Karlsruhe Institute of Technology

He-II Cooling: Possibilities for ET

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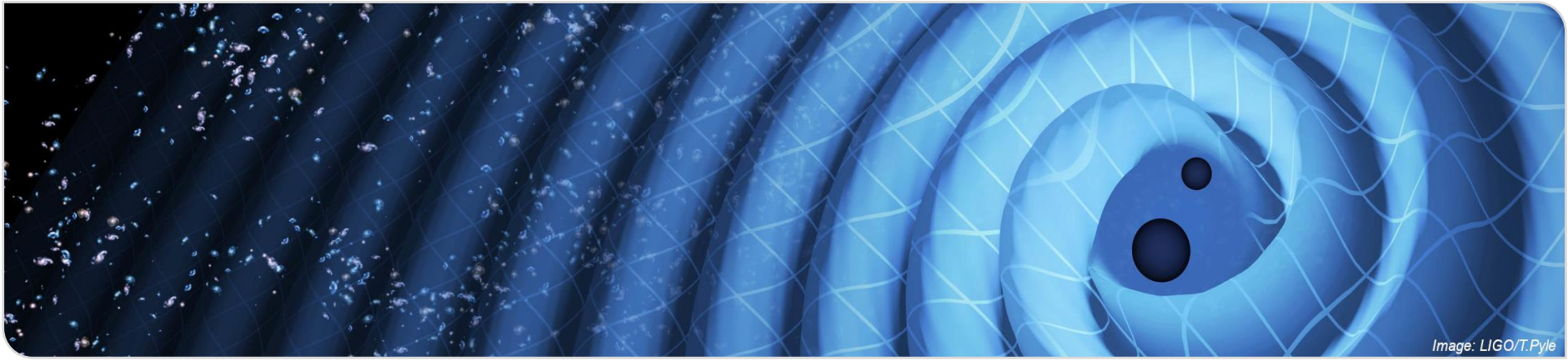


ET-LF Noise Budget

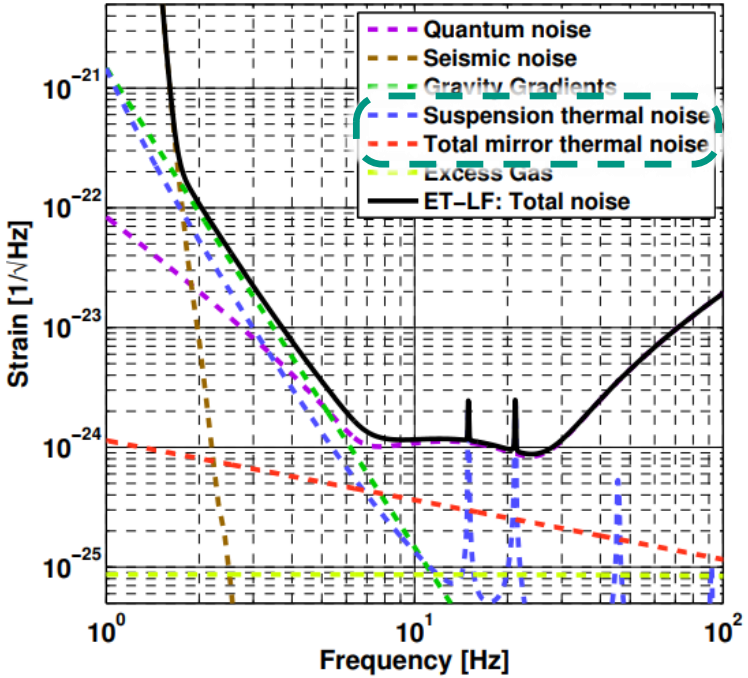
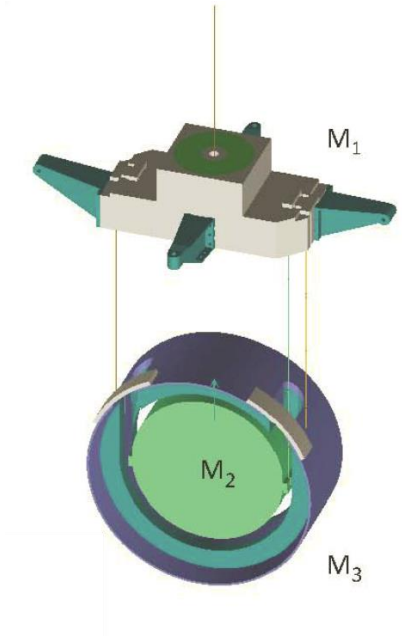


