LIGO Laboratory / LIGO Scientific Collaboration

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Technical Design Document of the fibre guard in the aLIGO ETM/ITM quad suspension

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Reference documents

Design documentation	
D0902505	Fibre guard Assembly all parts
D0902506	Fibre guard assembly
D0902507	Fibre guard Main Body
D0902508	Fibre guard Separator
D0902509	Fibre guard angle section 1
D0902510	Fibre guard angle section 2
D0902511	Fibre guard angle section 3
D0902512	Fibre guard angle section 4
D0902513	Fibre guard angle section 5
D0902514	Fibre guard angle section 6
D0902515	Fibre guard angle section 7
D0902516	Fibre guard angle section 8
D0902517	Fibre guard angle section 9
D0902518	Fibre guard angle section 10
D0902519	Fibre guard angle section 11

1 Introduction

The quasi-monolithic suspension of the ETM/ITM mirror from the penultimate mass is the final stage in the quadruple suspensions in aLIGO. The stage is constructed entirely of fused silica with interface pieces or ‘ears’ bonded to the sides of both the penultimate mass and the test mass and 4 silica fibres welded in between the horns on the ears to connect the two together. The final stage is one of the more valuable parts of the quad suspension in the monetary sense, but also from a

performance point of view and technological point of view. The thermal noise performance of this suspension has to meet some challenging requirements, and the technologically advanced method of welding in fused silica fibres, means that this stage should be handled with great care. Several safety features are in place like bumper stops that limit the motion of the penultimate mass and test mass to only a few millimeters in any direction, and fibre guards in between the masses that protect the fibres from human interference.

This document discusses the motivation and requirements for the fibre guards, gives a description of their design and gives some key notes on installation into the structure.

2 Motivation and design requirements

2.1 Motivation

One of the motivations for installing fibre guards is stated above: preventing human interference with the fibres (that have been welded in between the masses) while the structure is being handled or people are in close vicinity of the structure. In particular this is during transport of the main chain, before the reaction chain and main chain get connected, during chain connection, during transportation of the connected chains into the tank and finally while work is ongoing inside the tank (not much space) on the quad suspension or other suspensions nearby. In all these circumstances the fibres would be under full load (10 kg each), but the masses are locked down in 6 degrees of freedom.

There is another motivation as well: in the unlikely event of fibre failure the fibre guard can guide any shrapnel down and minimize the risk that shrapnel hits in particular other fibres and make them fail as well, producing more dust in the process and posing a larger risk for more major damage to for examples weld horns or the optical coatings on the front of the ETM/ITM.

2.2 Design requirements

- The fibre guard shall shield as much of the fibres from human interference or falling items as possible
- The fibre guard shall shield the fibres from each other as far a practically possible without compromising safety for the fibres during installation of the guard.
- The guard shall remain clear of the fibres at a reasonable distance as to minimize the risk of interference during installation.
- The fibre guard shall incorporate the detector unit of the violin mode sensor.
- The fibre guard shall be connected to the faceplates of the main chain suspension structure using dedicated holes for T-bolt and threaded bolt connections.
- The fibre guard shall not interfere with any other parts (and usability thereof) of the suspension like barrel bumper stops and the ring heater.
- The fibre guard shall be equal in weight or lighter than 4.1 kg (for the pair; one guard on each side; which is the weight of the prototype).

3 Description of apparatus and list of parts

The fibre guard assembly consists of two separate guards, one guard protects the fibres on one side of the mass, the other protects the fibres on the other side. Figure 1 shows Solidworks models of the fibre guard on its own and installed in the structure. The total weight of the guards is 4.1 kg.

Each guard consists of a U-shaped aluminium main body shielding the outside of the fibres to the sides, front and back from any human interference.

Brackets are attached to the sides of the fibre guard (indicated by blue arrows in Figure 1), that can be attached to brackets that are attached to the faceplates (indicated by red arrows). The faceplate brackets have heli-coiled tapped holes such that the guard with its brackets can be easily fixed to them with socket head cap screws.

Two guide rails at the top (one rail is indicated with a green arrow) aid in the alignment of the guard during installation, allowing for fixing the guard to the remaining brackets. Following this the guide rails are removed and the top brackets can be fixed with screws as well.

