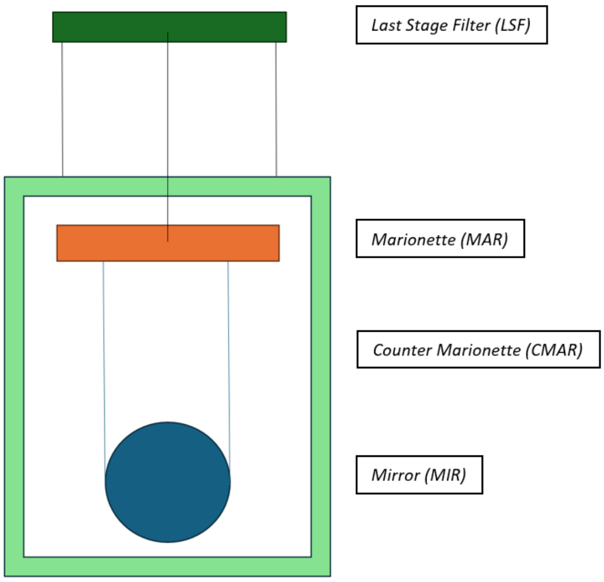
10K Cryogenic Payload

Role of the payload

A double pendulum suspension system in which, the Marionette (MAR) is used for dynamic positioning of the mirror in pitch, roll and yaw degrees of freedom. Feedback forces, both at level of the MAR and MIR, are applied from a coaxial reaction chain. The mirror double pendulum and its recoil chain are suspended, respectively, from the steering filter Keystone (GAS filter blades) and its body (LSF). The LSF is located outside the Cryogenic assembly system and penetrates via a Titanium pendulum wire the heat shields. All bodies will be DLC (Diamond Like carbon) coated in order to increase the emissivity of their surface with the aim of reducing the payload cooling down time.

MIR – Mirror

Core optical element of the interferometer.



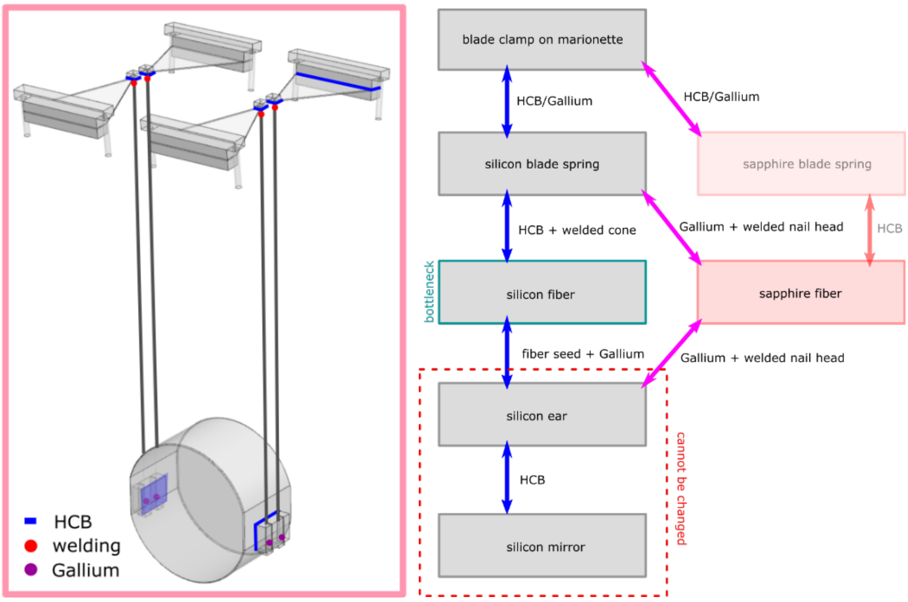
Quasi-monolithic silicon suspension

Reaching sensitivity at 10K requires crystalline materials. Silicon and Sapphire are candidate materials. We aim to R&D crystalline silicon material as test mass to meet the required sensitivity. Silicon is a suitable material due to its high thermal conductivity at 10-20K, high mechanical strength, low thermal noise, and low optical absorption.

The current baseline design for the ETpathfinder payload foresees silicon as material for the blade springs, fibres, ears and mirror, making the last stage a monolithic silicon suspension. The mirror has been polished by Zeiss MT and coating designs are being discussed with LMA. The design of the other parts and their connection is not yet finalized, with R&D ongoing in Maastricht, Nikhef, Glasgow, Perugia, Berlin and elsewhere. At Maastricht University for example, breaking stress and deflection of rectangular and triangular silicon blade springs are currently being investigated alongside techniques to apply a uniform Gallium layer for bonding the silicon fibres to the silicon ears. The geometry of the ears

is not yet fixed but will need adjustment to the shape of the silicon fibre seed to use Gallium under compression for the connection.
The silicon fibres and their connection are currently the bottleneck of the design in terms of production readiness and lead time. The Institut für Kristallzüchtung (IKZ) in Berlin has demonstrated that they can manufacture the needed silicon fibres with 1 mm diameter and 40 cm length, and weld a head to one side of the fibres, although they would like to optimise the procedure further before delivering welded fibres to Maastricht. Laser welding of silicon and welding a head to both sides of the fibre seems out of scope at the moment; timelines for fibres with the seed on one end and a cone welded to the other end are under discussion.

Options to manufacture some of the parts from sapphire are being discussed, but they require quite some research and development as well and are not a plug-and-play solution.



Mechanical design challenges around the integration of the quasi-monolithic silicon suspension:

- 8 sets of 123k Payloads available, re-use as much as possible for 10K configuration.
- Retro fit Monocrystalline Silicon Mirror assembly suspension into current Payload configuration. (keep track of the Zero Moment Plane)
- Connect KAGRA like thermal braids to Marionette and Counter Marionette. (keep track of dynamics)
- Design hoisting tools and rail system for 10k Payload (how to get the Payload into the Mirror tower).

Thermal modelling

This Payload is cooled to 15K to suppress the thermal noise of the mirror and its coatings. Realizing this involves understanding and control over both the cooldown time and the temperature stabilization during operation of the interferometer beam. Generally speaking, the 15K payload interfaces with a cold sink/cooler to take the payload from room temperature to a mirror temperature of (max) 15 K during operation. As with all thermal systems dealing with mechanical noise suppression, here, a competition arises: A stronger mechanical link of the payload will decrease the cooldown time. However, it negates the vibration isolation efforts, so an optimum has to be found.

During operation, the heat loads on the 15K payload are: thermal radiation from the cryostat, thermal radiation from the interferometer beam, conduction loads from suspension wires and dissipation in actuator magnets. In the design of the payload, great effort is made to reduce these as much as possible, from which a maximum of 25 mW is given to the requirements of the cooler. The cooler is built by the Dutch Cryoconsortium (Cooll, Demcon Kryoz and Uni Twente) and uses sorption technology to have ultra-low vibration levels. The 15K payload is connected to the cooler by ultra pure aluminium braids (KAGRA Jellyfish), which have very low transfer function for mechanical noise and very high thermal conductivity around 15 K.

Some parts on the payload are coated black to accelerate the cool down as the black coated inner radiation shield (for historical reasons called 15 K-shield) will rapidly be at 18 K. Thermal modelling is done to translate the 15K requirement on the mirror temperature to a cooler temperature, depending on the thermal path between the two, which is:
Mirror - Si-fiber - Si-flexblade - Marionetta - Al-braid - Counter Marionetta (‘reaction cage’) - Al-braid - Cooler.