Introduction to Cryogenic Suspensions

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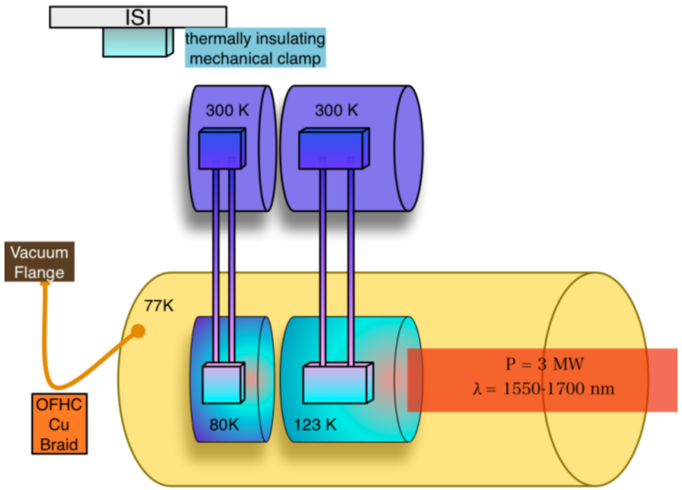
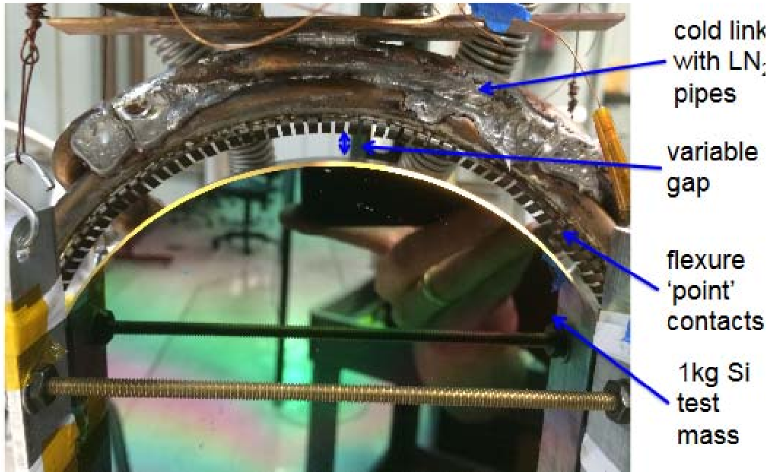
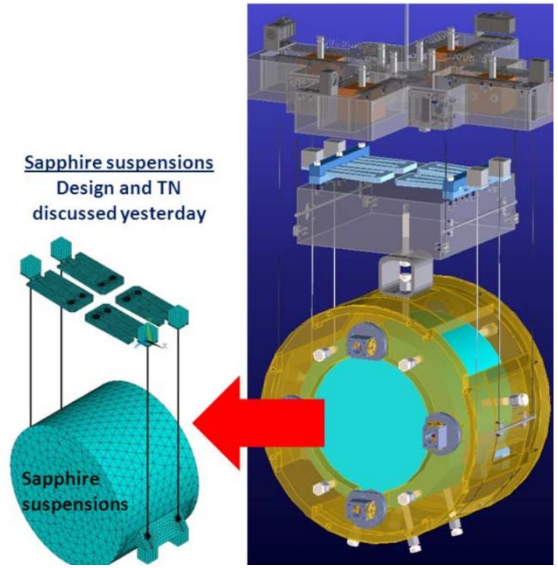
Aims of the Session

