Fused Silica Fibre Pulling Machine

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1) Introduction.

Silica has been demonstrated to be a suitable material for the last stage suspension in interferometric gravitational wave detectors. Its low internal mechanical dissipation and thermal expansion make silica a unique material for allowing low thermal noise in suspensions at room temperature.
In the frequency range of interest it seems possible to reduce the current suspension thermal noise by about one order of magnitude.
Beside this, silica has two more excellent characteristics:
(a) if it is treated with care, it shows a strength twice that of steel;
(b) since it is amorphous, the process of welding does not alter its mechanical and thermal properties.

2) The fibre-pulling machine.

Last version of the Perugia fibre-pulling machine represents a great evolution in respect to the original flame machines developed in Glasgow and in Perugia.
The fibre-pulling machine is completely controlled by a computer: the motion through an electrical engine and the O-H flux through an electro-valve that drives a pneumatical-valve.

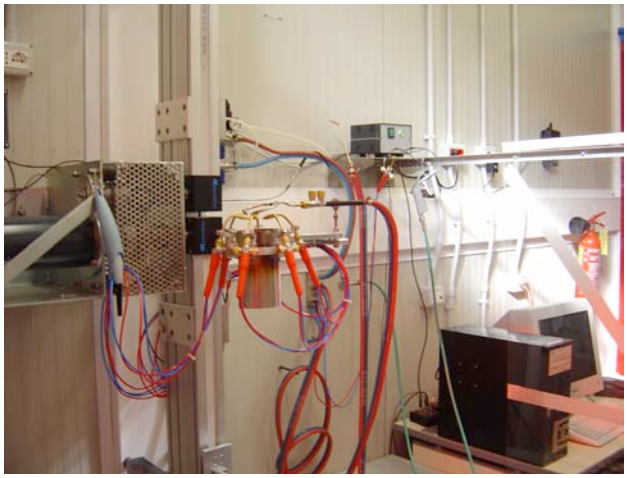

Fig.1-View of the central part of the new automated pulling machine installed in Cascina at the west middle arm building.

It is possible to set the desired diameter on the computer and it selects the pulling speed to drive the machine.
With this kind of facility it is possible to produce fibres with a diameter varying from few tens to 400 microns.
The facility permits to contemporary heat in the center part of a “flame stove” and cool near it to limit the melted volume of a fused silica bar placed in the right position. In this way it is possible to control better the dimension of the tapers of the fibres produced.

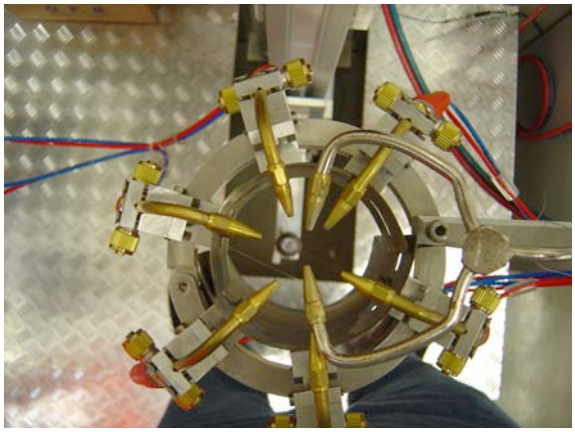

Fig.2-Detailed view of the "flame stove" with the two upper cool-air tubes to limit the melting region on the fused silica bar.

A 3D Laser Caliber is used to measure the diameter and shape of the fibre produced. It is possible to verify the circularity of the fibre section and to measure the diameter with a precision up to 0.1 microns.

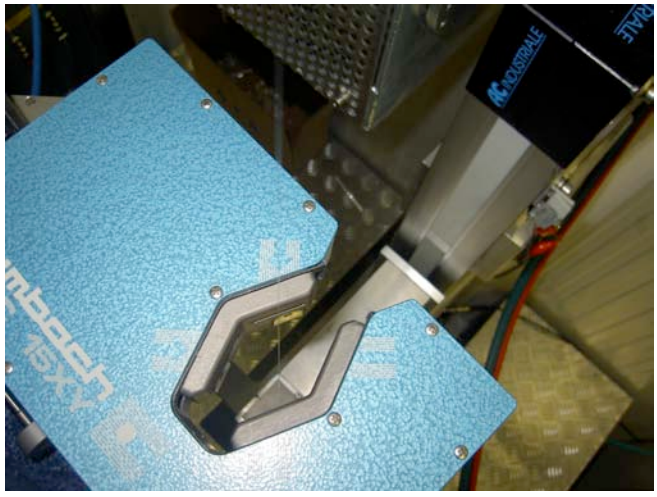

Fig.3-View of the facility with the 3D Laser Caliber in the measuring position.

