

LIGO Laboratory / LIGO Scientific Collaboration

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Advanced LIGO

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**Summary of silica suspension fibre breaks during the
aLIGO project**

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A summary instances when silica fibres have broken in aLIGO suspensions

There have been three incidents involving broken fibres on production suspensions during the construction of aLIGO.

- 1 ITMY 18th October 2011
- 2 ITMY 2nd March 2012
- 3 ETMY 16th December 2013

- 1) The first incident was on a completed quad (quadruple suspension assembly) during installation work. A bolt dropped from above the penultimate mass and "rattled" down one of the fibre guards, hitting and breaking a fibre on the way (<https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=1587>). A redesign of the fibre guards and suspension tooling took place to ensure that the risk of any future event was minimal.
- 2) The second incident occurred when a model controlling the active isolation was compiled in a way that resulted in uncontrolled output to an actuator. The end result was that the suspension was driven beyond its design limits for many hours. Approximately one hour after the initiation of this uncontrolled state, at least one fibre failed (<https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=2352>). A series of subsequent tests on excitation of fibres under load at Glasgow confirmed that long term excitation of the fibre would not result in a break if the mass was constrained within the suspension design limits. These tests are documented in G1200385 and include shaking for several hours in excess of the accelerations experienced at the site, in addition to shaking while dropping plastic and metal chips onto the fibre. The two most likely explanations for a breakage in this event are: impact on the fibre due to an object released by the excitation **or** a large enough roll mode amplitude such that the fibre touched the fibre guard. The evidence for the former is only one small metal fleck and some "cloth type" fibres found on the chamber floor, and neither of those is likely to have cause the break (see video "metal_chips_2.avi" in G1200385). The latter explanation would require a mode amplitude large enough to reduce the fibre tension to zero, or about 6 mm. There is evidence from the OSEMs that the roll mode was rung up just before the break, with a large amplitude at the break. There are no mechanical constraints on the mass for the roll mode, unlike the other degrees of freedom. If the fibre did come in contact with the inside surface of the guard, it would then almost certainly break when under full load.
- 3) The third incident occurred during the welding of the fibres between the test mass and the penultimate mass, prior to integration into the full quad and installation in chamber. After being welded in place, the fibres were left under tension over a weekend. On the Monday morning it was found that two of the fibres had broken. (<https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=8979>). During an inspection of the area around the mass a dead bug was found and at least one other live one. It is perfectly reasonable that an insect landing on a fibre under tension could cause it to break. However, in this case the lower suspension assembly had been stored under a cloth cover, and so it was unlikely that the insect could have both

got into the fibres and then ended up back outside again. The only previous occasion where a fibre was observed to fail more than a few minutes after full tension had been applied was during a welding training event in Glasgow. In that case, an early version of the welding control program had caused the mirror directing the laser beam during welding to jump and misdirect the beam, which then hit the fibre. Although the fibre did not break at that time, nor even when put under full tension when the mass was suspended, it did break during the next 12 hours. The ETMY welding at LHO (16th December 2013) was one of the first times we had used a metal shield on the sapphire prism. It is possible that a reflection of the welding beam from this shield had hit one of the fibres. Welding practice has subsequently accommodated the awareness of this possibility, and hence we should avoid future occurrence of such an event.

Of the three fibre failure events, the only one where we do not have good direct or circumstantial evidence of the root cause is the December 16th event. Experience suggests that accidental heating of the fibre during welding was the cause, as:

- a) there is no strong evidence of any other cause
- b) we have seen this type of failure once previously
- c) it is possible that the fibre could have been hit by a reflection from the prism shield.

The process of welding the four fibres between the penultimate mass and the test mass, and subsequently installing the full quad has been successfully completed 11 times. The current status of the fibres in the quads in aLIGO is that they have been under tension, at or close to their working value, since construction. The operational life equates to more than 65 fibre-years, with the two "in-situ" failures coming from external causes.