- This session is a discussion of 20K/120K options, and anything in between



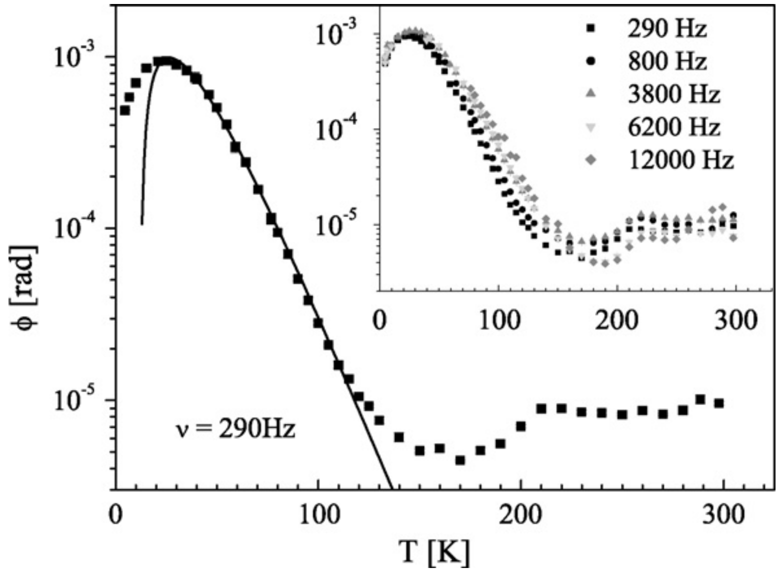


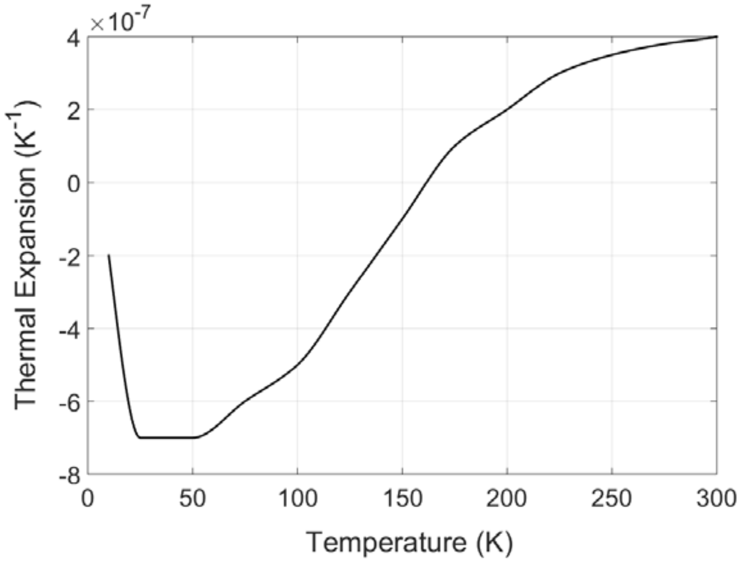
- I will show the thermal noise performance for these options
- Other speakers will talk about the details
- Then discussion …



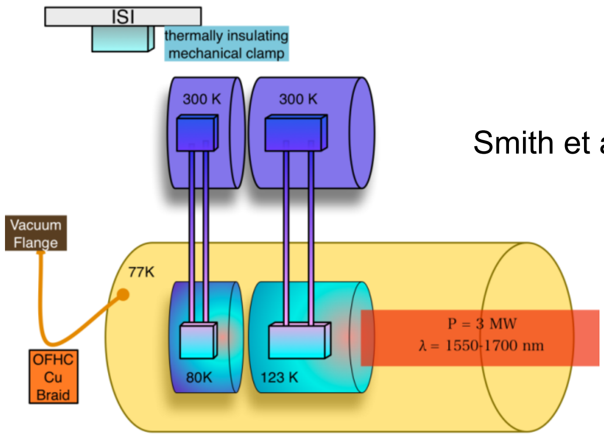
Hybrid Suspensions

- Hybrid suspensions are those which utilise silica fibres but with a silicon test mass (e.g. G1500312-v1)
- Silica has broad dissipation peak at low temperature. But can you still benefit from lower temperature operation?