3) Wire production procedure.

In order to achieve the maximum reliability in fused silica fiber production procedure to be followed when the production of new fibers is in order has been designed and tested. A specific document has been realized and delivered to EGO in May 2006.

Such a procedure is specifically aimed at the test mass suspension wire production for the VIRGO interferometer, as discussed and defined in previous documents and scientific papers.

1. Fiber pulling

In order to pull the fibers with the facility the procedure is:

a) The rod is cut into about 15 cm long pieces. The cut is made by bending the rod by hand after drafting a circular cutting line with a hard tool on the rod surface.

b) The two extremes of the rod are clamped at the two sides of the pulling machine using the two mandrels. Special care has to be taken in clamping the rod in order to achieve the maximum alignment (verticality) of the rod itself.

Fig.4-The two mandrels clamping the rod.

c) Parameters setting. Once the rod is in place and tightly held it is necessary to set the fiber pulling parameters by using the software interface designed at this aim. The final average diameter and the length of the fiber are thus chosen by setting their numerical values.

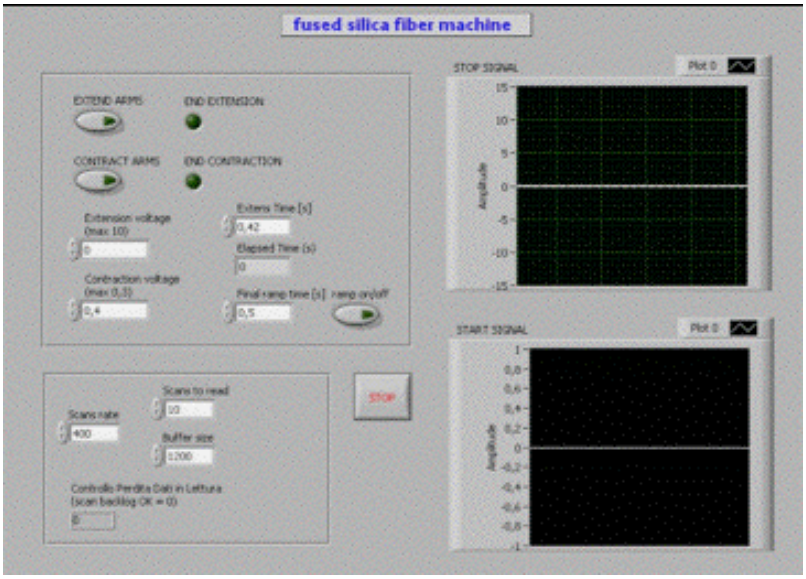

Fig.5-Screenshot of the software interface

Once the parameters are set, the automatic driving is ready to operate.
The OH flame is ignited by hand (special care and some experience required) and the symmetry of the six flames about the axes of the rod is checked. Activating the software button on the control panel starts the pulling.
Once the pulling is completed the automatic control system performs a tension ramp in order to keep the fiber under a proper tension.

2. Fiber validation

After the pulling, the fiber is still held under tension in the pulling machine.

The validation process is the following:

a) by visual inspection the absence of cracks and major defects is checked.

b) The fiber diameter (its profile) is measured by the laser caliper (check on the diameter regularity: constant within 10%).

If the fiber survives the checks it is validated and is ready for storage or installation.

4) Last upgrades

A new version of the clamping system and of the “flame stove” has been studied and tested to better control the melted volume to increase the diameter control of fibres produced.

The clamping system is made of steel blocks that with their high thermal capacity maintain the upper and lower parts of the bar at ambient temperature. Two tungsten shields are placed to protect the steel blocks from the heat produced by the stove.
The new pipe for the flame has been developed to better fit between the two steel clamps.