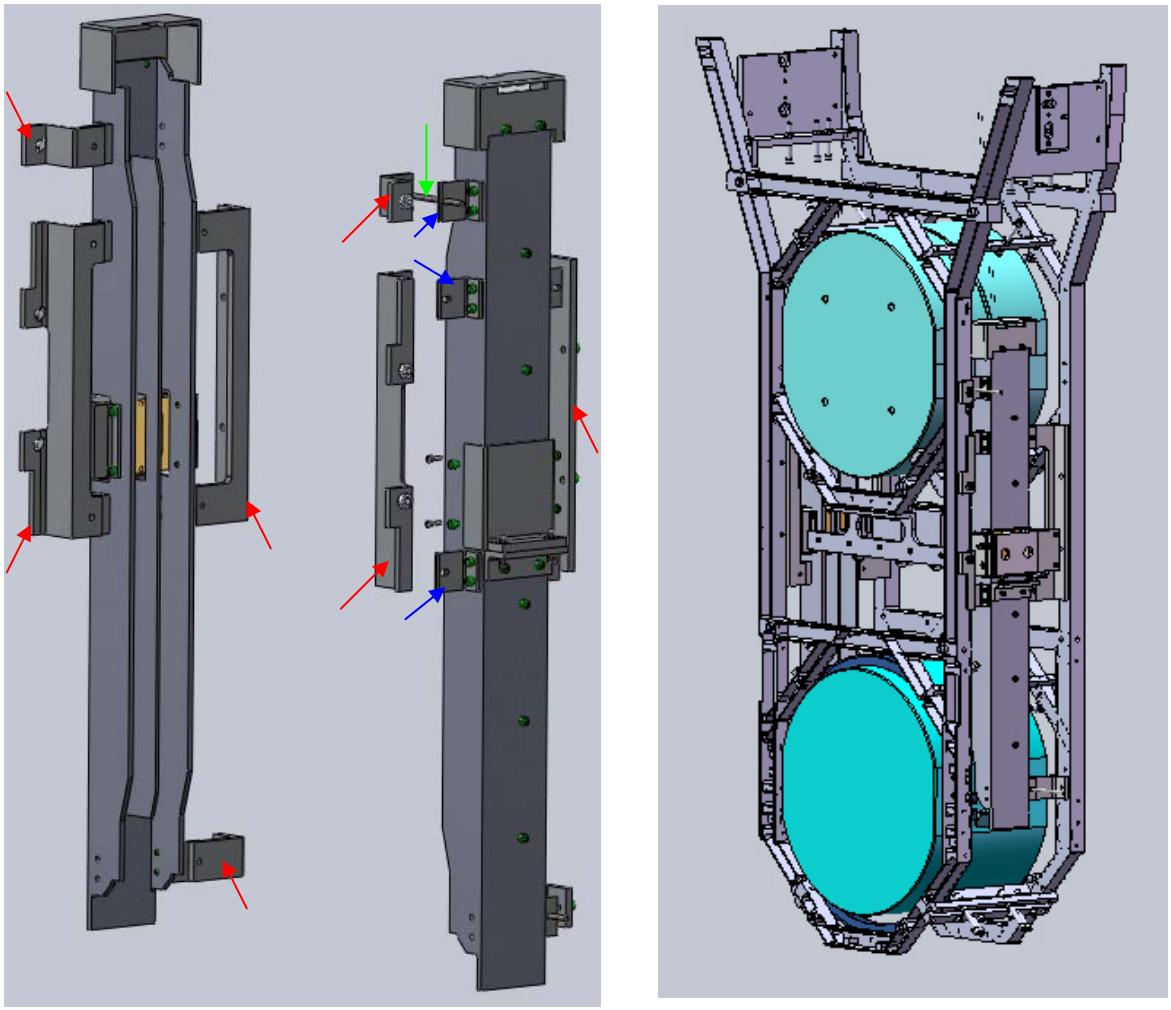


Figure 1 Left: Solidworks model the fibre guards with brackets. Brackets indicated with a red arrow are attached to the structure, brackets indicated with a blue arrow are attached to the fibre guard. The green arrow indicates a guid rod, that aids alignment of the guard during installation. Right: Solidworks model of the fibre guard installed into the structure with sleeve.

Figure 2 shows a zoom-in on the fibres inside the fibre guard. Between the fibres a dividing wall is connected to the guard. It shields one fibre from its closest neighbour. This reduces the chance that in the unlikely event that one fibre breaks, shrapnel will hit another fibre and produce more dust and shrapnel in the process. The dividing wall goes up to where the flats start, so not the entire lengths of the fibres are shielded from each other.

The fibre guard approaches the masses to within 3.3 mm. The fibres are at least 13 mm from any part of the fibre guard when it is in its installed position.

There is no shielding between the fibres on the two different side, because of limited space, possible interference during installation with other parts of the assembly and increased risk to the monolithic assembly during installation.

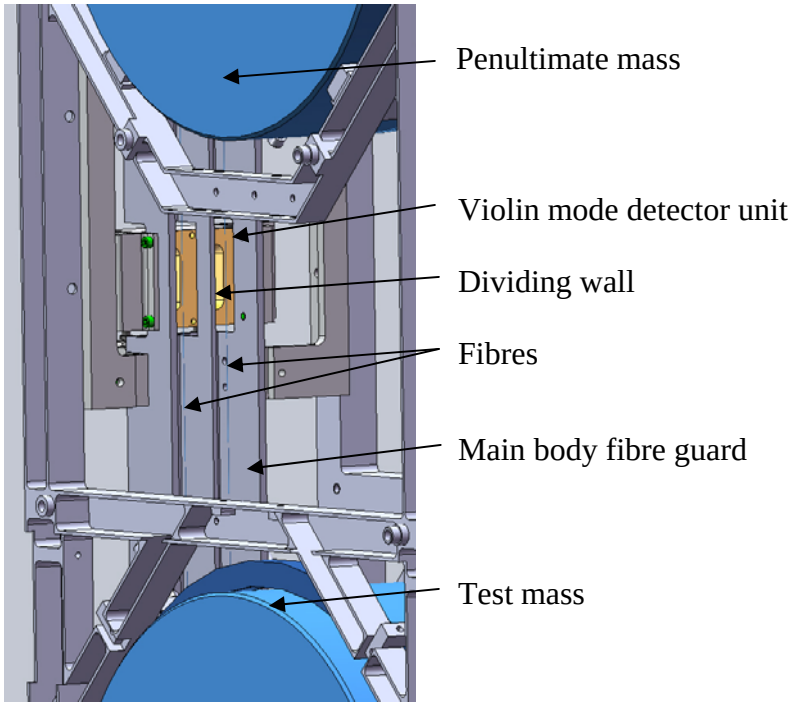


Figure 2 Fibres protected by the fibre guard

A protective cap is installed on top of each guard to protect the ear on the penultimate mass and the fibres below from any things falling down. It is screwed onto the main body and has a view port in the front to aid with installation to help with alignment and to make sure the fibre guard never hits any part of the monolithic suspension. It also has a cut out to stay clear of the PM suspension wires.