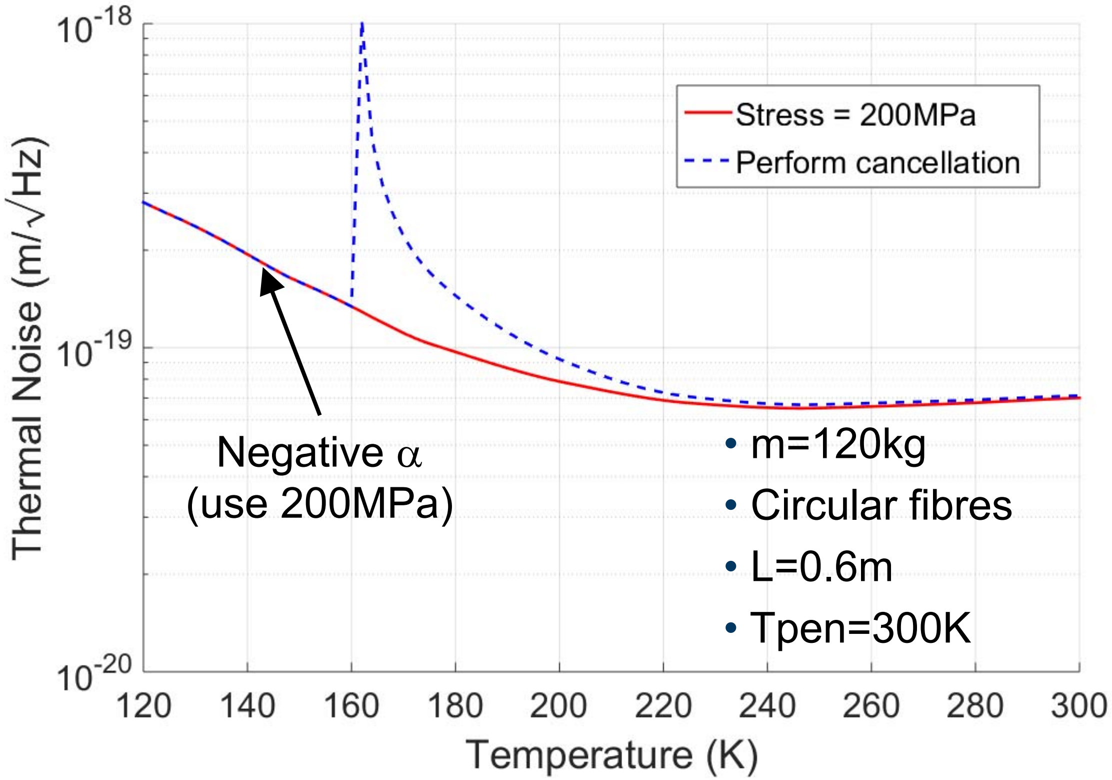
- Travaso et al., Materials Science and Engineering A 521–522 (2009) 268–271



Smith et al., G1500312

Hybrid Suspensions

- Model assumes mirror of 120kg.
- Modest benefit in noise performance when cooled, and performance at 120K is ×3 worse