Figure: ET Conceptual Design Study (2011)

Two <u>thermal noise</u> contributors:

- Suspensions
- Mirrors

ET-LF Payload



M_1: Marionette

M_2: Test Mass

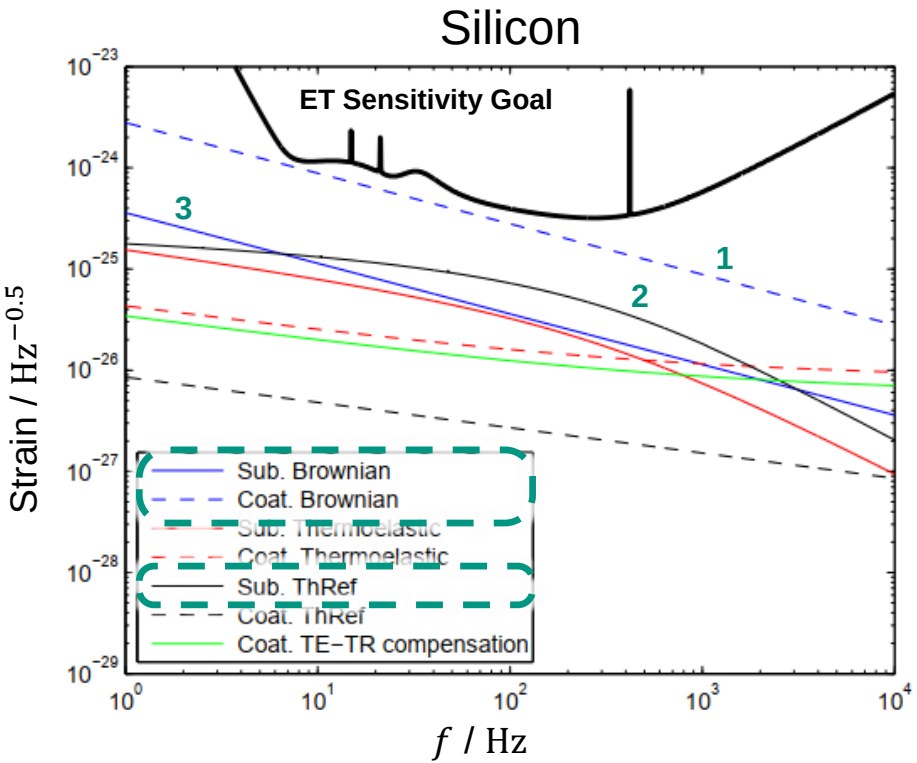
M_3: Reaction Mass

Figure: VIRGO-like suspension (payload), ET Design Report Update (2020)

- **Suspension Thermal Noise**
  - Marionette
  - Suspension Fibers
  - Reaction Mass
  - Test Mass

  } Pendulum
- **Mirror Thermal Noise**
  - Test Mass

Mirror Thermal Noise at 10 K



Major Contributions:

- Coating Brownian
- Substrate Thermo-Refractive
- Substrate Brownian

Figure: ET Conceptual Design Study (2011)

