# Noise budget

# VS

# Wavelength

Observatory design & Noise budget working package

ET wavelength workshop

2021.09.03

# Wavelength impact

Direct:

Quantum noise
- Shot noise $\propto \lambda$
- Radiation pressure noise $\propto 1/\lambda$
- Optical losses

Indirect:

Substrate material
- Substrate Brownian noise
- Substrate Thermoelastic noise

Coating material

Residual gas noise: Cavity Geometry

# Quantum noise

Assumption:

- Arm power 18kW for three cases.
- Test mass 200kg for three cases.
- 15dB injection Squeezing for three cases.
- 10km long filter cavity for three cases.
- Optical losses:

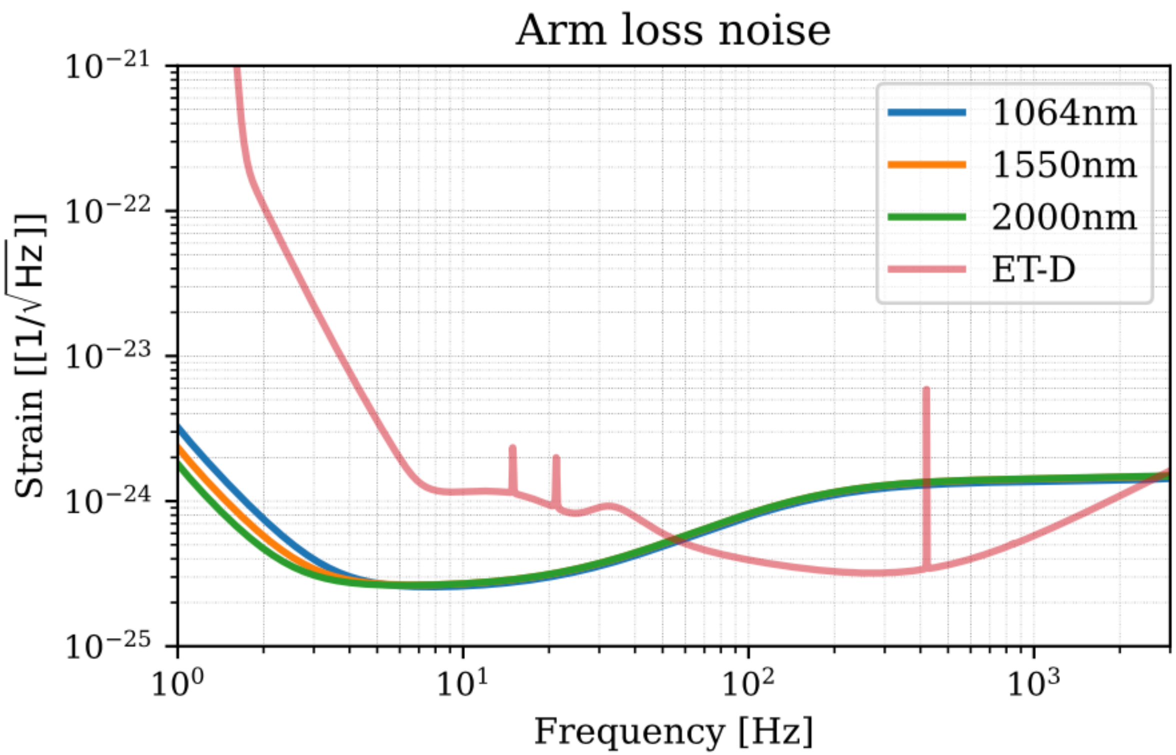
| | Arm m L | Filter Cav RT L | PD E |
|---|---|---|---|
| 1064nm | 37.5ppm | 150ppm | 0.97 |
| 1550nm | 18+10ppm | 75ppm | 0.97 |
| 2000nm | 10+10ppm | 47ppm | 0.92 |