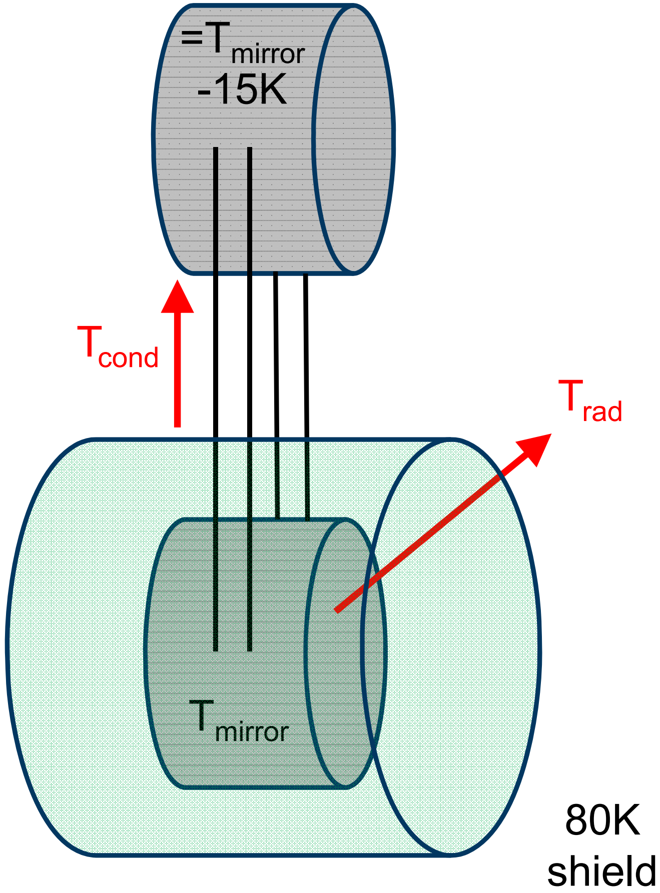


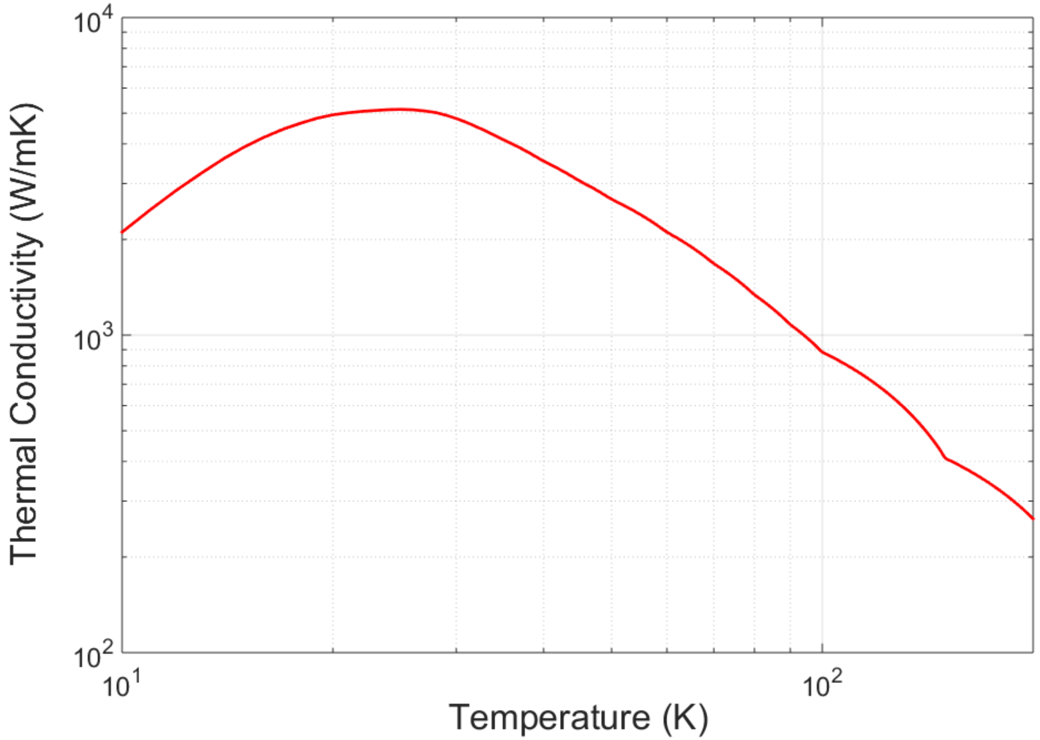
$$\phi_{\text{thermoelastic}} = \frac{YT}{\rho C}\left(\alpha - \sigma_o \frac{\beta}{Y}\right)^2 \left(\frac{\omega\tau}{1+(\omega\tau)^2}\right)$$

- aLIGO uses thermoelastic cancellation to meet 10Hz requirement
- For cold silica, thermoelastic dominates <240K
- A negative α means cancellation is not possible <160K
- Challenges also with jointing materials with different CTE=>induced stress

Silicon Suspensions

- Baseline for ET
- Model assumes radiative cooling to a thermal shield at 80K (no radiative cooling for temperatures <80K)





