Selective Cooling for advanced detectors

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Braginsky's idea to reduce susp TN

[Meas.Sci.Tech. 10 (1999)]

V B Braginsky *et al*

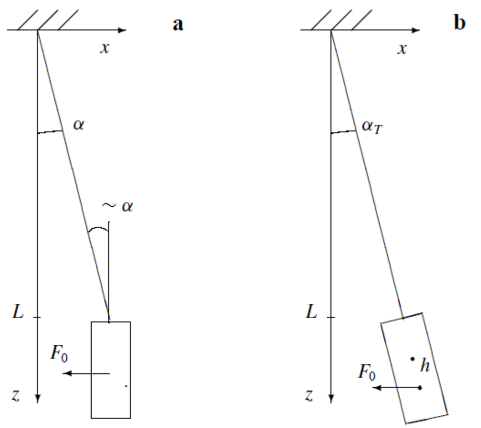
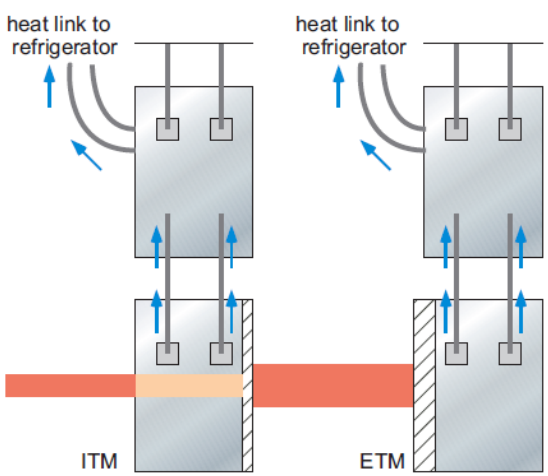


Figure 2. Motion of the test mass and the suspension fibre under the action of an oscillating force applied at the centre of the laser beam spot in two different cases: (a) the beam spot is positioned at the mirror centre, the fibre bends equally at the top and the bottom; (b) the position of the beam spot is shifted down from the centre of the mirror so that there is no bending of the fibre at the bottom.

- Shift the beam from the center
- No fiber bend at the bottom
- Susp TN is reduced by sqrt[2]



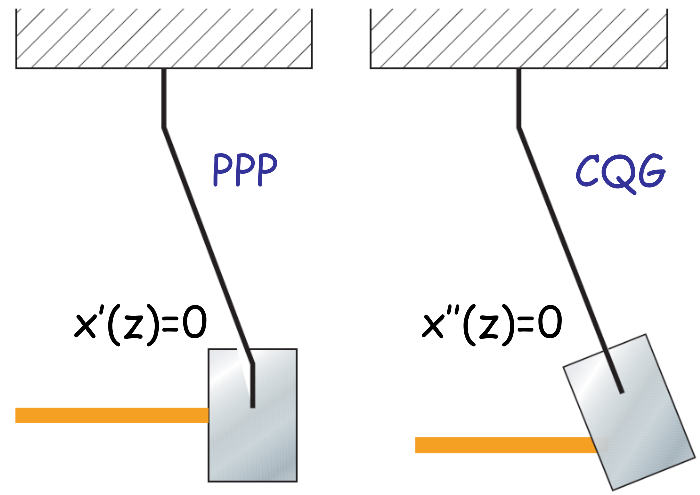
Reduction is more than sqrt[2] for a cryogenic detector as its top part is cooler than the bottom

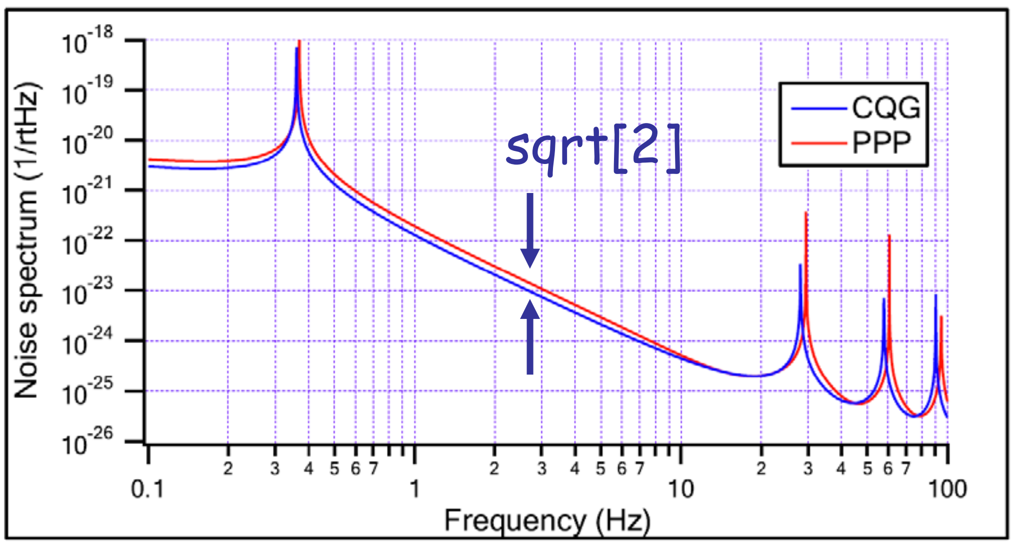
- LCGT top/bot: 10K/20K -> sqrt[3] reduction
- ET-LF top/bot: 5K/20K -> sqrt[5] reduction

