

CREATING vibration free cryocooler for ET.



KRYOZ

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OF TWENTE.**


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Introduction

The Einstein Telescope (ET) includes interferometer mirrors that need to be cooled down to <10 K. The main optics are thermally controlled to reduce thermal and vibrational noise, boosting low-frequency sensitivity compared to Virgo, LIGO and KAGRA (Figure 1). ETpathfinder develops and tests the required technologies, including a sorption-based cryocooling system aiming for strict vibration and temperature demands.

Main requirements:

- Vibration of the cold tip: <32 nm peak-to-peak
- Cold tip cooling power & temperature: 50 mW @ 8 K (-265 °C)
- Cooldown time: <4 weeks

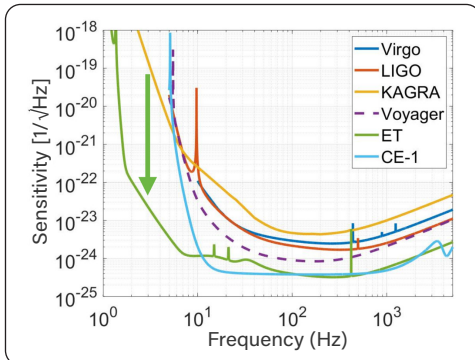


Figure 1 Aimed Einstein Telescope sensitivity [Amaro-Seoane, Pau & Bischof, Lea & Carter, Jonathan & Hartig, Marie-Sophie & Wilken, Dennis. (2021). LION: laser interferometer on the moon. Classical and Quantum Gravity].

Approach

The cascaded Joule-Thomson (JT) cold stages use neon, hydrogen and helium and are driven by sorption compressors. These compressors use adsorbent materials and passive valves to generate gas flow, resulting in a (nearly) continuous gas flow through the cold stages. A mechanically driven pre-cooling unit is only used for initial cooldown and is decoupled during steady-state operation to eliminate vibration sources (Figure 2).

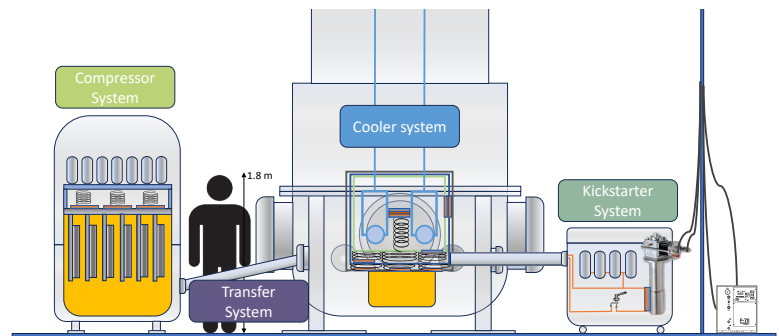


Figure 2 System architecture.

LEM analysis

A dynamic Lumped Element Model (LEM), developed by Demcon kryoz, was used to simulate and optimize the complex dynamic thermal and fluidic behavior of the complete system, including the sorption compressors, JT-stages and radiation-assisted cooldown (Figure 3). The model supports system dynamic behavior sensitivity analysis, margin estimation, and trade-off studies involving buffer volumes, flow stability, and thermal response. It also analyses the compressor control strategy, which aims to minimize pressure and flow fluctuations through optimized cycle timing and sensor-actuator coordination.

Results

The results of the LEM analysis (Figure 3) show that a cooldown time of 3.2 days can be achieved, to reach the required cold stage temperatures. The system design demonstrated a cooling power of 70 mW at 8 K, exceeding the required 50 mW. The remaining fluctuations in cooling power can be damped by the use of a heater.

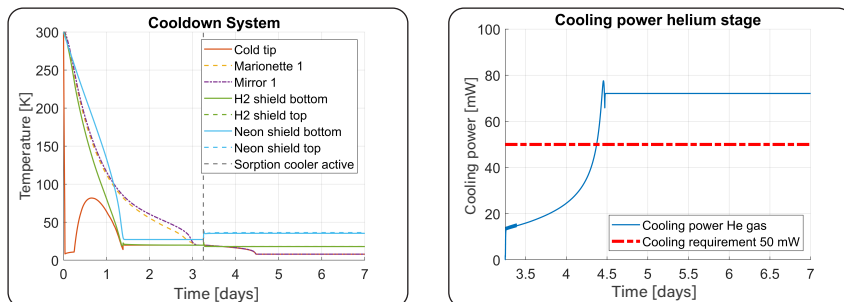


Figure 3 System cooldown times (left) and cooling power at helium cold stage (right).

Outlook

Manufacturing started in 2025 and verification testing of the coolers is planned in the beginning of 2026, demonstrating 8 K cold tip temperatures with 50 mW cooling power. Additionally, vibration tests will be conducted to verify compliance with the 32 nm peak-to-peak requirement.



Figure 4 Test setup at the University of Twente.

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