Silicon Suspensions

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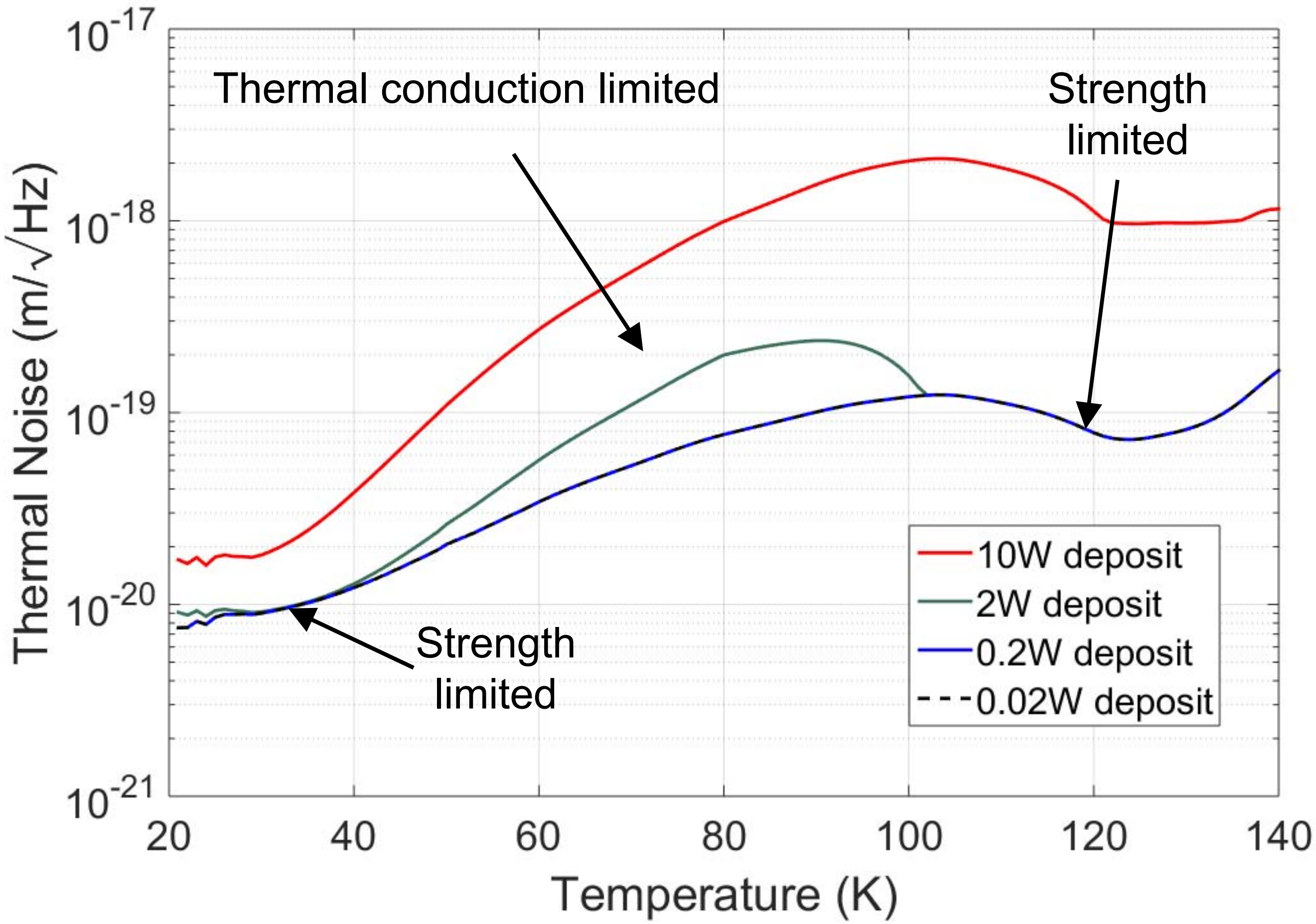