Susp TN analysis in iLIGO/AdVirgo

Gonzalez CQG (2000) for iLIGO
- Braginsky's idea taken into account
- Boundary condition at bottom: x''(z)=0

PPP VIR-015E-09 (2009) for AdVirgo
- Braginsky's idea is not used
- Boundary condition at bottom: x'(z)=0

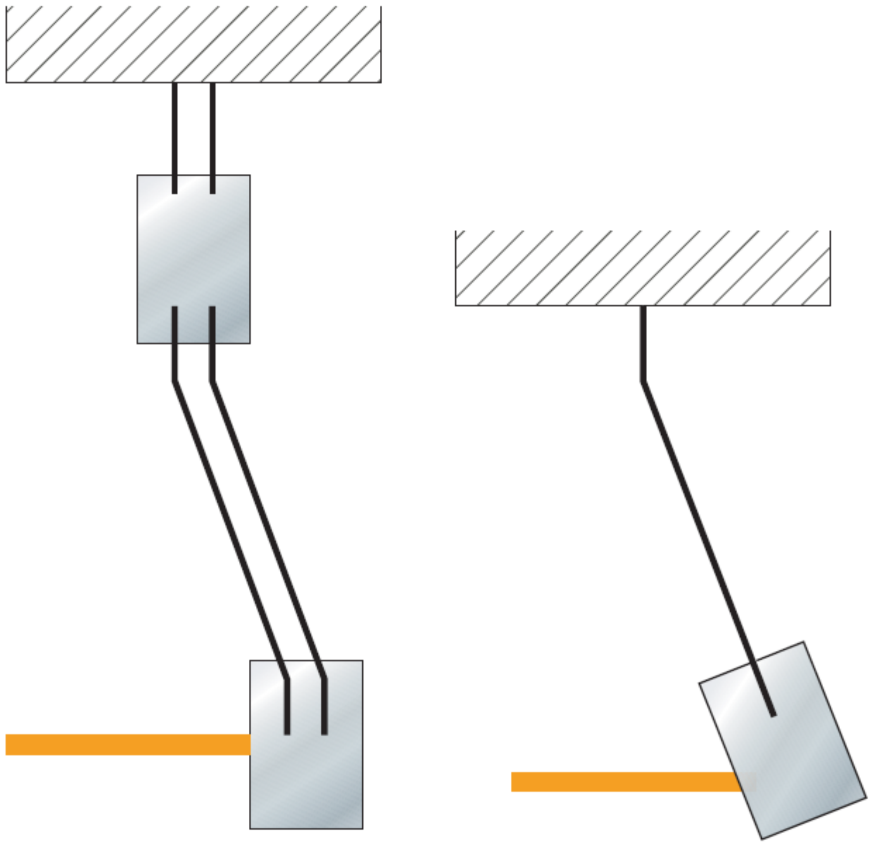




With a same parameter set, the floor levels are different by sqrt[2].

Difference for dissipation at the bottom!!