Mirror Thermal Noise Evolution

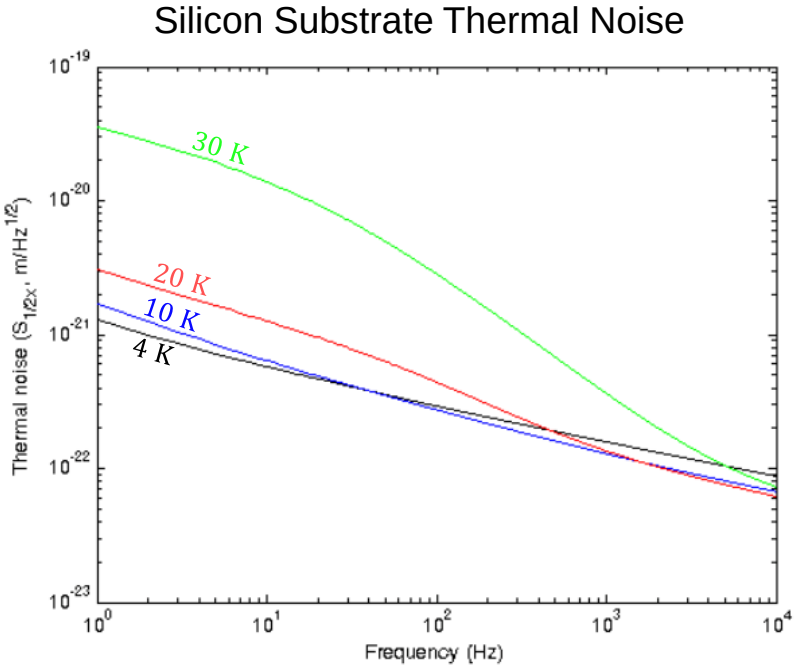
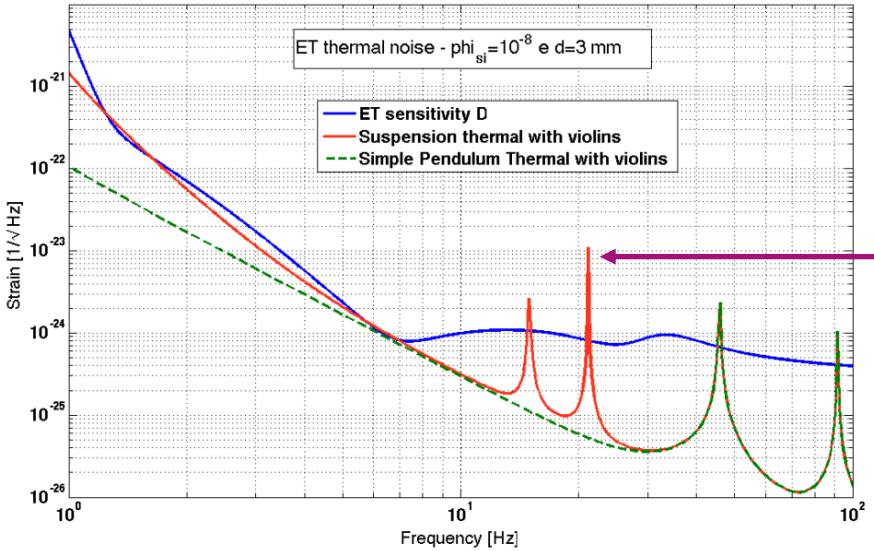


Figure: Franc et al. (2011)

Strong mirror cooling motivation in 30…10 K-range

Suspension Thermal Noise



ET Conceptual Design Study (2011)

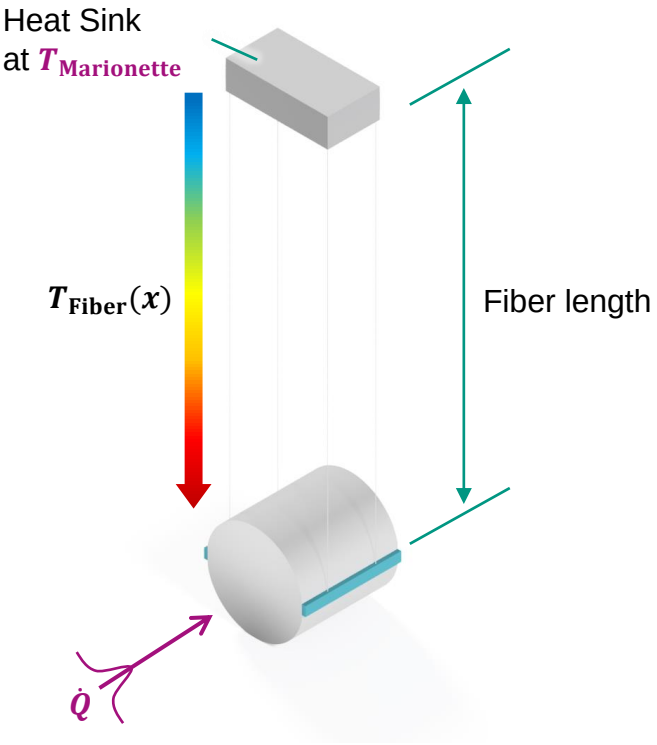
ET-LF last stage suspension design parameters:

	Marionetta	Recoil Mass	Mirror
Masses for ETDLF (kg)	422	211	211
Wire Diameter (mm)	3	3	3
Wire length (m)	2	2	2
Wire Material	Ti6Al4V	Silicon	Silicon
Loss Angle	10^{-5}	10^{-8}	10^{-8}
Temperature (K)	2	10	10

ET Conceptual Design Study (2011)

Original design implies He-II cooling!

Mirror Cooling Possibilities



Analytical Calculations

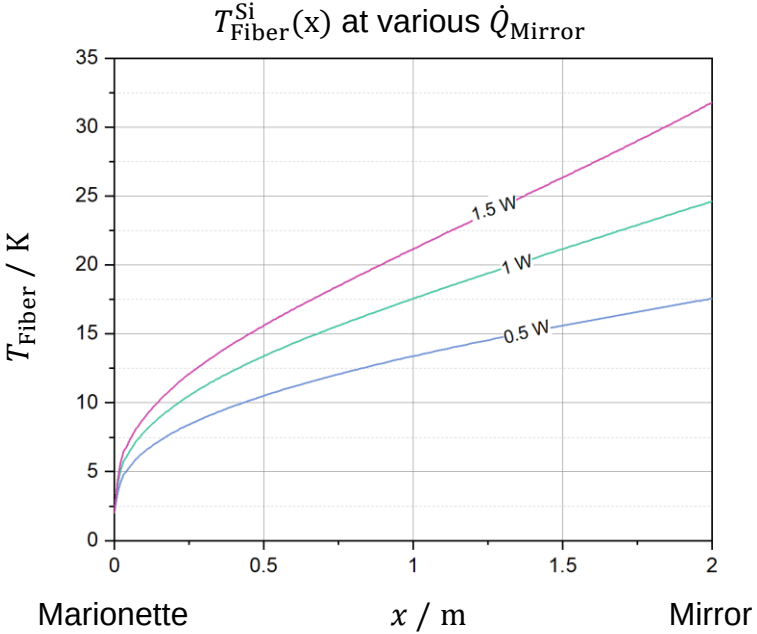
Constants:

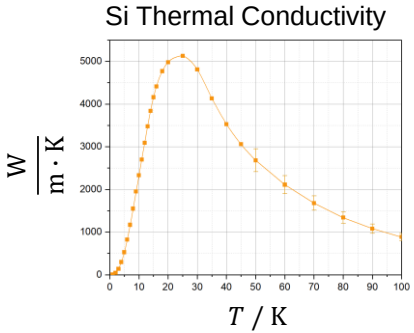
- Fibers per mirror: 4
- Material: Silicon/Sapphire with $\lambda = f(T)$
- Fiber length: $2\ \mathrm{m}$
- $d_{Fiber} = 3\ \mathrm{mm}$

Variables:

- Heat load on mirror $\dot{Q}$
- $T_{Marionette}$

Fiber Temperatures



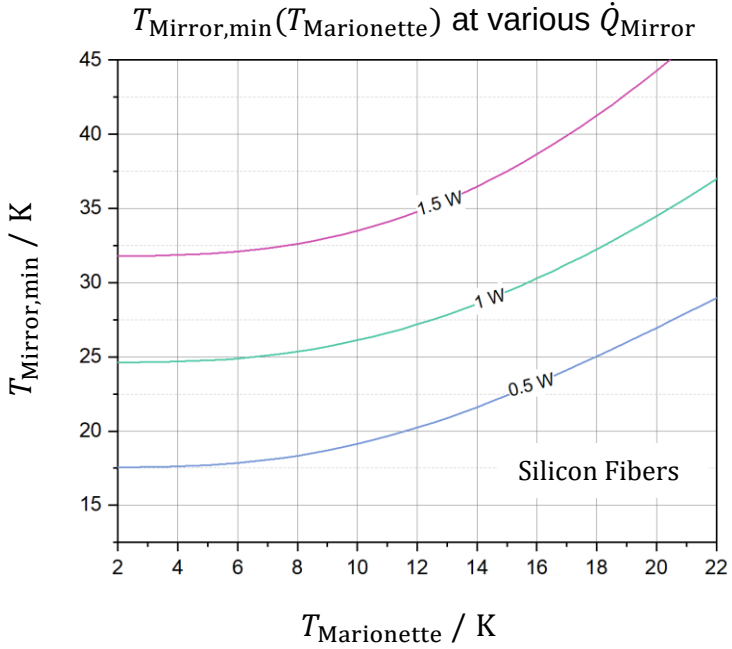


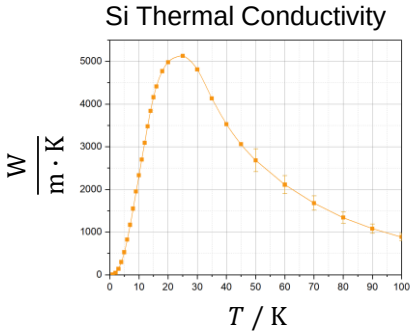
Basis: He-II Cooling

$T_{\mathrm{Marionette}} = 2\ \mathrm{K}$			
$\dot{Q}_{\mathrm{Mirror}}$ / W	0.5	1.0	1.5
$T_{\mathrm{Mirror,min}}$ / K	17.6	24.6	31.8

