Summary of Oct. 12th discussion on mirror suspensions. **JGW-T1201341**

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See also documents JGW-G1201312 JGW-T1201320 JGW-T1201317.

The main aim is to understand how to suspend the mirror in B-KAGRA.

We consider the options on the table, which for the “wires” are:

Monolithic rods with nail heads, commercially made by Impex (and with one head only by Moltex), studied by Kazuhiro and Ettore.

Composite rods with nail heads brazed, proposed during a discussion with Impex.

Silicon flexures, sapphire ribbons and silicon springs, studied by Alessandro and Riccardo.

None of these techniques is mature enough to be used in initial B-KAGRA.

All these “wire” options can use the same technique to attach to the mirror, which consists in using alcoves carved inside the sides of the mirror with Ultrasound Milling.

We discussed the technique of building the alcoves. The ultrasound Milling is a relative of diamond grinding and polishing, it is not expected to produce more damage than diamond grinding, but it will almost certainly require an annealing process. This will crystallize and destroy any coating. The alcoves must be carved before polishing the mirror front face and before coating.

We consider the possibility of carving alcoves on the mirrors even if other suspension solutions will be used initially, to have them ready later on. Ettore points out that the effective bending point of the nail head rods is ill defined, and its distance from the head changes dramatically with diameter and loading. One can only carve alcoves for this type of “wires” only after deciding precisely which diameter stem is used and which free stem length between the head and the rod.

In the case of the silicon flexures, the bending point is well defined, but the design is not final yet, and will be finalized only after prototype tests.

Besides we do not know yet what kind of processing to apply to the carved alcoves.

We recognized that none of the techniques described above is ready it time for initial B-KAGRA.

Only metal wires seem to be sufficiently understood to be used initially and we discussed several types of metal wires. The only solution that may give good guarantees of reliability and good thermal conductivity is two slings of pure aluminum wires. We know it works because they have been well tested in CLIO. It only needs to be rescaled to the KAGRA larger masses. We also know that pure aluminum wires will not satisfy the B-KAGRA thermal noise specification, but will allow B-KAGRA to operate and be thoroughly commissioned.

We also realize that pure aluminum is subject to linear creep at room temperature (as opposed to logarithmic creep where the creep slows down with time), the wires will slowly stretch at constant speed, and will do it indefinitely.

*Additional information. When cooling, though, the creep slows down very rapidly (for Maraging creep slows down ~25% per degree, for Aluminum it is unknown but it will probably have a similar rate).*

Even if pure aluminum is selected, we still did not engineer how to suspend a 22 kg mass; we will need wires of large enough diameter to have small creep even at room temperature.

*Additional Information: Pure aluminum has a yield point of 10 MPa, less than 1 kg/mm2, possibly even less for the deeply annealed wires used for thermal conductivity.*

*To stay safely away from the creep zone (half of the yield point) one needs a cross section of 6 mm2 per wire, i.e. a minimum 2.8 mm diameter.*

*Large diameter wires are notoriously difficult to clamp sufficiently tight to avoid slipping, without causing significant plasticity at the clamp point.*

We all concur that some development will be necessary even with aluminum wires. At present we have no fully developed technique to cryogenically suspend KAGRA’s mirrors.

Carving alcove (or other attachment techniques) will have to wait for a future time when we will know better the option to implement.

What about R&D on the low thermal noise options:

Ronny, collaborating with Alessandro, will make tests of carving alcoves in sapphire with the same UltraSound Milling company used to develop the silicon flexures.

Things to be studied are surface finish, possible sub-skin damage, annealing processes, et cetera.

Kazuhiro, Ettore, Riccardo and Alessandro will continue developing the nail head rods and ribbons with flexures.

Alessandro and Riccardo will continue on the development of the silicon springs.

It is estimated that if the brazing is successful, the rods with nail heads will be available first. It was also noted that without vertical compliance it would not be possible to satisfy KAGRA’s design sensitivity over its entire frequency band.