Single-loop vs double-loop



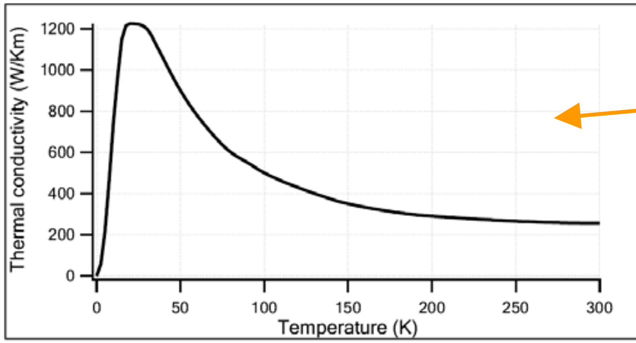
iLIGO: single pendulum
= single loop

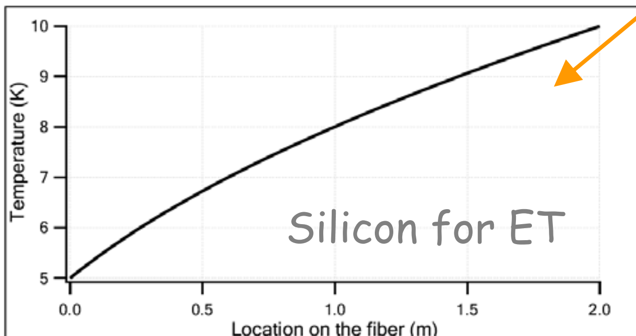
AdVirgo: multiple pendulum
-> double loop

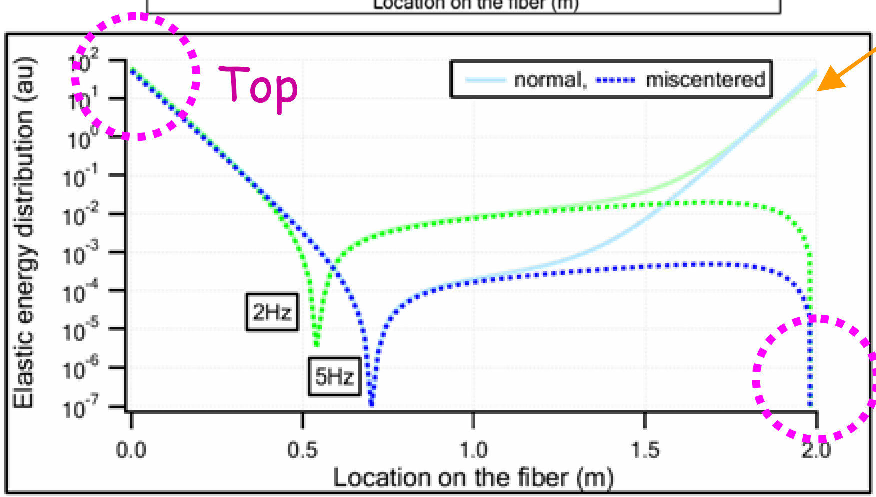
Braginsky's idea is good only with a single-loop system

Let's consider a single-loop cryogenic suspension.

Braginsky's idea in cryogenic suspensions







1. Thermal conductivity vs T
2. Temperature profile is given
3. Apply imaginary force on test mass (mis-centered)
4. Dissipation profile is given
5. TN spectrum is given

No dissipation at bottom

Selective-cooling Applications

(1) LCGT or ET-LF

~ 30-45% TN reduction

(2) LIGO2.5 with cooled suspension & 290K mirrors

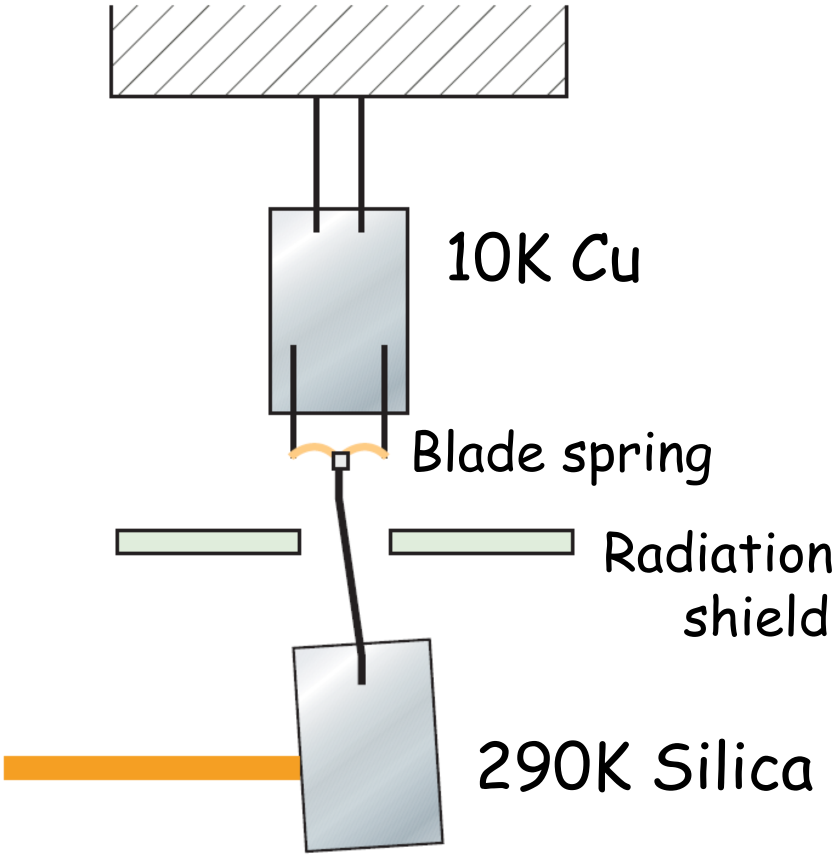
~ high-power operation + good coatings

(3) ET-HF with 120K Silicon

~ high-power operation without heat problems

But there are some issues…

Selective cooling for LIGO 2.5?

