Summary of Oct. 10th meeting on cryogenic suspensions. **JGW-T1201317**

Participating: Kazuhiro Yamamoto, Ettore Majorana, Luca Naticchini, Riccardo DeSalvo, Masayuki Nakano.

Document JGW-G1201312 is used to guide the discussion.

The main aim is to define the interfaces between cryogenics, mirror, cryo-suspensions, seismic and vacuum.

It is noted that the forward baffle in front of the mirror will receive ~ 4-5 W of scattered light from the mirror, and covers about 4 steradians in front of it.

That baffle is by far the largest contributor to scattered noise to the interferometer.

That baffle is crucial to attenuate the scattered light and to reach the KAGRA sensitivity target.

It is reminded that even at ppm-level scattered light from that mirror, due to the large covered solid angle, is capable to disrupt the gravitational wave performance, unless the baffle is sufficiently seismically isolated.

Majorana resumes the Virgo experience, pointing out that (made several examples) suspended but not damped mirrors, much farther away from the test mass, induced significant noise in the Virgo sensitivity curve.

In a second-generation interferometer, with ~ 1 order of magnitude more light and ~ 1 order of magnitude better sensitivity, such noise would be disastrous.

Therefore the forward baffle needs to be at the very least suspended and damped, (and possibly even suspended and controlled to track the mirror and null the relative motion induced by the microseismic activity).

It is noted that the cryostat inner shield stiffness is critical to hold the baffle, which is large, must be rigid, and will be significantly heavy, of the order of 50 kg. The inner skin of the cryostat shield may be too weak to suspend the baffle and may be excited by the pulse tube mechanical noise. As known the inner shield may be excited by both cryocooler and seismic mechanical noise. Yamamoto points out that the baffle shape can be significantly improved. DeSalvo reminds that because of solid angle coverage requirements, although its diameter can be reduced some, it is doubtful that it can be significantly shortened.

It is concluded that in the best configuration from the mechanical point of view, the baffle should be suspended from above the cryostat, through the shield. This solution was already envisioned by Tomotada.

In addition the baffle needs to be carefully aligned (1 mrad according to a conservative estimation calculated for Advanced Virgo), and it is mounted forward with respect to the mirror, extending to the edge of the cryostat inner shield. The back baffle (needed in the input test masses) is less demanding, but also needs to be carefully aligned to the mirror. Therefore a sort of table below the mirror is necessary to hold the baffles.

With the above constraints, one ends with a vertical structure shown in figure 1 (not to scale).

The obvious bottleneck, clearly visible in the top view of figure 2, is the 800 mm inner diameter tube leading to the SAS system.

The bottom filter body is 730 mm diameter, to which one need to add at least 20 mm of cabling and the space for a safety structure, which does not fit in the 800 mm tube. Therefore the bottom filter must be positioned above the attachment point of the springs supporting the baffle structure.

These basic arguments alone fix most of the geometry.

Eleven suspension wire penetrations are needed through the cryostat, in a pattern fitting within the 800 mm diameter of the tube to suspend the parts needed to make the interferometer work at second generation GW sensitivity. The only other alternative, without touching the present shield already constructed, would be to develop a seismic attenuation stand, sitting on the floor of the radiation shield.

This second solution is not discarded, because for a choice between the two options we need a more advanced design of the baffle and a deeper analysis of its opto-mechanical noise in the two configurations, and all related effects on the interferometer. However the suspended solution proposed here seems conceptually better, simpler, and cheaper.

It is foreseen that each wire will have to carry a few small baffles to stop thermal radiation to channel through the penetrations.

It is understood that Kimura-san must be contacted as soon as possible to study how to integrate the baffles in the cryostat, and possibly how to implement the proposed penetrations. Riccardo makes himself available to help Kazuhiro to develop the integration, especially for the mechanics and to evolve the suspension design according to the test results from our European collaborators.

Tomotada-san needs also to be involved for what concerns the baffle improvement studies and its integration.

Of course one can start with a simplified interferometer structure, for example without the suspended baffle, without vertical cryogenic springs, and simplified suspensions, but the entire system needs to be carefully engineered so that the missing parts can be later added progressively, as the sensitivity increases.

To allow this staged commissioning, the main issue, which needs to be addressed immediately, is the penetrations in the cryostat heat shield roof that will allow proper suspension of the delayed components.

Several other questions have been identified, concerning the performance in different configurations, and the heat flow.

Virgo has abandoned the lock strategy based on recoil mass precisely due to the need of suspending baffles and other optical components close to the mirrors. LIGO was actuated from a suspended bench, without a recoil mass, and advanced LIGO actuates on the end mirror from a separately suspended mass, both schemes conceptually similar to what proposed here.

Different lock acquisition strategies need to be studied, comparing them to the recoil mass method used in Virgo, TAMA and the KAGRA recycler mirrors. The recoil mass strategy is now abandoned by all other second generation interferometers.

Even though the lock acquisition forces from a recoil mass may seem the best solution for KAGRA cryostat, different strategies should be considered as well. The separate platform illustrated in JGW-G1201312 is just one option.

It is recognized that final engineering of the mirror cryogenic, sapphire suspensions will be possible only after obtaining the results of prototype tests of sapphire rods and/or ribbons and silicon components, while the rest of the system can, in large part, be pre-engineered.

The necessity of intensive simulations, of the evolving configurations of the system is recognized as well.

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Figure 1: Schematic side view of the cryostat, obviously not to scale.

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Figure 2: Schematic top view of the cryostat and the mirror assembly. The boxes representing the parts are in very good approximation “to scale”.