystalline $Al_xGa_{1-x}As$
- Loss of bulk GaAs is completely unknown at low temperatures

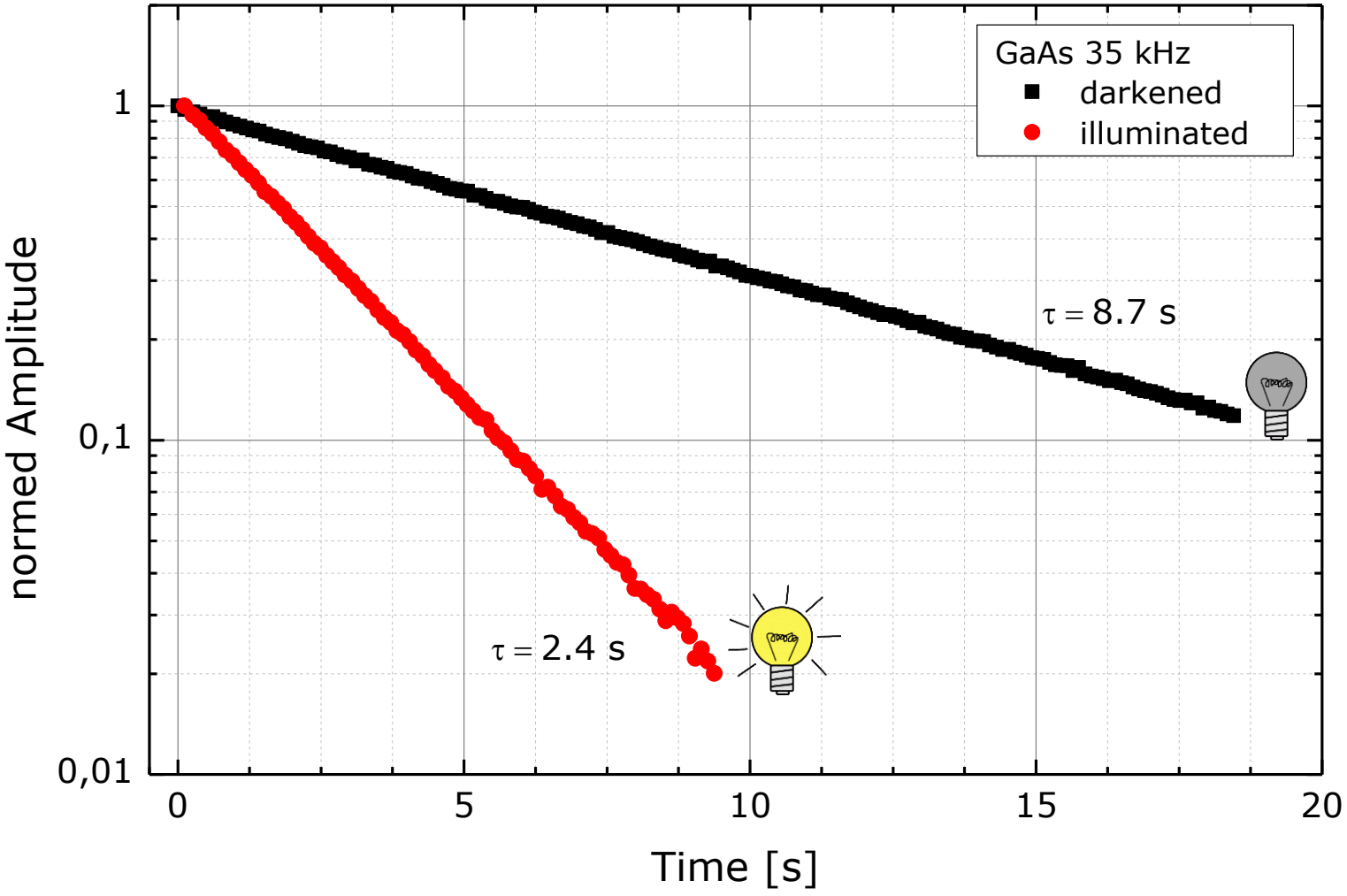


Cole et al.[11]