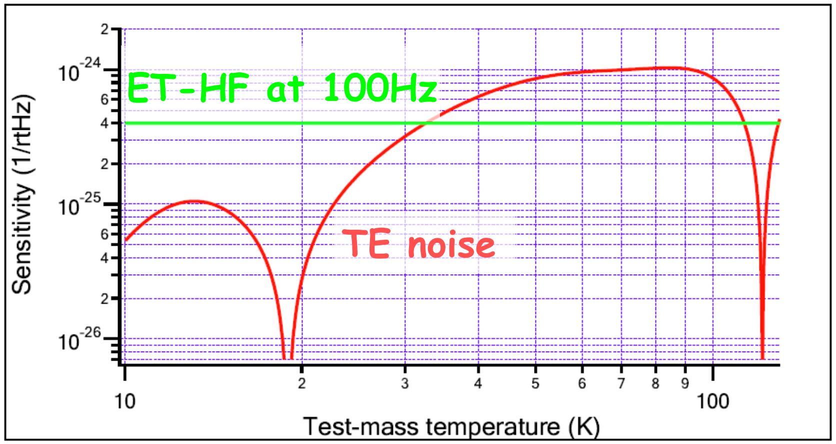


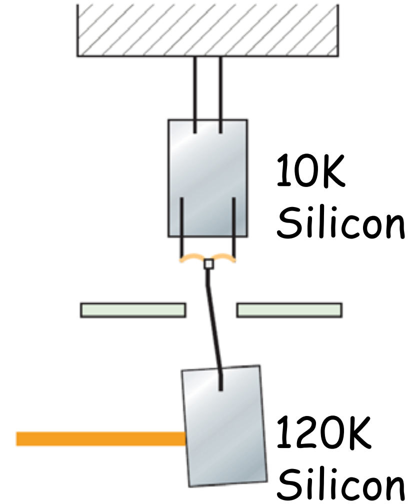
- 290K Silica TM
  - -> Good coatings
- 10K IM
  - -> Low susp TN (top)
- Mis-centered beam
  - -> Low susp TN (bottom)

Issues

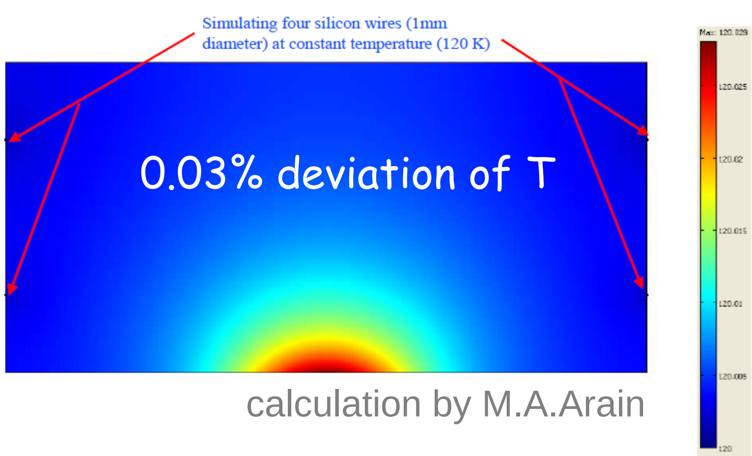
- low-loss fiber at 10-290K?
  - -> Silica + Silicon? Alloy?
- vertical-mode TN
  - -> Blade spring on top? VSPI?

Selective cooling for ET?