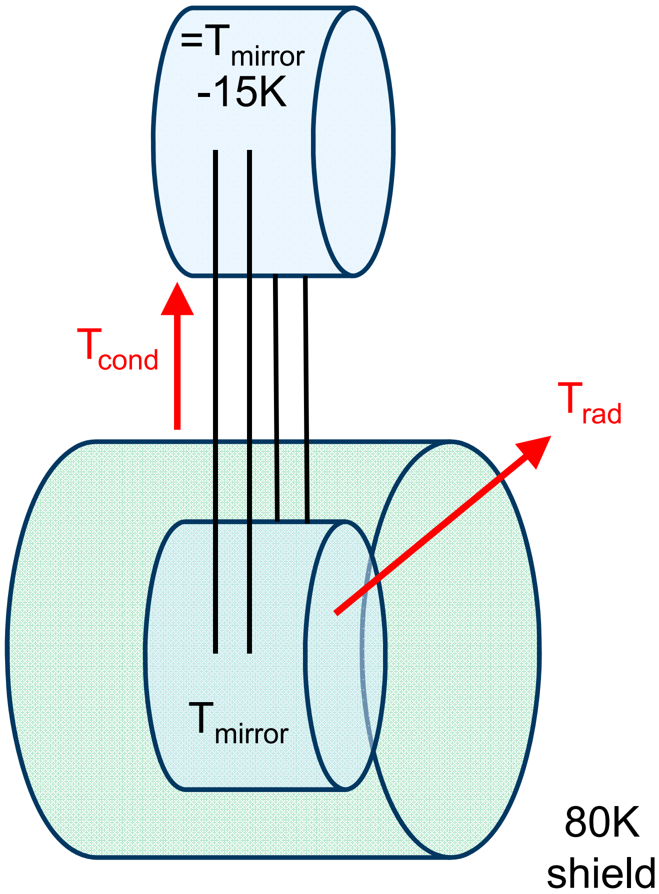
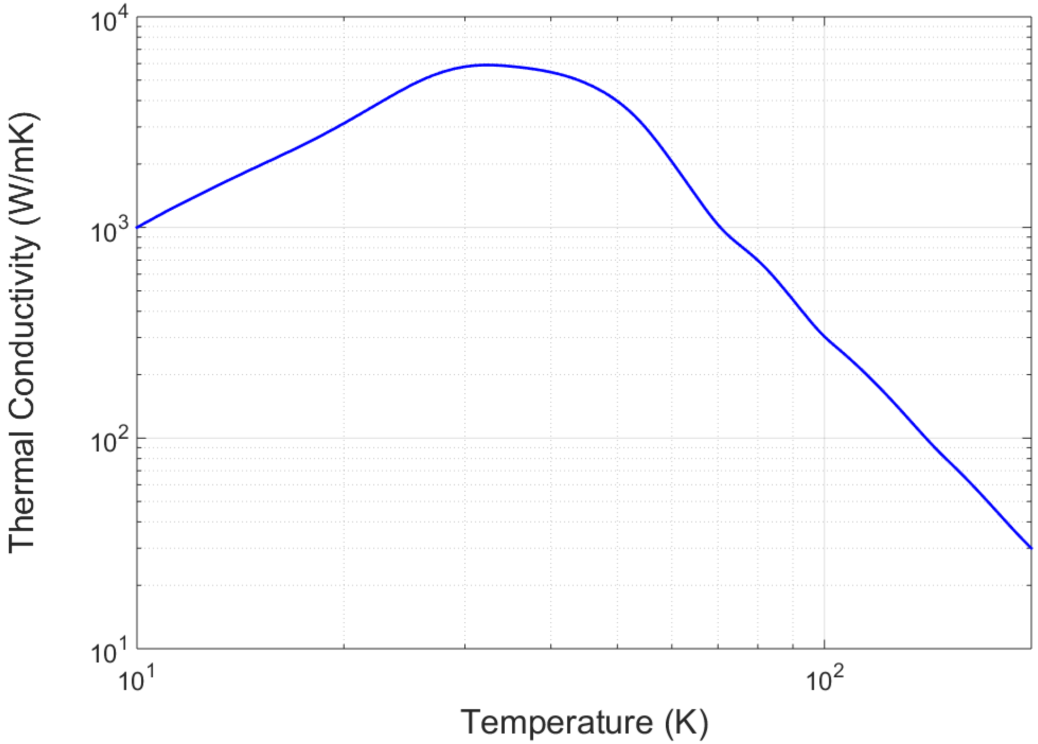