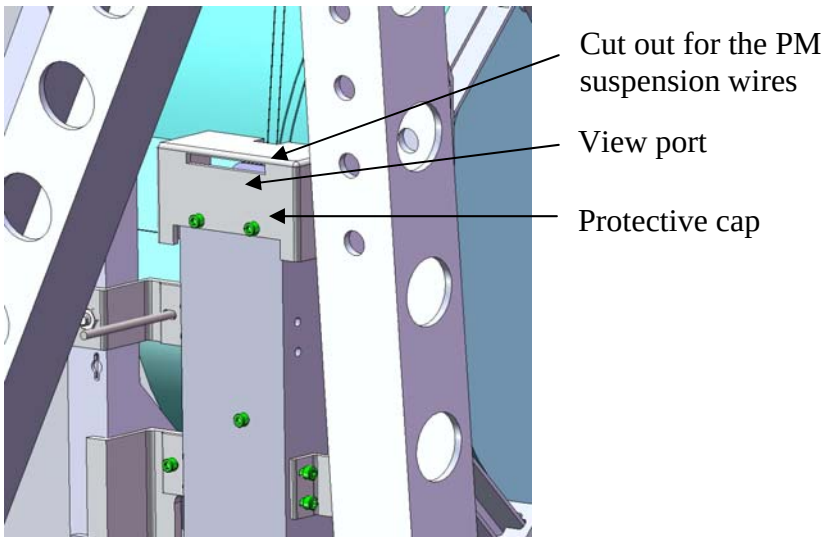


Figure 3 Protective cap on top of the fibre guard.

The fibre guard is narrow enough so that the barrel stops are outside the fibre guard such that the dedicated tool to adjust the stops can be used comfortably. This is shown in Figure 4.

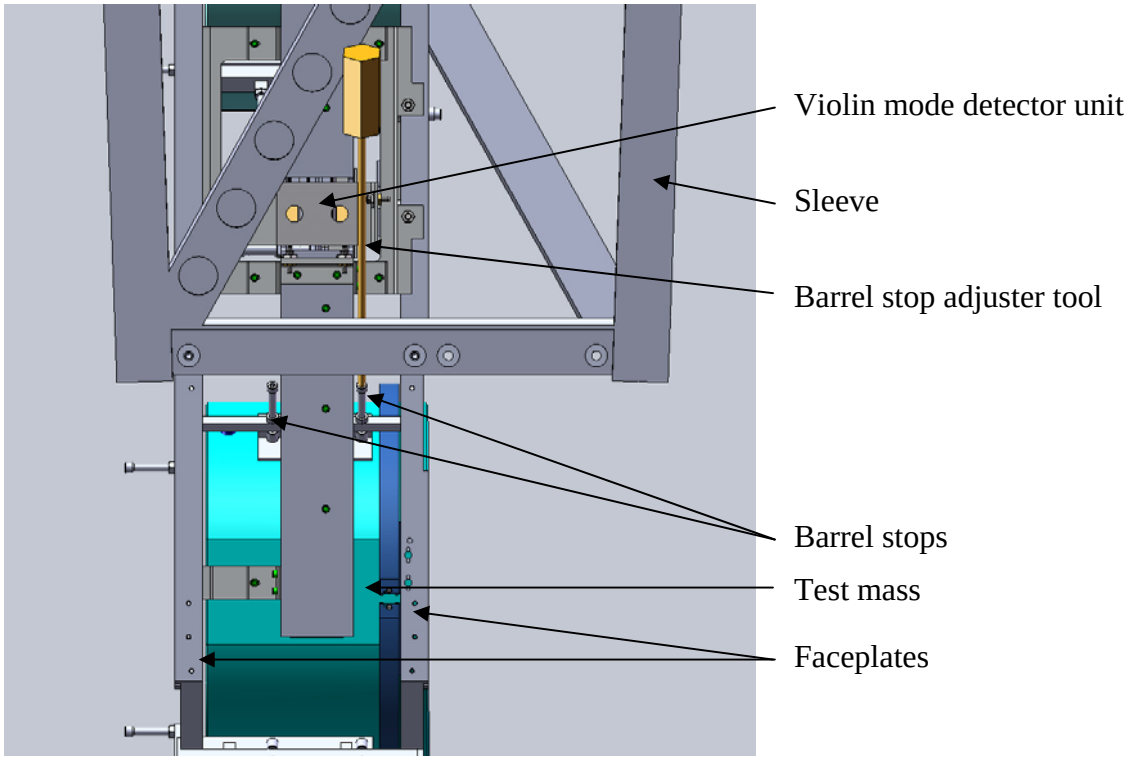


Figure 4 Fibre guard in structure with barrel stop adjuster tool in place.

Figure 4 also shows the violin mode detector unit installed into the fibre guard. The fibre guard has a cut out for it. Shelves are attached to the fibre guard underneath and at the sides of the detector with adjuster screws against which the detector rests and fixing screws to lock down the detector unit.

4 Notes on installation

After completion of welding in the fibres remove all weld shelves, scaffold etc. The brackets D09025016, D0902517, D0902518 and D0902519 should be attached to the lower structure as shown in Figure 5.