10 K mirror temperature not reachable

Mirror Temperature Limitation

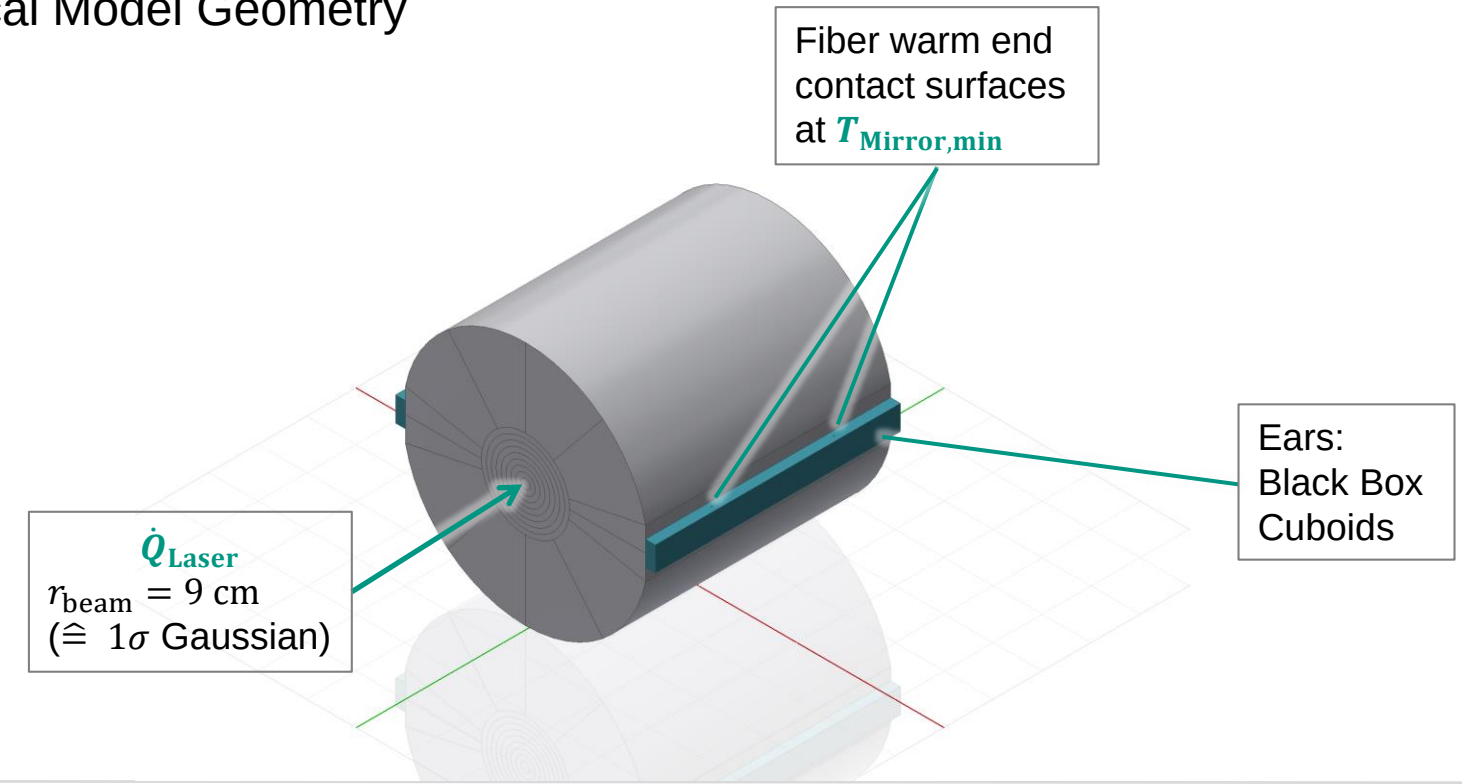




$\dot{Q}_{\mathrm{Mirror}} = 1$ W (Estimation 2020)			
$T_{\mathrm{Marionette}}$	2 K	10 K	20 K
$T_{\mathrm{Mirror,min}}$	24.6 K	26.1 K	34.5 K
Cooling Technology	He-II	Cryocoolers (?)	Cryocoolers