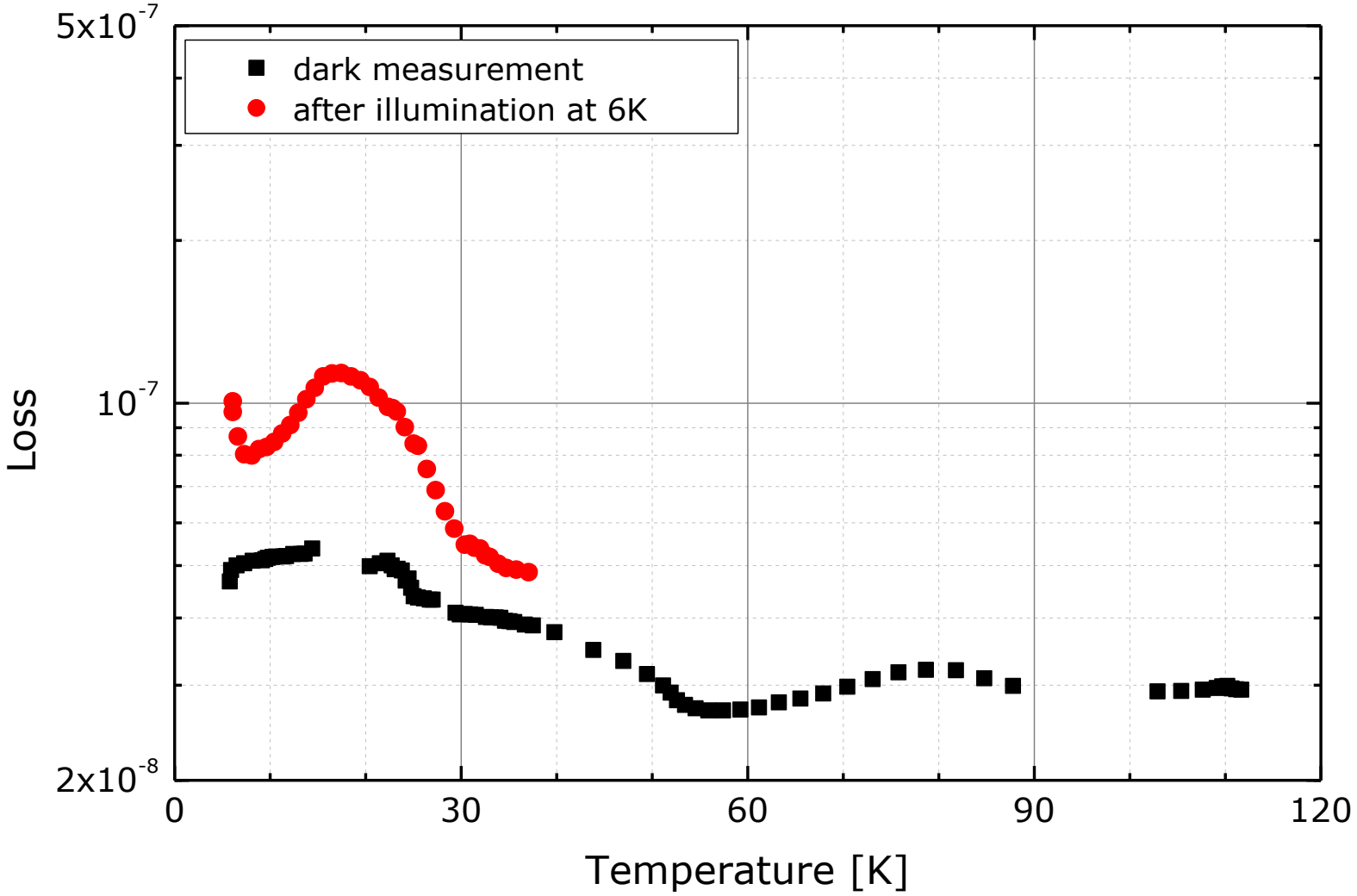
Loss measurement of bulk gallium arsenide sample



Ring down measurement with and without light



Loss measurement of bulk gallium arsenide sample



Summary

- Silicon and sapphire for future GWDs
- In silicon a loss peak around 115 K is caused by oxygen
- Gallium arsenide
  - first measurement
  - light induced damping observed
  - after illumination it stays at high losses

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References

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