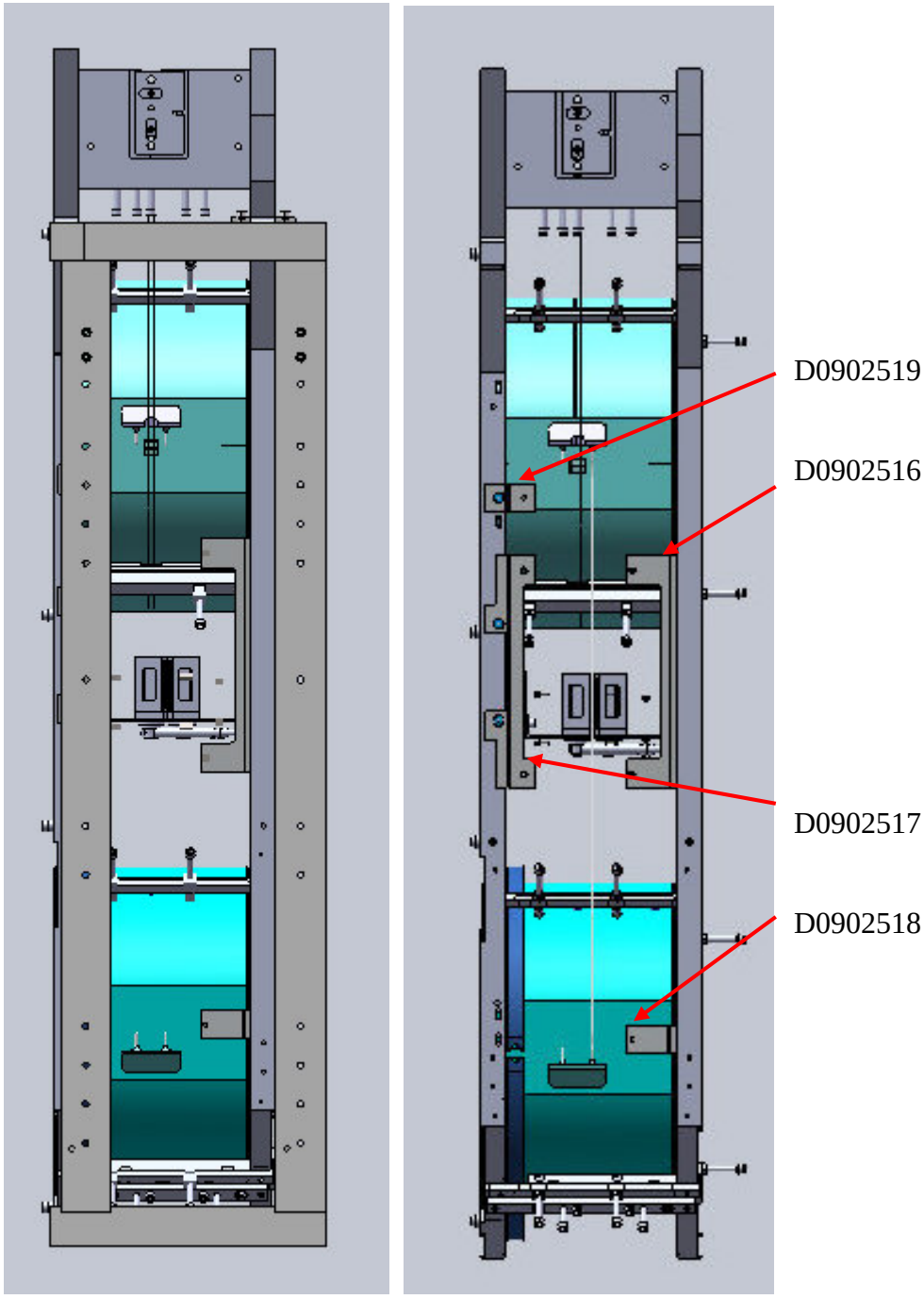


Figure 5 Brackets attached to lower structure with LSAT shown (left) and removed (right).

The T-bolts (D901941) used to attach brackets to the lower structure behind the leg of the LSAT are inserted as shown in Figure 6, rotated to lock in place then attach brackets D0902519 or D0902517 using nuts.