- m=120kg
- Circular fibres
- L=0.6m
- Tpen=Tmirr-15K
- Tshield=80K
- stress=70MPa
- fvertical=40Hz
- fviolin=140Hz
- $\phi_{surf}=7\times10^{-13}$

Sapphire Suspensions

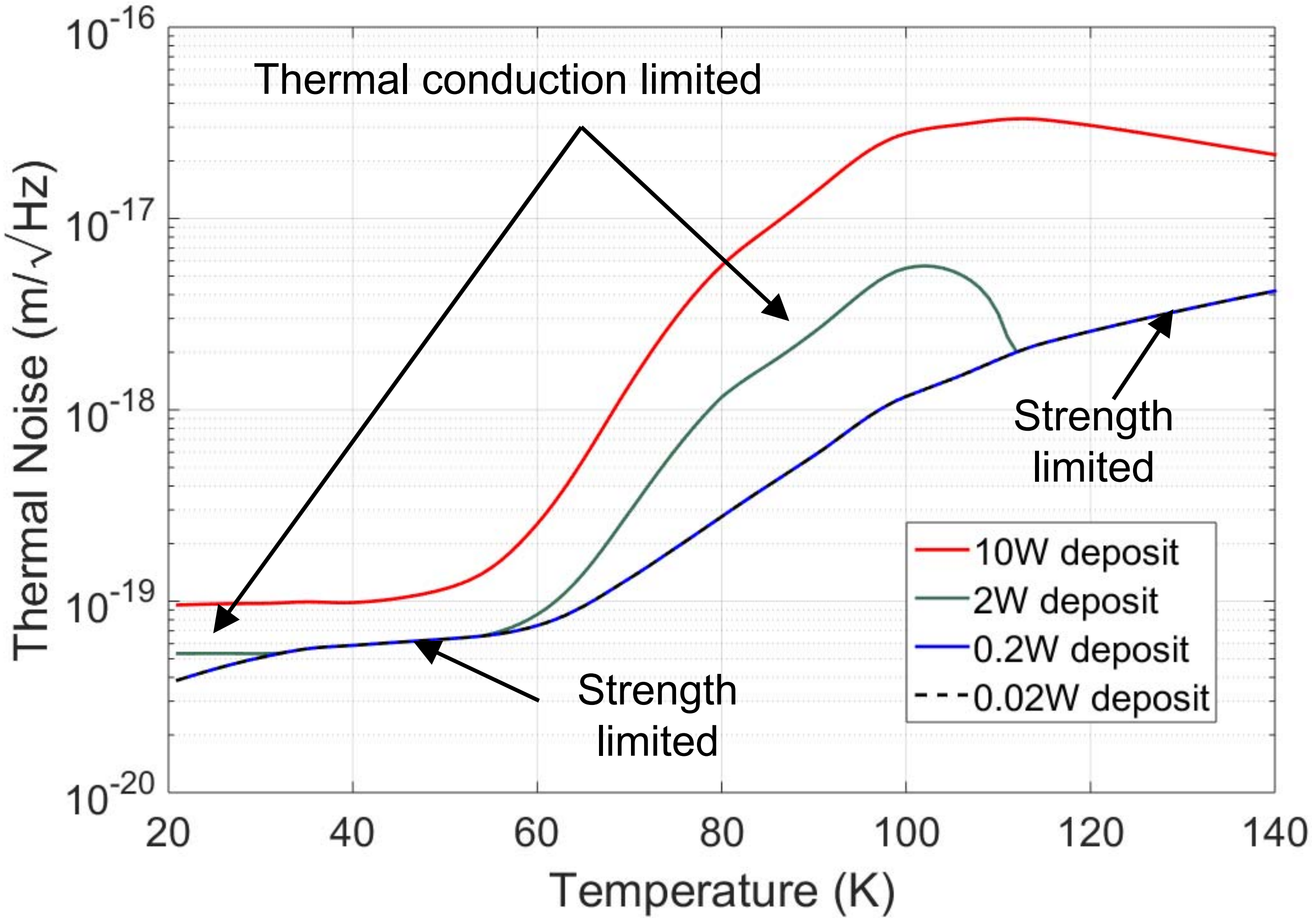
- Baseline for KAGRA
- Model assumes radiative cooling to a thermal shield at 80K (no radiative cooling for temperatures <80K)





