Calculation of Heat Flow in KAGRA Cryogenic Payload

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LIGO-G2301682

Abstract Cooling of the all main mirrors is one of the main features of KAGRA, and conductive cooling between sapphire fibers or heat links are the main cooling method at cryogenic temperatures. We calculated the heat flow in each heat path and confirmed that there was no unexpected heat flow.

1. Introduction

- In, KAGRA, the main mirror is cooled down to around 20 K.
- At cryogenic temperature, thermal conductive cooling is the primary cooling method.
- For conductive cooling, heat links are connected to the suspension system (sapphire fibers between TM & IM), and there is heat flow (P) through them **[1]**.
- We calculated P and evaluated the value (for ETMX) in this poster.

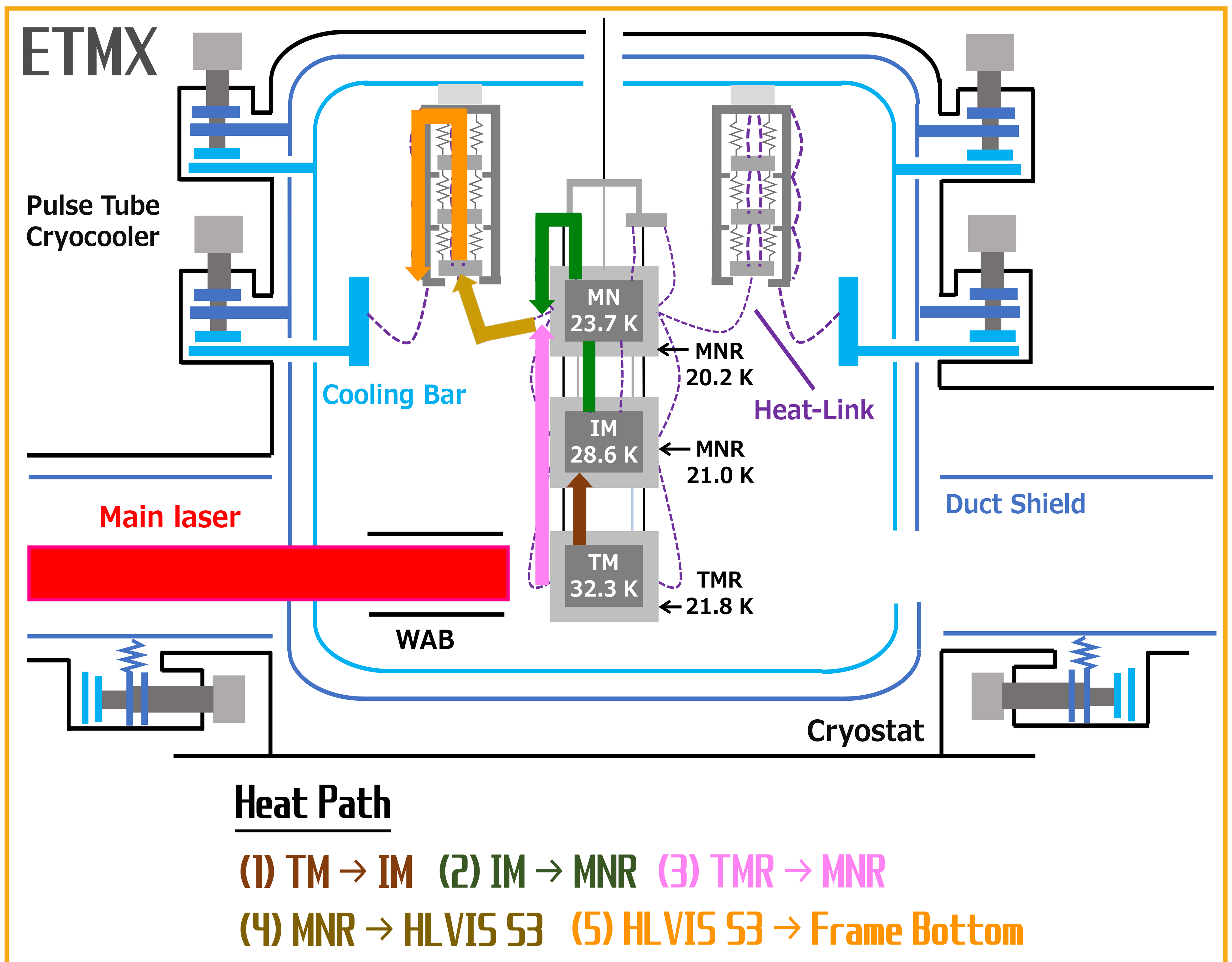

Fig1. KAGRA cooling system and heat path (ETMX). Temperature shown in this figure is current one (2022.08.30).

2. How to Calculate

- The parameters needed for the calculation are the values in [2], and temperature gradient ΔT is calculated from the current cooling conditions (Fig1).
- We assume $\kappa(T)$ as linear with respect to T [2], so we can use thermal conductivity at the average temperature of both end as the thermal conductivity of the path.

$$P = \frac{\Delta T}{R(T)} = \frac{s\kappa(T)\Delta T}{L}$$

Parameters P: heat flow [W] ΔT: temperature gradient [K] R: thermal resistance [K/W] s: cross-sectional area [m^2] $\kappa(T)$: thermal conductivity [Wm^{-1}K^{-1})] L: path length [m]

3. Results

- The results are summarized in the table on the right (Tab1).
- Main contribution of the error is temperature accuracy of thermometer.

Heat Path	Heat Flow [W]	Heat Flow [W] in O3GK [2]
Path (1): TM → IM	0.26 ± 0.20 (32.3 K → 28.6 K)	0.36 ± 0.20 (22.3 K → 18.7 K)
Path (2): IM → MNR	1.7 ± 0.5 (28.6 K → 20.2 K)	1.1 ± 0.5 (18.7 K → 14.7 K)
Path (3): TMR → MNR	0.59 ± 0.50 (21.8 K → 20.2 K)	1.1 ± 0.5 (17.2K → 14.7 K)
Path (4): MNR → HLVIS S3	1.6 ± 0.4 (20.2 K → 15.6 K)	0.99 ± 0.44 (14.7 K → 12.1 K)
Path (5): HLVIS S3 → BF	0.98 ± 0.25 (15.6 K → 13.9 K)	1.1 ± 0.3 (12.1 K → 8.80 K)

Tab1. Resuslt of heat flow calculation

4. Discussion & Outlook

- Compared to O3, MNR is not sufficiently cooled (need to investigate or think about the reason for this), but there does not seem to be any unexpected heat flow.
- A similar investigation should be conducted once the other suspensions have been cooled.

Reference [1] T. Yamada *et, al.*, Cryogenics, **116**, 103280, (2021) [2] T. Yamada, Dissertation, the Univ. of Tokyo, (2020)