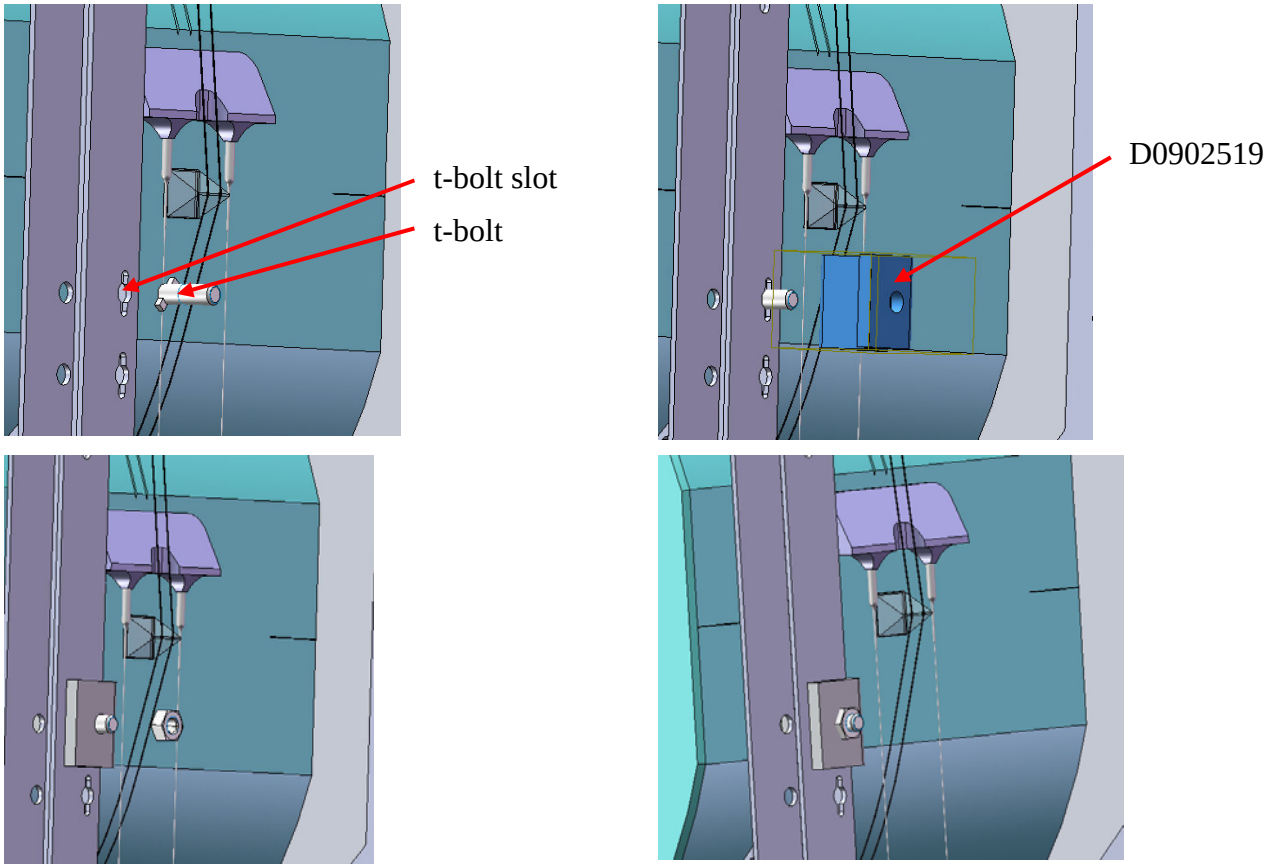


Figure 6 (top-left to bottom-right) t-bolt being inserted into structure, after locating the t-bolt the bracket is brought in and positioned over the t-bolt and finally the bracket is attached using a 1/4-20 nut.

Brackets D0902518 and D0902516 attach using standard #8-32 bolts as shown in Figure 7.

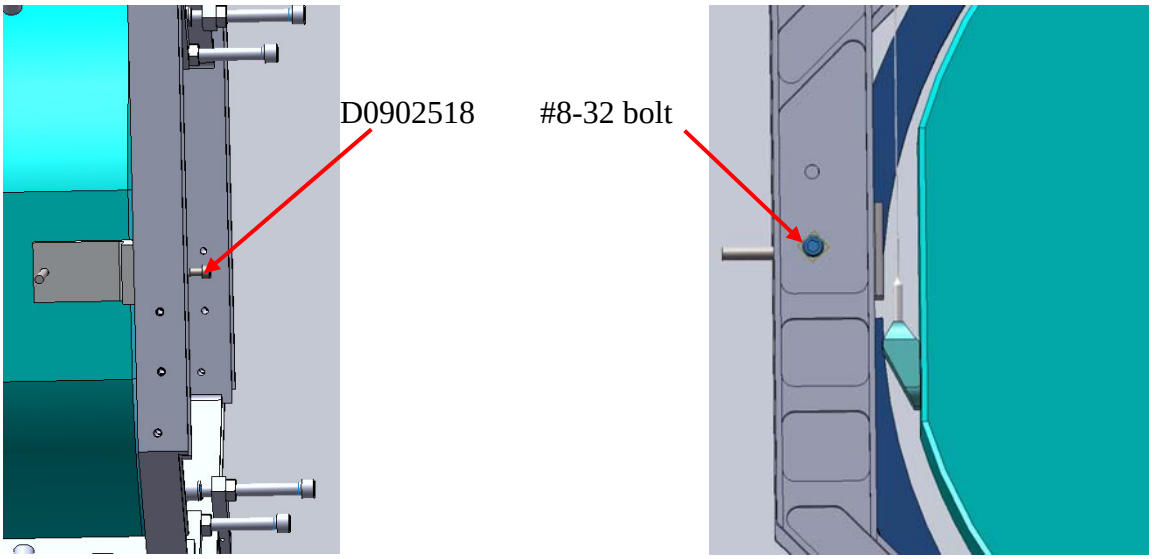


Figure 7 Brackets positioned over clearance holes in lower structure as shown then bolted directly into the sctructure

The guide rods (D1001830) are screwed into the top and bottom brackets (D0902518 and D0902519) shown in fig. 8.

