Evolution of the mirror suspension in Virgo and beyond

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The Present Solution

The Virgo present solution for the suspension last stage uses four 200 µm diameter C85 steel wires.
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The Virgo present solution for the suspension last stage uses four 200 \(\mu\)m diameter C85 steel wires.
Status of the Monolithic Suspensions for Virgo+

- Two fibre pulling machines available (in Perugia and Cascina);
- One laser CO$_2$ machine available in Cascina (developed by the Glasgow group);
- A validation procedure for fibre production has been defined;
- A new approach for the suspension is under test in these days

The monolithic team is composed by the groups of Firenze, Perugia and Roma
Profiles of the necks are equal within a 10 µm accuracy level.
Below is a table showing the bending points and frequencies for different laser power settings:

<table>
<thead>
<tr>
<th>Laser Power (%)</th>
<th>Violin mode (Hz)</th>
<th>Bouncing Mode (Hz)</th>
<th>Distance between bend. Points (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>453±1</td>
<td>6.0±0.1</td>
<td>669.5±0.2</td>
</tr>
<tr>
<td>50</td>
<td>453±1</td>
<td>6.0±0.1</td>
<td>669.8±0.2</td>
</tr>
<tr>
<td>50</td>
<td>452±1</td>
<td>6.0±0.1</td>
<td>670.2±0.2</td>
</tr>
<tr>
<td>50</td>
<td>451±1</td>
<td>6.0±0.1</td>
<td>669.6±0.2</td>
</tr>
<tr>
<td>50</td>
<td>450±1</td>
<td>6.0±0.1</td>
<td>669.6±0.2</td>
</tr>
</tbody>
</table>
Steel Wire Suspensions LC

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New Suspension Approach
- Aluminum Alloy samples of the lower clamp have been produced
- A fused silica head (5mm diameter with conical tip) is inserted in the aluminum to mimic the lower clamp
- Using the laser machine, a 1.5 mm FS bar is welded to the tip
- The fiber is then pulled directly from the bar
- The upper clamp is welded to the fiber head using the flame
Dummy Payload suspended
Dummy Payload suspended

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Advanced Virgo Suspensions

- A final design for the Advanced Virgo suspensions is under study;
- Fused Silica monolithic suspensions will be used;
- Mirrors in Suprasil of about 40 kg mass (35 cm diameter, 20 cm thickness) are assumed;
- Fibre length and separation are maintained the same as in Virgo: 70 cm and 5 cm respectively;
- The possibility of machining the lateral ears out of the test mass lateral surface was proposed;
- Various solutions for the whole suspension are under study (e.g. MRM).
Monolithic Design
EGO R&D for a new payload configuration that includes a reference mass for the marionette hosting the coils for the actuation system (proposed by Roma 1, Pisa and LMA);
Third Generation Suspensions...

- The idea is to develop a cryogenic suspension;
- The suspension has to be monolithic;
- Mirrors in Silicon or Saffire seems to be the most realistic choices;
- The suspension elements have to extract the heat from the mirrors;
- Silicon ribbons are under study;
- Silicate bonding between silicon and saffire is under test for the mechanical and thermal point of view;
- A cryogenic facility has been developed in Cascina.
Facility cryostat: design

- The cryostat consists of an external vacuum-proof steel cylindrical vessel (2.6 m height, 1.4 m diameter).
- Inside the room temperature vessel there are two nested super-insulated Al chambers which are foreseen to reach their thermal equilibrium respectively at about 70K and 5K.
- The 5K chamber is able to host the payload and one anti-seismic filter. It has a height of 2m and a diameter of 1.2m (about 2.2 m³).

See Puppo & Rapagnani’s talk
Payload design

- The designed test payload consists of a mono-crystalline silicon mirror (350mm diam., 100 mm thick) suspended to a silicon marionette by two couples of low dissipative, monolithic silicon ribbons (30mm x 0.8 mm x 300 mm).
- The ribbons should be silicate bonded on the two mirror and marionette sides.
- This payload will be cooled down to about 5K to make measurements of the temperature dependence of the mirror $Q$, without and with coating.

Proposed by R. Passaquieti (Pi)
Si and Al$_2$O$_3$ silicate bonding

- The INFN Perugia group has performed room temperature measurements of the silicate bonding shear stress strength on Si and Al$_2$O$_3$ cylinders (diameter of 5 mm, height of 10 mm) of different crystal orientations.
- The breaking strength has been evaluated on the $\lambda$/10, $\lambda$/7 and $\lambda$/4 for bonding times of 1, 2 and 3 weeks.
- A maximum strength of ~15 MPa was measured.

The breaking of the Si-Si bonded sample starts in the surface of the bonding continuing inside the silicon, probably following some crystal plane.
Mono-crystalline Silicon fibers

Silicon mono-crystalline fibers have been produced at the Pisa INFN (M. Tonelli) with the micro-pulling down technique:

Fiber characteristics:

• mono-crystalline
• diameter between 0.4 and 3 mm
• pure silicon at 10 ppm
• surface opaque
Mono-crystalline Silicon fibers

Fiber length $L=308$ mm, mean diameter $746$ mm

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Mono-crystalline Silicon fibers

Excess losses are evident on the thermoelastic peak:

→ Etching in HNA:

→ diameter is decreased of about 170 µm

Fiber length L=308 mm, mean diameter 746 mm
Mono-crystalline Silicon fibers

Fiber length $L=308$ mm, mean diameter 746 mm

Fiber length $L=308$ mm, mean diameter 746 mm
Mono-crystalline Silicon fibers

Fiber length $L=111.5$ mm, mean diameter $242$ mm
Silicon thermal conductivity with and without silicate bonding

Samples have been bonded by the Glasgow group and measured in Florence.
Cryogenic loss angle

- The measure has been performed down to 80 K
- The clamping is made in copper with the pression of a spring.

Excess losses are evident, probably due to the clamping

Loss angle for the 6680 Hz mode

Perugia group

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Conclusions:

• Monolithic Suspensions for Virgo+ are now at a good point in terms of reproducibility and stability

• Monolithic Suspensions for AdV are still under study but the approach of the suspension seems to be at a good point

• Other evolutions have been proposed and will be studied

• A cryogenic suspension for third generation detectors is under study in various laboratories (Cascina, Florence, Perugia, Pisa and Rome)

• We are converging…