Light scattering

$$\mathcal{L} = \left(\frac{4\pi\sigma}{\lambda}\right)^2$$

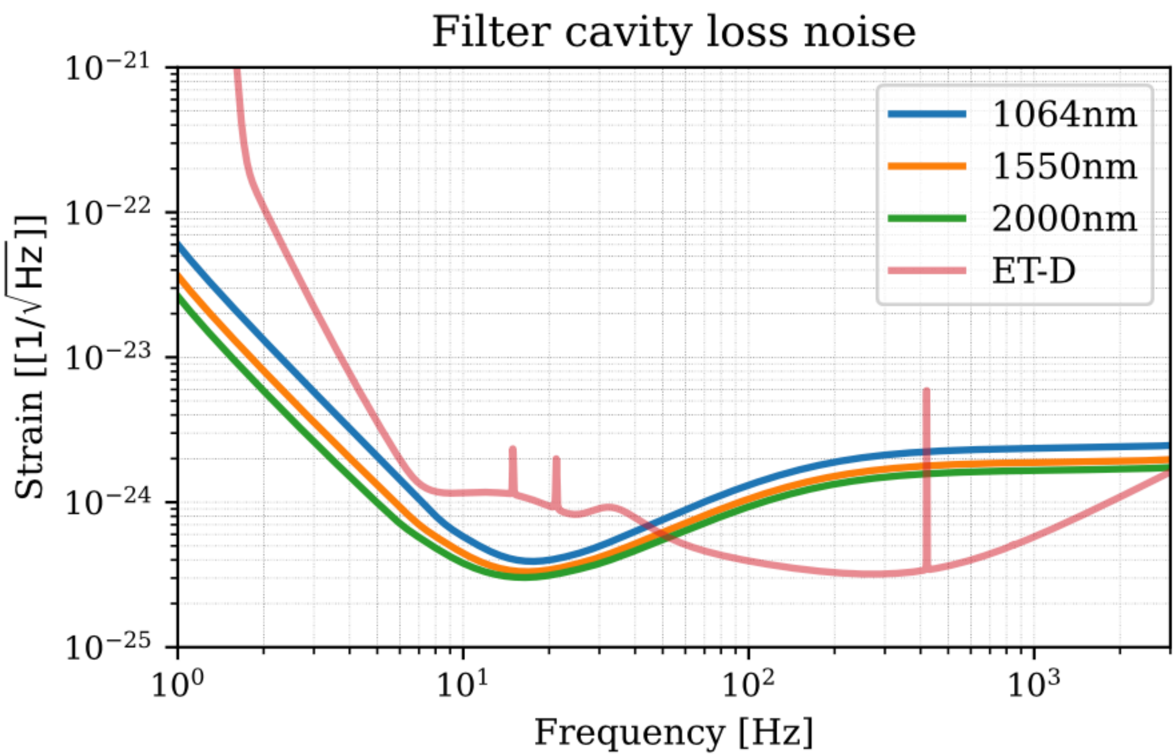
10 ppm loss is added as a margin for losses from absorption, clipping, etc.