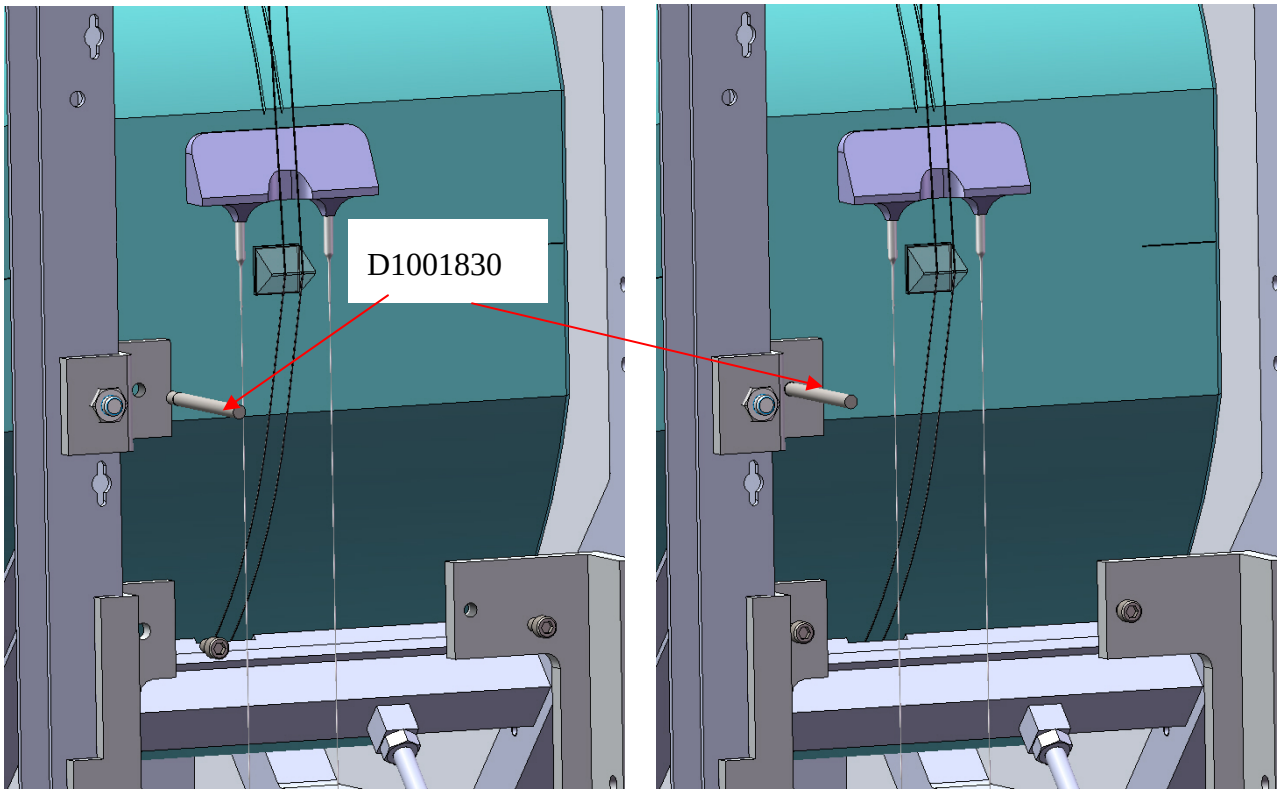
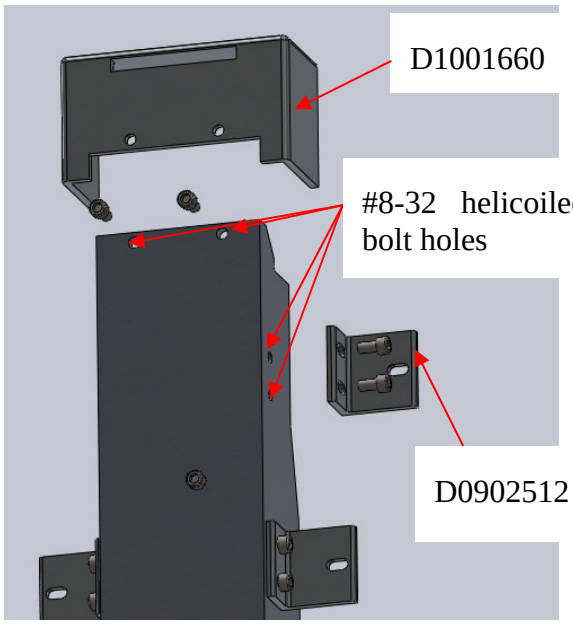
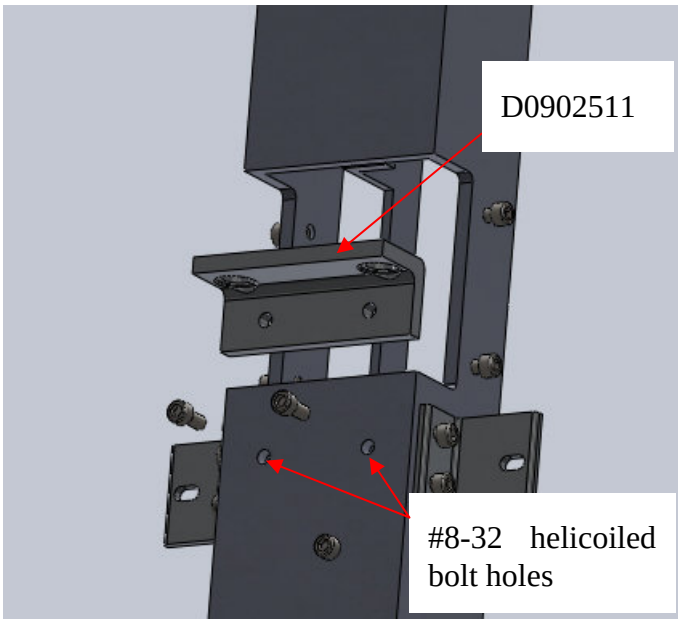


Figure 8 Guide rod being threaded into bracket prior to insertion of the fibre guard main body. Left: guide rod in approach. Right: guide rod in place.

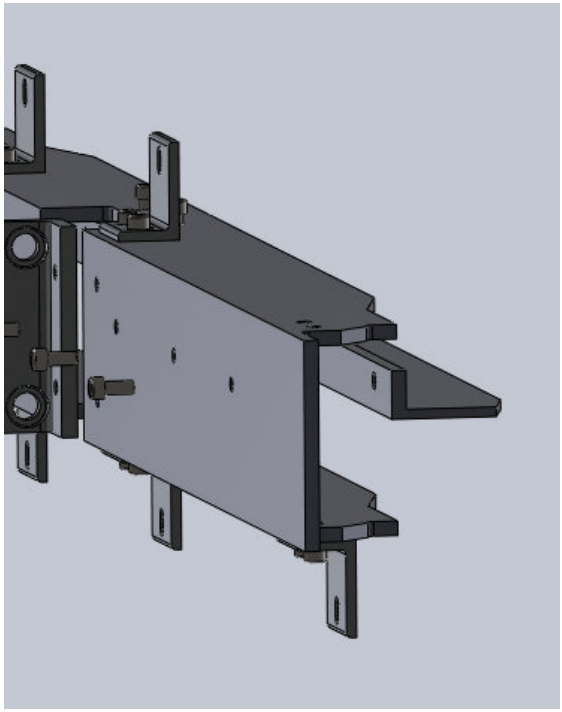
Brackets D0902512 attach to the body of the fibre guard (D0902507) as shown in fig. 9, the spine (D0902508), top cap (D1001660) and the base support for the violin mode sensor (D0902511) are also bolted to the main body.



a) Installation of the cap and brackets



b) Installation of the violin mode shelve bracket



c) Installation of the spine

Figure 9 Installation of brackets and spine onto main body of fibre guard

The guard can then be manoeuvred into place in the structure using the guide rails and the 4 central bolts used to fix it in place. The guide rails are removed and the final bolts inserted. This is shown in Figure 10.