Mirror Temperature Distributions

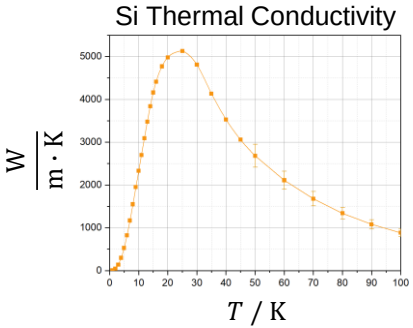
Numerical Model Geometry

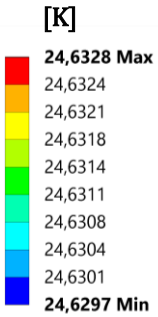


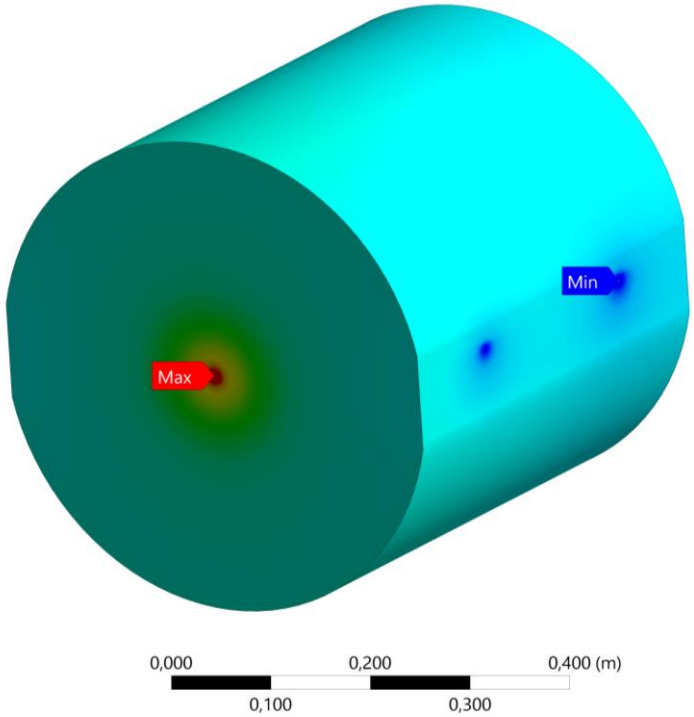
Mirror Temperature Distributions

Numerical Results

$T_{\mathrm{Marionette}} = 2\ \mathrm{K}$

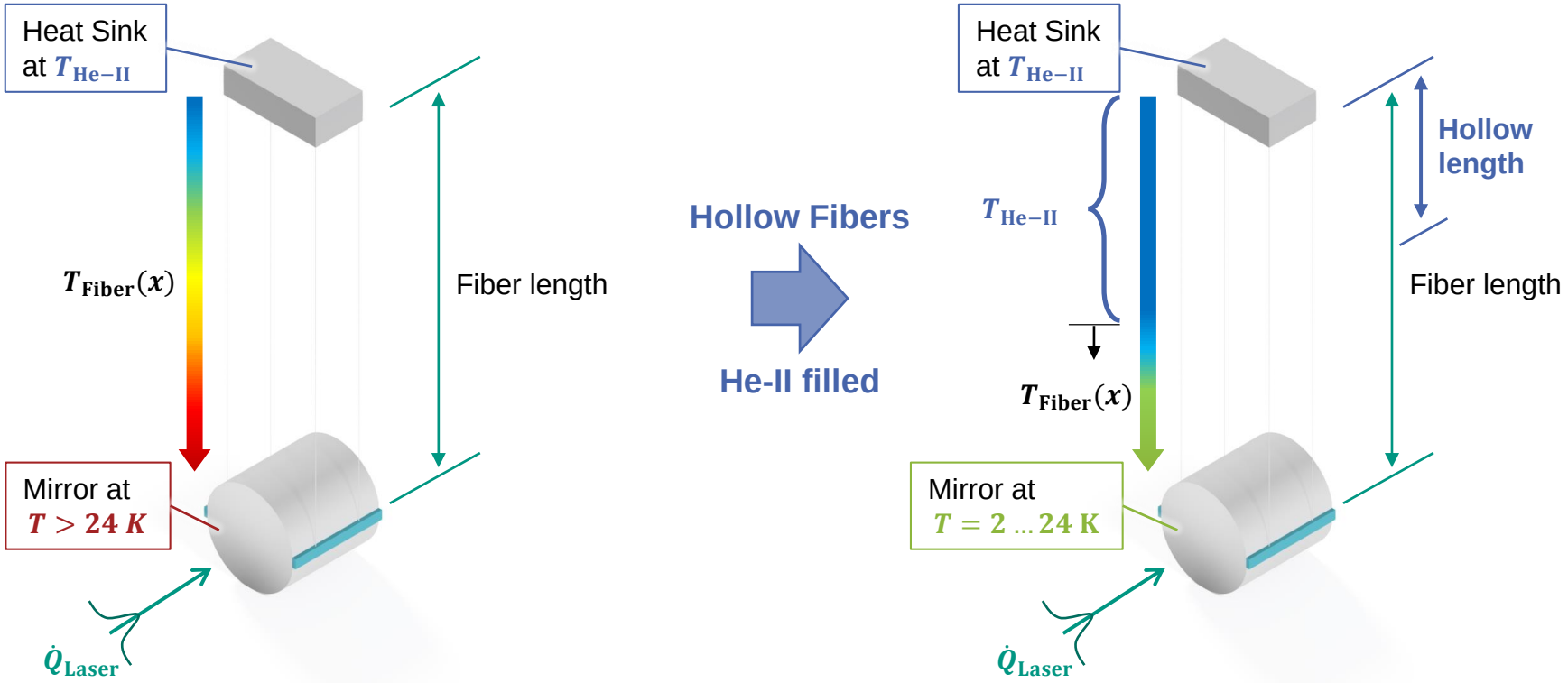




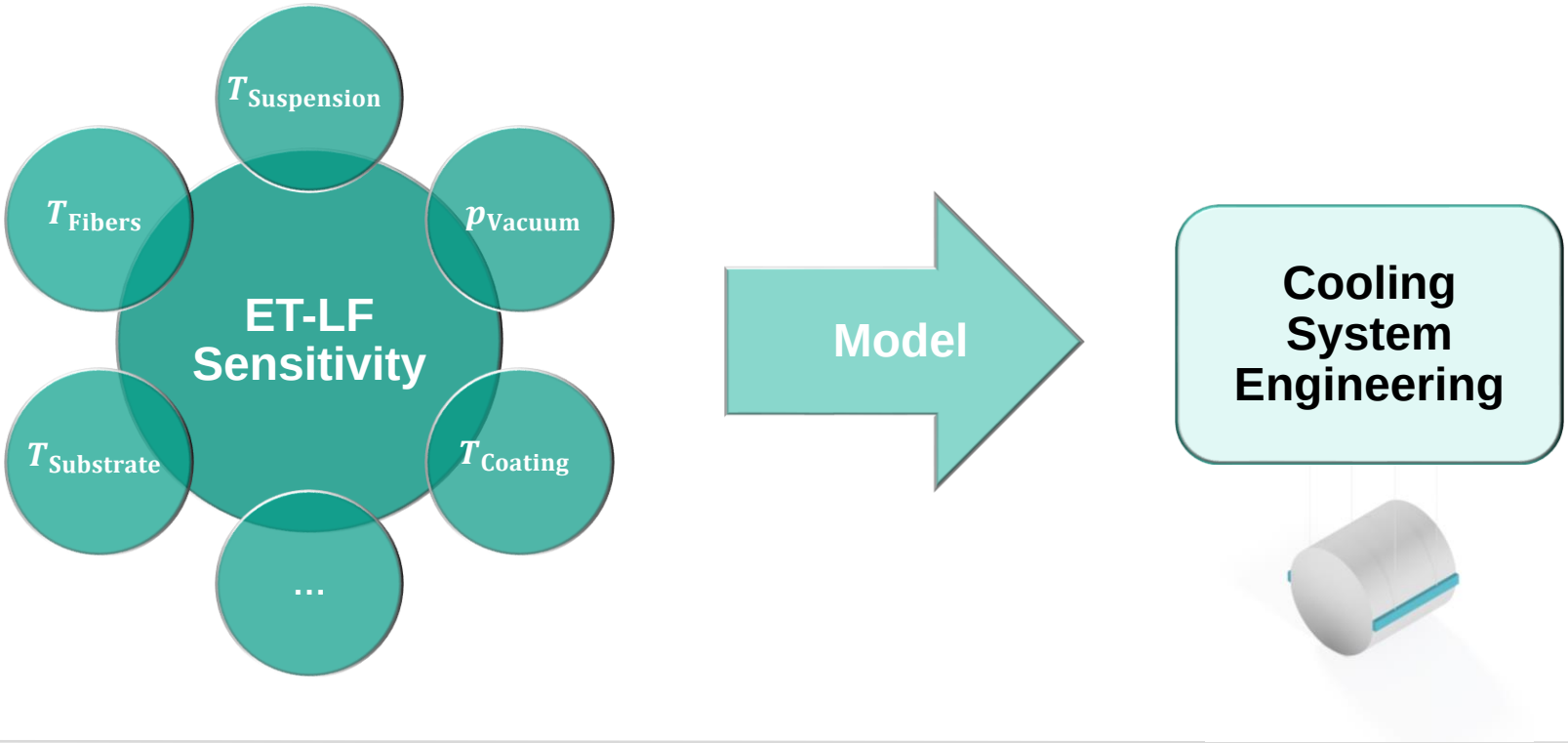


$\dot{Q}_{\mathrm{Laser}} = 1\ \mathrm{W}$ (ET Estimation 2020)			
$T_{\mathrm{Marionette}}$	2 K	10 K	20 K
$\Delta T_{\mathrm{Mirror,global}}$	3 mK	3 mK	4 mK

Mirror Cooling Possibilities below 25 K



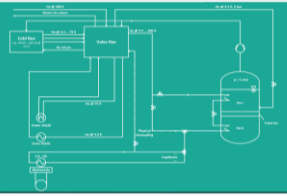
Payload Condition Influence on Sensitivity



Next Steps

Conceptual Design

- He-II cooling → Marionette



Noise Propagation Model

- Stationary He-II

Experimental Concept Development

- Ultra-low noise cooling system

Thank you for your attention!

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