Sapphire Suspensions

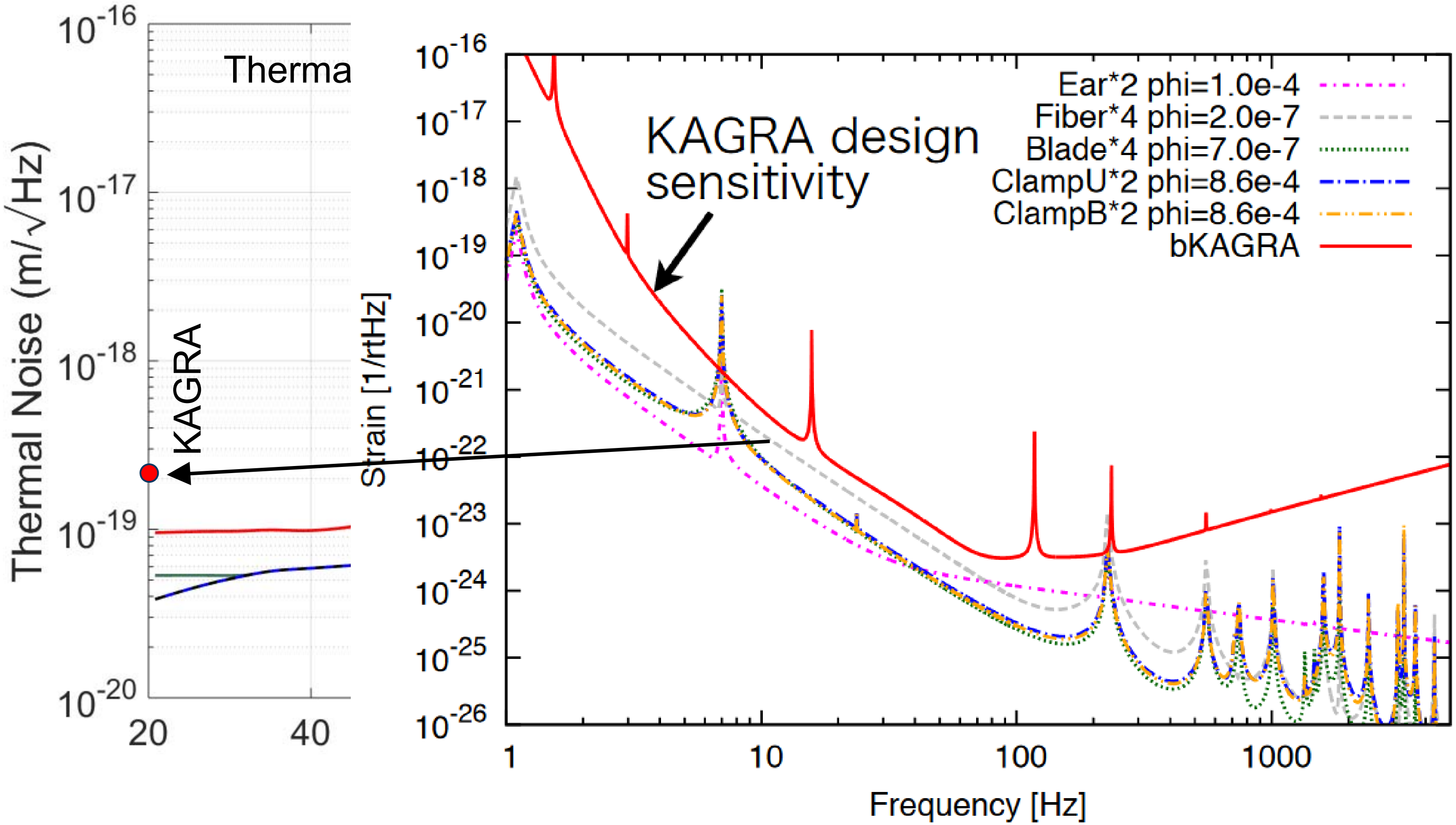
- Baseline for KAGRA
- Model assumes radiative cooling to a thermal shield at 80K (no radiative cooling for temperatures <80K)



- m=120kg
- Circular fibres
- L=0.6m
- Tpen=Tmirr-15K
- Tshield=80K
- stress=70MPa
- fvertical=75Hz
- fviolin=105Hz
- $\phi_{surf}=1\times10^{-11}$

Sapphire Suspensions

- Baseline for KAGRA
- Model assumes radiative cooling to a thermal shield at 80K (no radiative cooling for temperatures <80K)



Summary

- Hybrid suspensions:
  - no significant performance gain
  - challenges with thermal gradients, jointing
- Silicon suspensions
  - Above 105K, radiative cooling ensures high powers can be supported
  - Best performance at 20K
  - At 120K, surface loss limits the performance
  - Vertical bounce mode and violin modes are close together (40Hz and 140Hz)
- Sapphire suspensions:
  - Above 118K, radiative cooling ensures high powers can be supported
  - Good performance at 20K/120K, not quite as good as silicon
  - Vertical bounce mode and violin modes are close together (75Hz and 105Hz)
  - Sapphire fibres are easier to fabricate