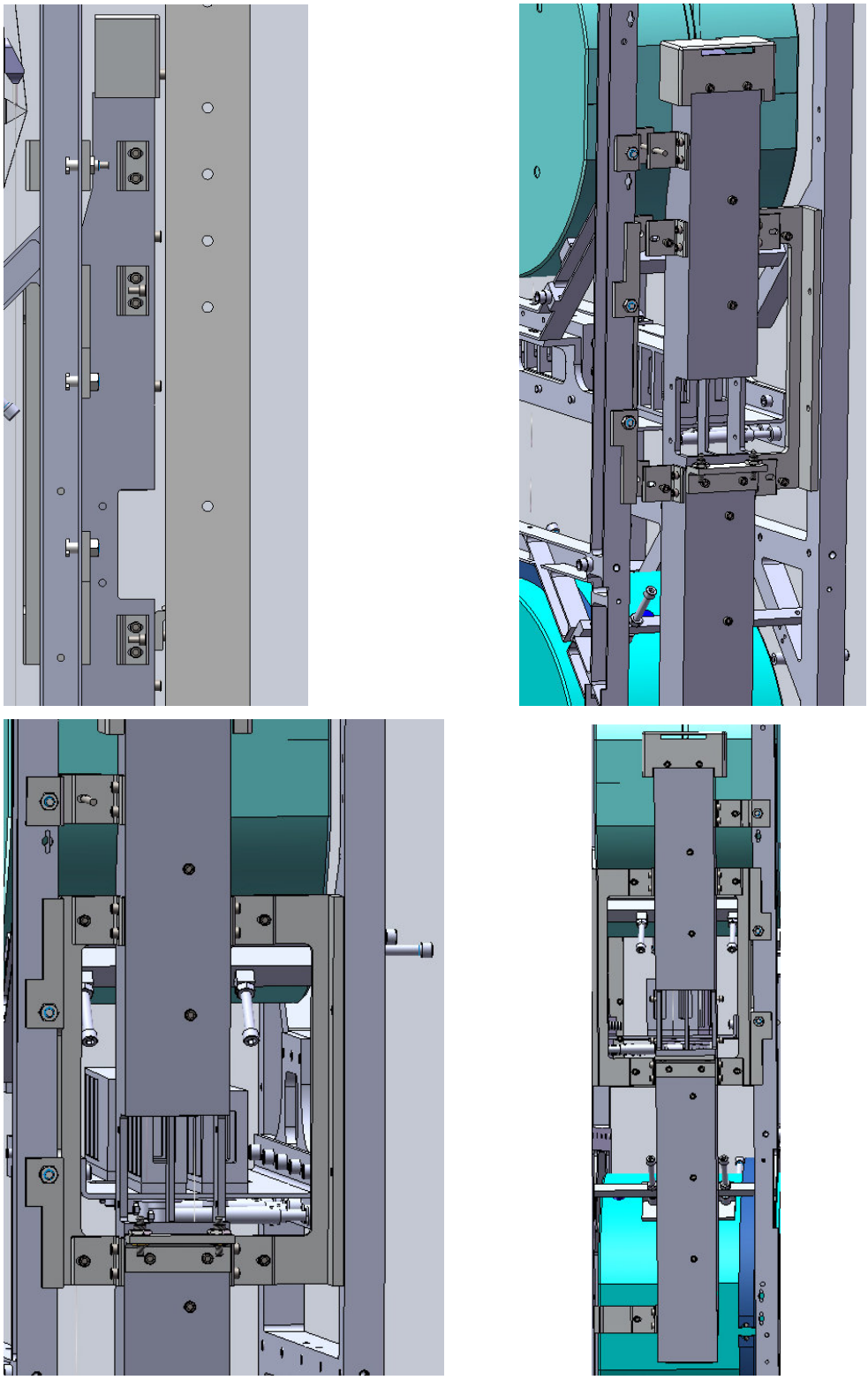


Figure 10 Top left: Clearance between guard and LSAT during insertion. Top right: the guard sliding along the guide rails prior to fixing using 4 the central bolts. Bottom left: 4 central bolts fastened. Bottom right: Guide rails removed and all bolts fastened.

At this point the violin mode sensor housing can be inserted into the structure if required (Figure 11) or the blanking plate (D0902513) can be used to cover the opening in the guard (Figure 12).