- 120K Silicon TM
  -> No TE noise
- No thermal lensing
- No need of thick fiber
- Low suspension TE noise

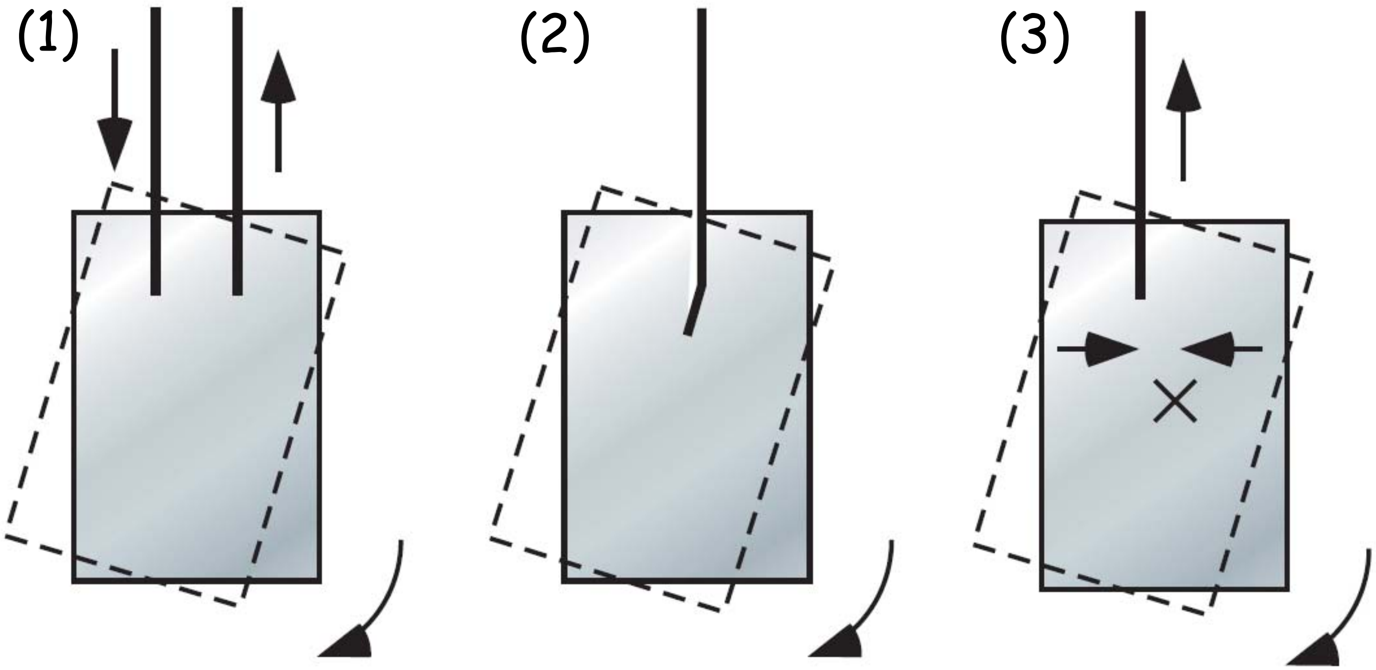


calculation by M.A.Arain

Issues

- Temperature control
- Vertical-mode TE noise

Vertical/pitch TN



Differential vertical TN
-> couple to pitch
-> length

Bend at bottom
-> couple to pitch
-> length

Vertical TN
-> couple to pitch
-> length

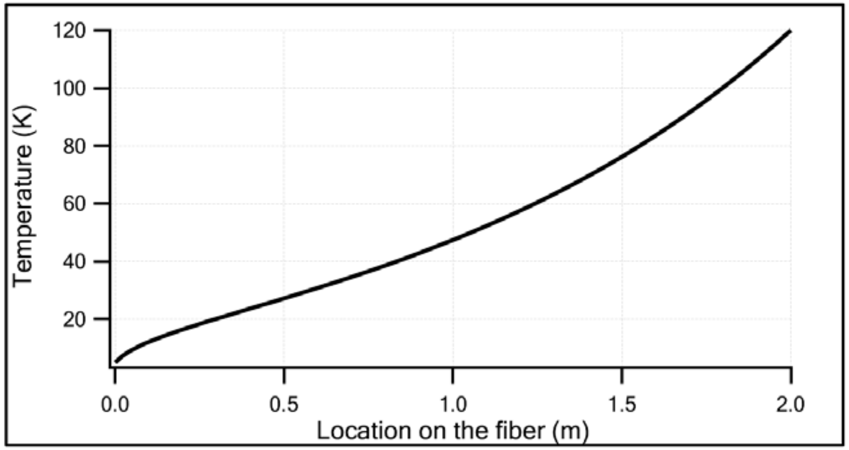
(1) doesn't exist for single loop

(2) can be removed by Braginsky's idea

(3) is challenging

Summary

- Braginsky's TN reduction idea is more effective in a cryogenic detector
- Suspension TN comes from dissipation due to the bend at the top/bottom of fiber
- Low-T at top and no-bend at bottom
- Application to LIGO2.5: cold IM + 290K TM
- Application to ET: high-power, low-T detector
- Many issues: fiber material, vertical TN



Temperature profile of 10-120K 2m fiber