120K a derisking approach for the 1st Einstein Telescope Generation.

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General Idea/Context

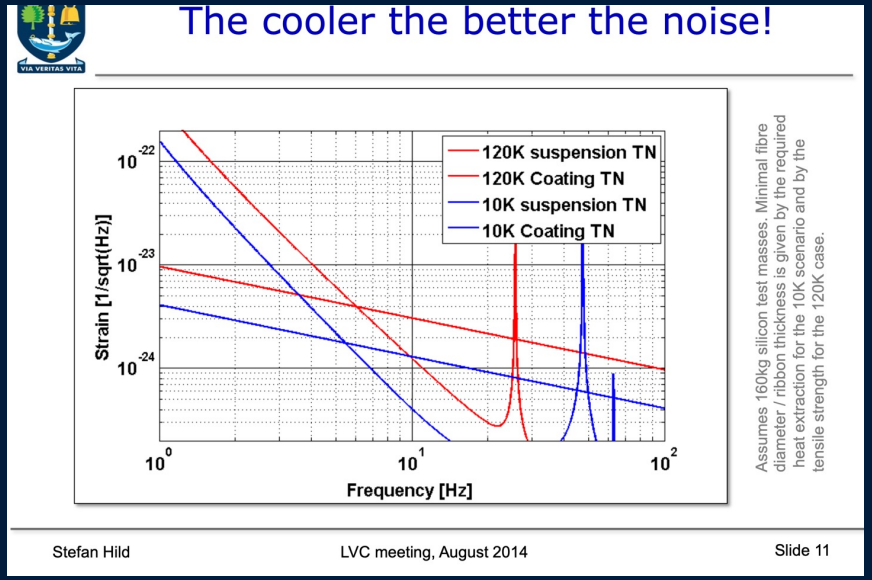
- Einstein Telescope LF baseline temperatur is 10-20K

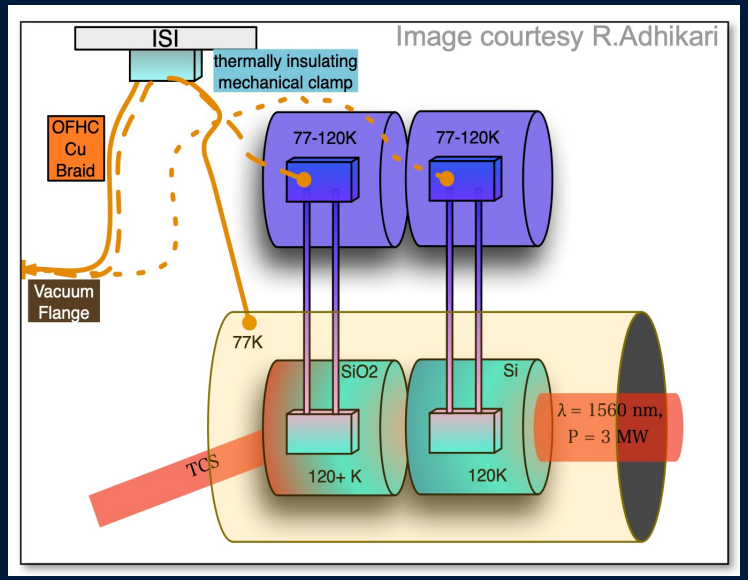
- So far nobody has ‘demonstrated’ low noise operation at this temperature in an ET-like environment.
  - Candidates: Soprtion cooler (ETpathfinder), superfluid He-II (KIT), pulsetubes (Rome/Kagra), radiative cooling with larger couplers (E-TEST).
  - Not clear at which point we have to fix the design, but what if all of the above solutions are demonstrated too late?

- Our planning anyway includes to run also the 1550nm arm at 120K initially as a stepping stone for us. => I wonder whether should make this more conscious and define this a major Etpathfinder Science Goal to show 120K operation as a deresiking of the initial ET-LF detectors?

120K Operation

- Stefan Boltzmann Law: $P = \varepsilon\sigma A(T_{mirror} - T_{shield})\text{^}4$





Etpathfinder Noise budget

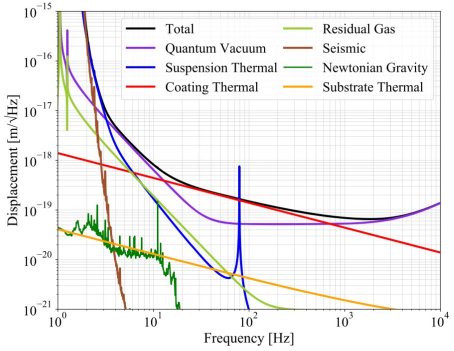


Figure 2. Projection of displacement sensitivity for the ETpathfinder operating at 1550 nm laser light and 18 K (a) and at 2090 nm and radiatively cooled down at 123 K (b).

Table A1. Summary of the most important parameters for both ETpathfinder interferometers at two different temperatures. Both interferometers have a similar baseline of 9.2 m and their seismic isolation system is similar with last stage suspension fibres length of 0.4 m.

Parameter	ETpathfinder-light	ETpathfinder-A	ETpathfinder-B
Temperature (K)	123	18	123
Wavelength (nm)	1550	1550	2090
Arm-cavity finesse	2050	2050	2050
Test mass weight (kg)	3.2	3.2	3.2
Beam waist (m)	1.8×10^{-3}	1.8×10^{-3}	2.1×10^{-3}
Beam radius at test mass (m)	2.2×10^{-3}	2.2×10^{-3}	2.5×10^{-3}
Substrate Young modulus (Pa)	155.8×10^{9}	162.0×10^{9}	155.8×10^{9}
Substrate thermal conductivity (W m^{-1} K^{-1}))	700	3000	700
Thermal expansion coefficient (1/K)	1×10^{-9}	1×10^{-9}	1×10^{-9}
Substrate specific heat (J kg^{-1} K^{-1}))	333.0	3.5	333.0
Thermo-optic coefficient	1×10^{-4}	1×10^{-6}	1×10^{-4}
Substrate loss angle	1.25×10^{-9}	1.25×10^{-9}	1.25×10^{-9}
Last stage suspension material	Copper beryllium	Silicon	Silicon
Last stage suspension fibres diameter (m)	1.5×10^{-4}	7.0×10^{-4}	7.0×10^{-4}
Coating $\phi_{\text{high-n}}$	5.7×10^{-4}	5.6×10^{-4}	5.7×10^{-4}
Coating $\phi_{\text{low-n}}$	4.8×10^{-4}	9.2×10^{-4}	4.8×10^{-4}

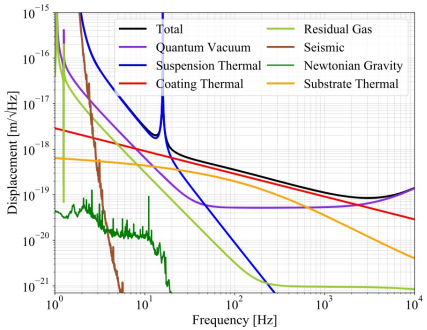


Figure B1. Projection of displacement sensitivity for the initial phase of ETpathfinder.