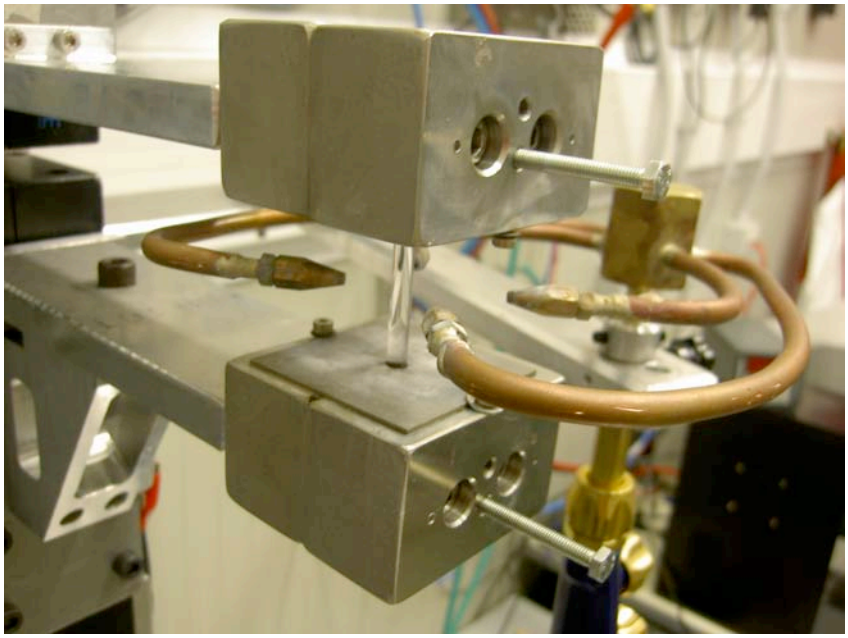

Fig.6-View of the new clamping system with the "flame stove" in place for the pulling of the fiber. A Fused Silica bar has been put in position.

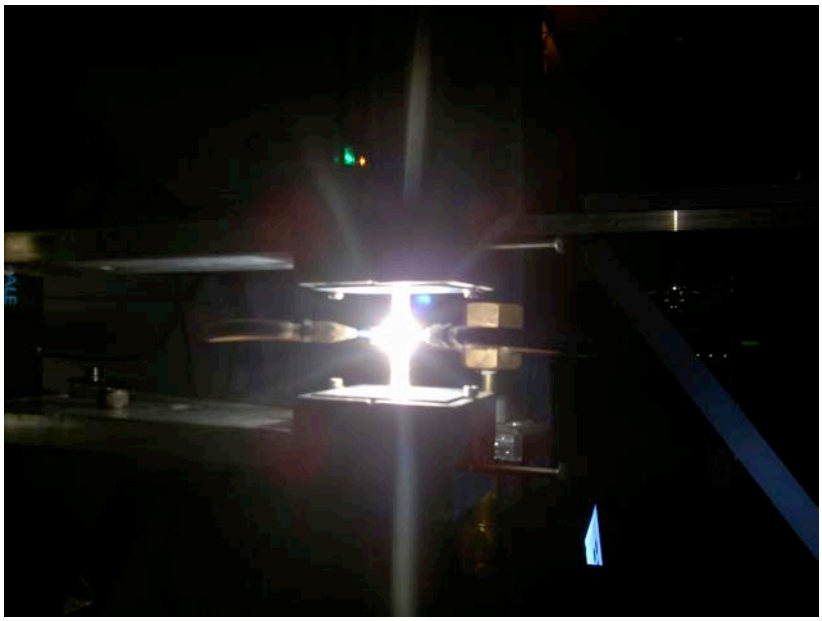

Fig.7-Picture of the Fused Silica heating procedure before the pulling of the fiber.

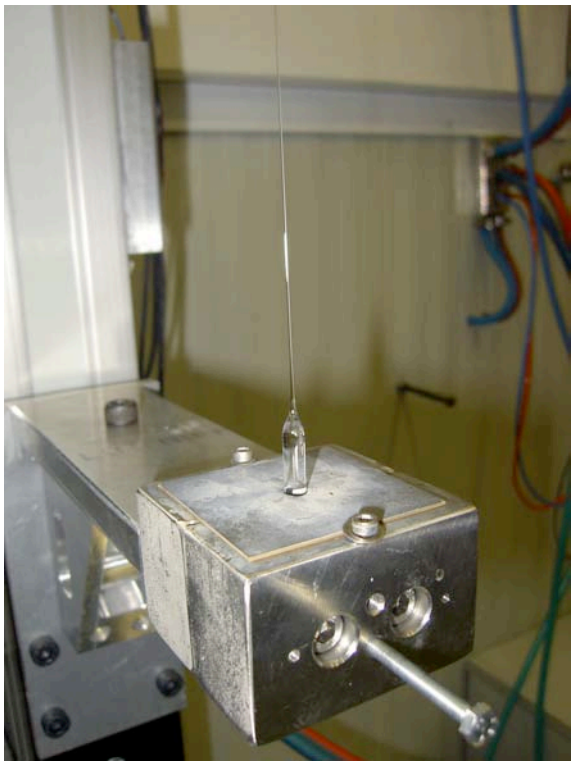

Fig.8-View of the fiber produced and of the lower taper

5) Conclusions.

A fully working facility has been delivered to EGO at the west middle arm building.
The facility has been installed and tested since January 2006, it is now ready and results fully automatic and very stable.
The last upgrades are working very well and at the moment are used for the Fused Silica fiber production for the monolithic suspension tests for Virgo.

6) Acknowledges

The authors want to thank the INFN and EGO financial and technical support for the realization and the installation of the facility.
The good results have been due to the huge support of the mechanical workshop of the Physics Department of the University and INFN of Perugia and of the workshop in EGO.