# Quantum noise



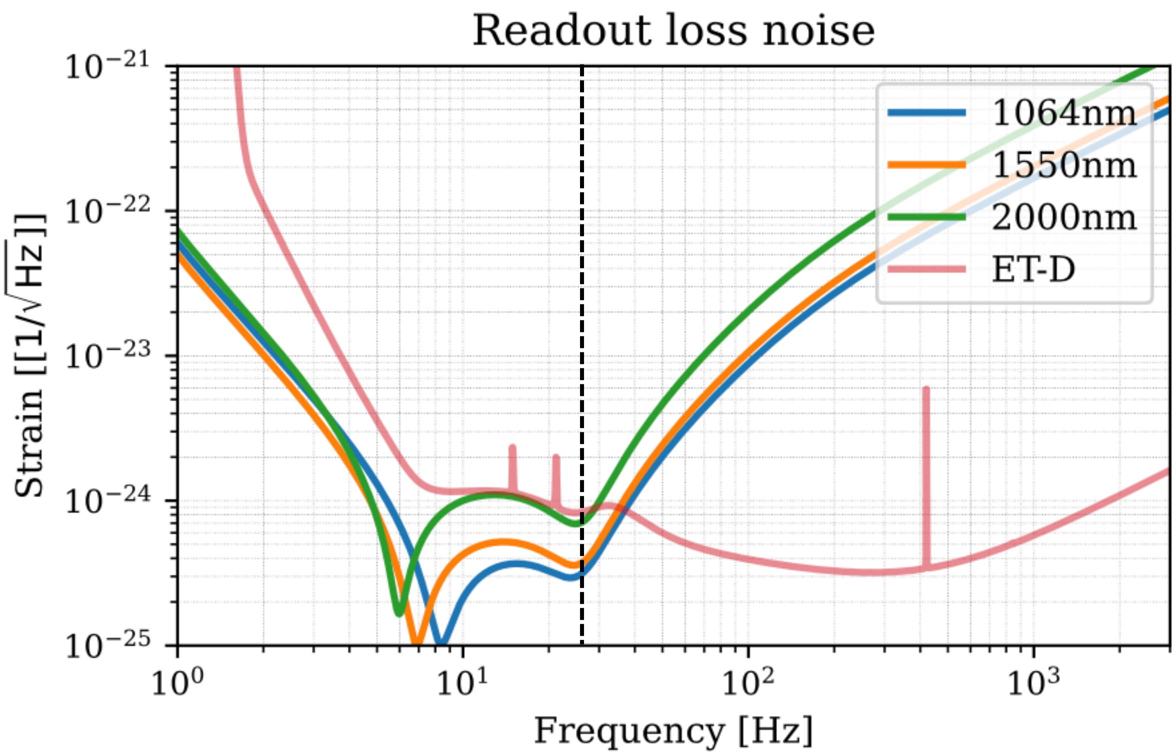

The overlap of high frequency shot noise comes from the compensation between loss coefficient and scaling $1/\lambda$.