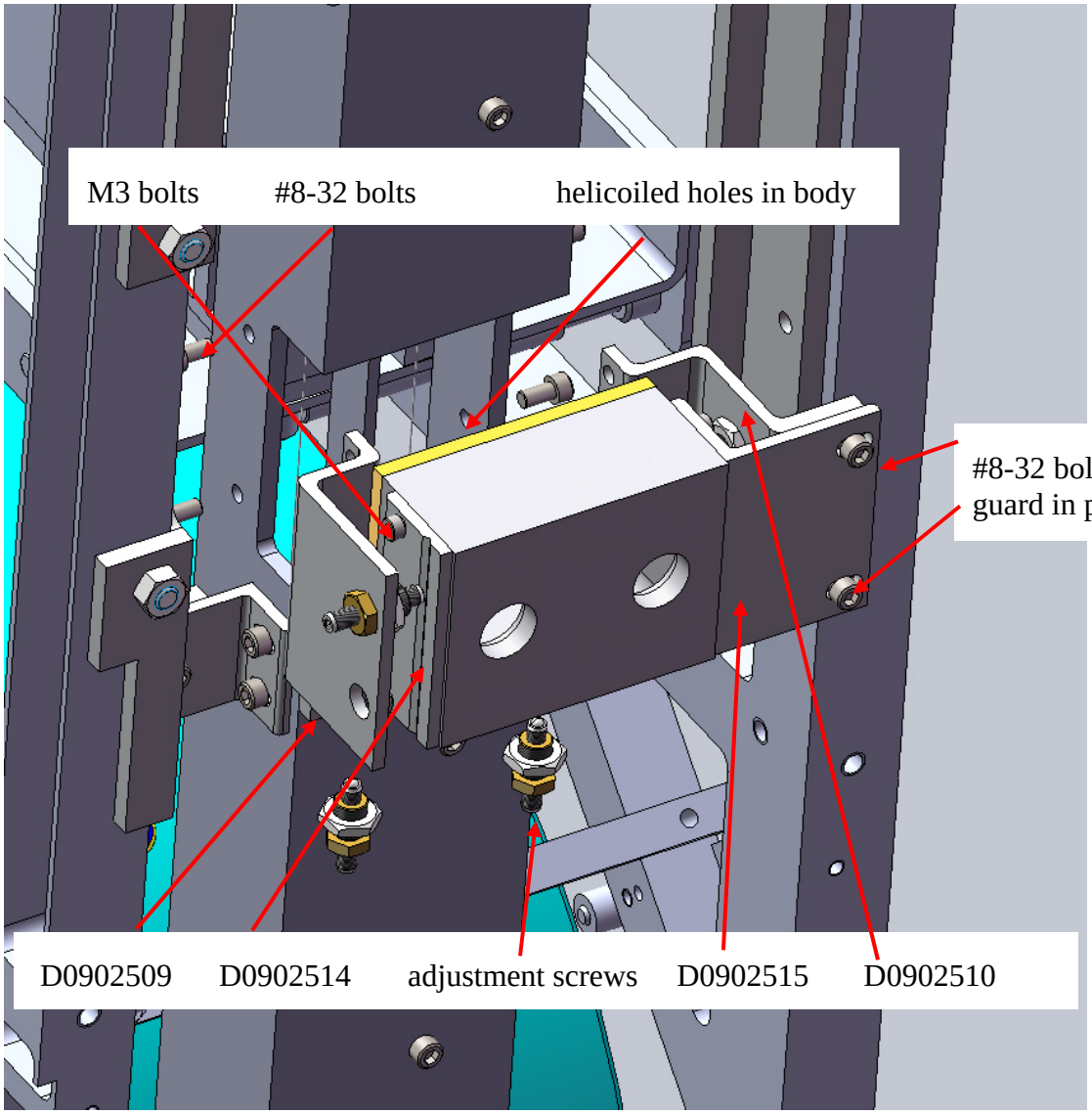


Figure 11 Installation of violin mode sensor housing, with adjustment screws and brackets

Brackets D0902509 and D0902510 should be secured to the body using #8-32 bolts. The ultrafine adjuster assemblies should then be put in place before inserting the assembled violin mode sensor. D0902514 and D0902515 are secured to the sensor body with M3 bolts. When the sensor is suitably positioned the fixing bolts are tightened. If the VMS is not required then the blanking plate (D0902513) can be used to cover the opening in the guard.

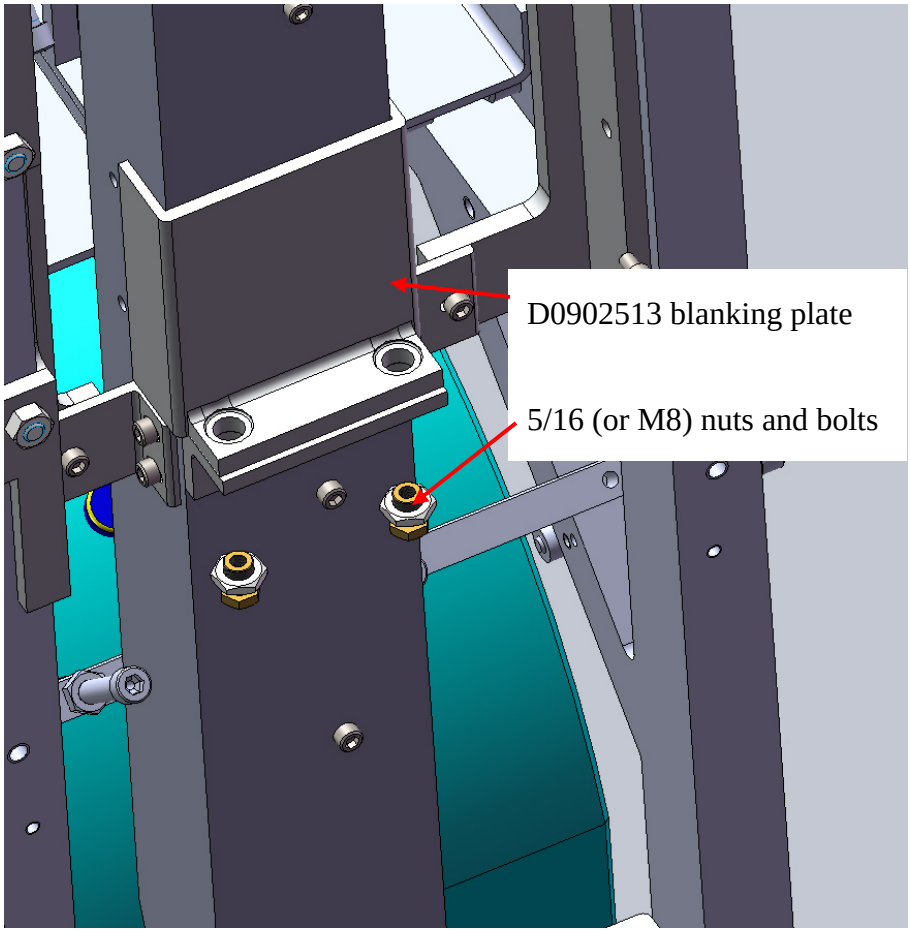


Figure 12 Blanking plate in fibre guard with 2x 5/16 bolts (or M8) to secure