# Quantum noise



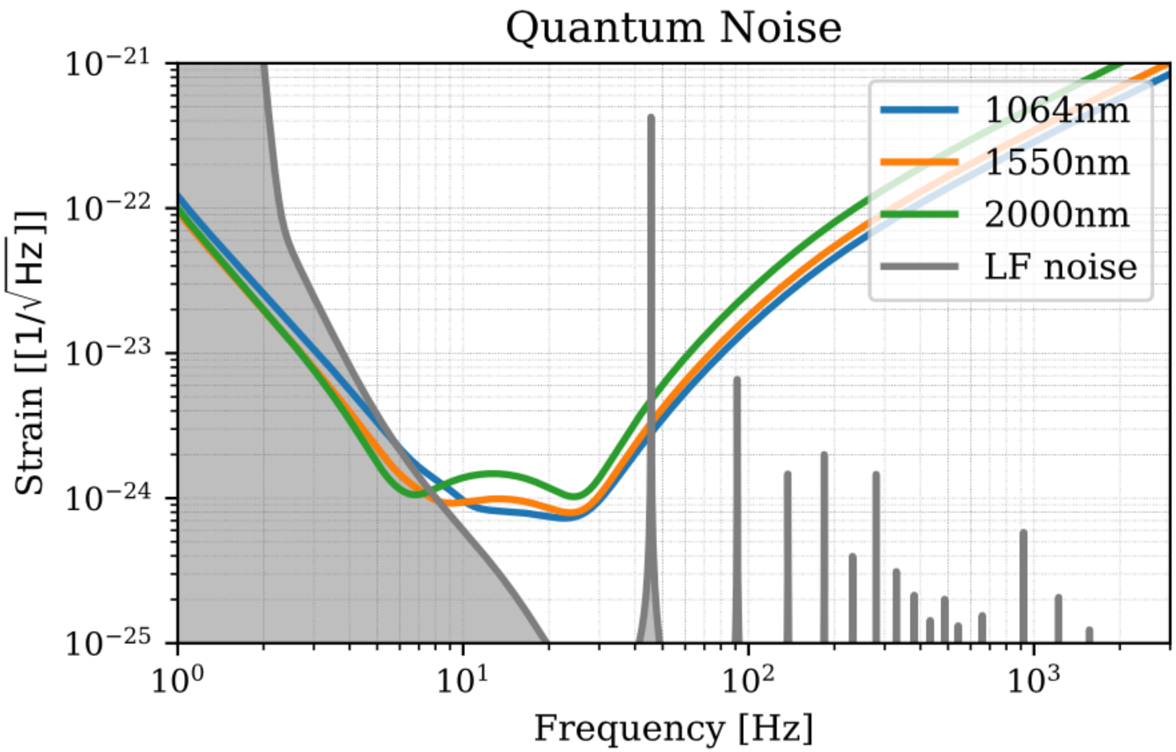

Long wavelength gives lower loss.

# Quantum noise




The SRC is detuned to give identical optical resonant frequency. 92% PD efficiency is assumed for 2000nm.

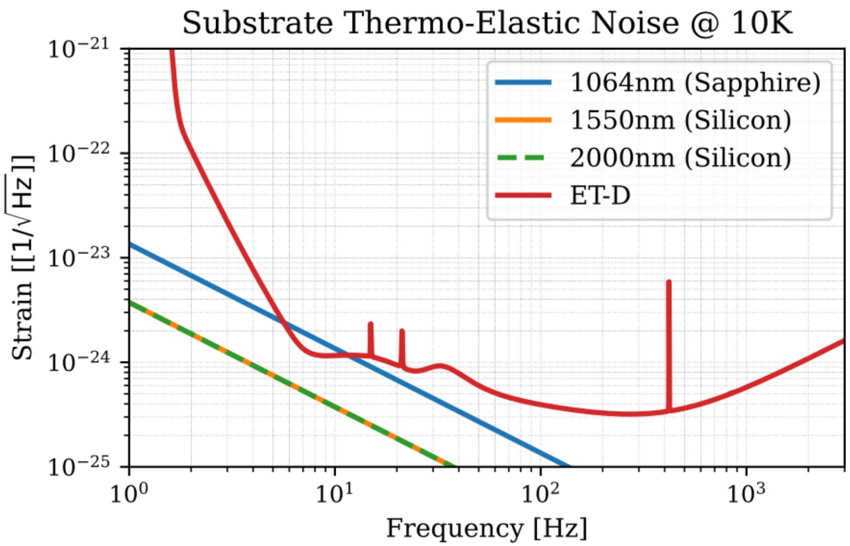
# Quantum noise

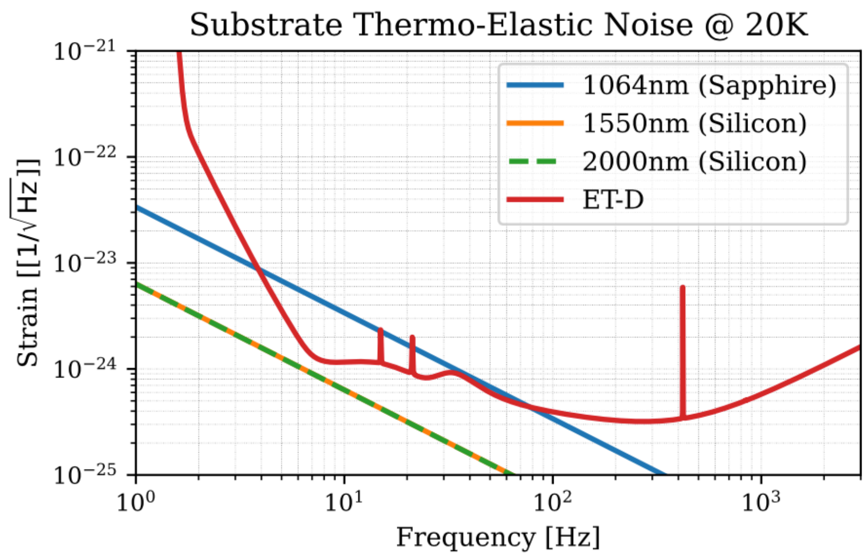



The sum of seismic, Newtonian and suspension thermal noise@10K is set to be the low frequency barrier.

# Substrate Thermoelastic noise

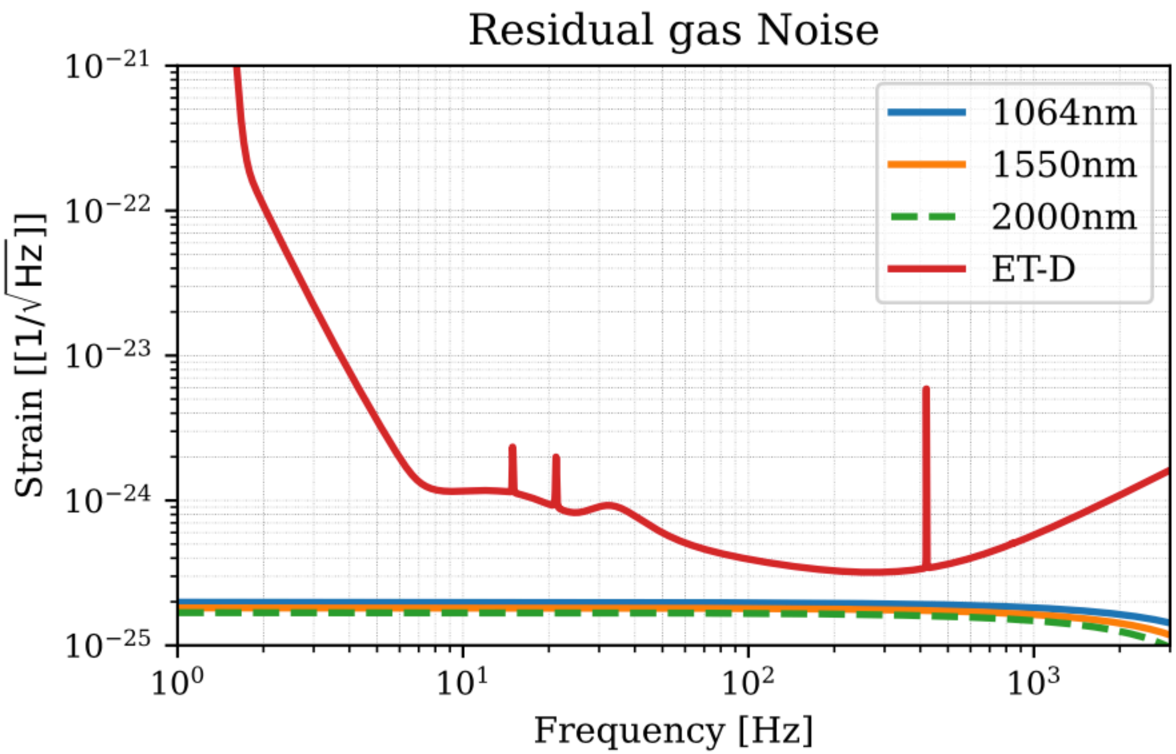
$$S_{TE}^{s} = \frac{4k_b T^2 \alpha_s^2 (1+\sigma_s)^2 \kappa_s}{\pi^{5/2} (C_s \rho_s)^2 w^3 f^2}$$




| | Silicon (10K) | Silicon (20K) | Sapphire (10K) | Sapphire (20K) | Silica (300K) |
|---|---|---|---|---|---|
| $K_s$(W/m/K) | 1000 | 3000 | 2900 | 4300 | 1.38 |
| $\alpha_s$(1/K) | 4.8e-10 | 2.9e-9 | 5.3e-10 | 4.6e-9 | 3.8e-7 |
| $C_s$(J/kg/K) | 0.276 | 3.41 | 0.085 | 0.72 | 739 |

# Residual gas noise




Assumption:

- 5e-7Pa hydrogen
- the same beam size on test masses (different cavity g factor)

# To be revised and solved:

1. Revising substrate material parameters.
2. Coating solutions.
3. Revising optical losses
4. The allowable arm power considering different optical absorption from coating and substrate.
5. Optimizing SRC detuning for different wavelength.