We thank both referees for their comments. We have addressed all the comments in our revised submission. We give details below on each comment.

*1: The abstract is lengthy. Many of the sentences are repeated in the introduction section, and it displeases readers. The authors should replace this part by a concise abstract that represents the long paper.*

We have reduced the abstract by approximately a factor of two. We copy the revised abstract below.

“We describe the design of the suspension systems for the major optics for Advanced LIGO, the upgrade to LIGO - the Laser Interferometric Gravitational-Wave Observatory. The design is based on that used in GEO600 – the German/UK interferometric gravitational wave detector, with further development to meet the more stringent noise requirements for Advanced LIGO. The test mass suspensions consist of a four-stage or quadruple pendulum for enhanced seismic isolation. To minimize suspension thermal noise, the final stage consists of a silica mirror, 40 kg in mass, suspended from another silica mass by four silica fibres welded to silica ears attached to the sides of the masses using hydroxide-catalysis bonding. The design is chosen to achieve a displacement noise level for each of the seismic and thermal noise contributions of 10-19 m/√ Hz at 10 Hz, for each test mass. We discuss features of the design which has been developed as a result of experience with prototypes and associated investigations.”

*2: (1.Introduction) Although most of the readers of this paper would be in the same GW field, it would still be a good idea to explain why suspension is needed in interferometric GW detectors in the first place.*

We have added text at the beginning of paragraph two of the introduction. This now reads as follows.

“Gravitational waves are ripples in the curvature of spacetime which propagate at the speed of light. A passing wave distorts spacetime and results in a relative displacement change between free, or inertial, test masses. An interferometer provides a convenient method for making measurements of such changes. The aLIGO detector topology comprises a Michelson interferometer with Fabry-Perot cavities (Harry et al. 2010) and incorporates four test masses in each detector, one at each end of each arm. These test masses are required to be suspended to act as inertial masses in the frequencies of interest and to provide isolation from seismic disturbances.”

*3: (Section 2.5.1) More explanations are needed to explain the effect (not in the figure). It is difficult for the readers to understand the importance of this effect, since no numbers are shown. (E.g. xxx % of reduction in resonant frequency for xxx Kg load at xxx-degree wire tilt.)*

We have modified the text for section 2.5.2, including numbers. It now reads as follows.

“2.5.2 Geometrical antispring effect

The wires attached to the tips of the springs are not vertical. To varying degrees they are angled towards the root of the blade, so the load on the tip has a longitudinal, as well as a vertical, component. A longitudinal load on a straight blade will have no effect on blade deflection. However, the blades are typically not straight in operation, so any longitudinal load will generate a bending moment at the tip (as shown in figure 3, fourth diagram). This moment will cause additional deflection of the blade, so the overall blade deflection is greater than would be the case were the wires vertical. This effect tends to soften the vertical compliance of the springs and make the vertical frequencies lower than would be seen without this effect. For example, the top springs are each loaded by 62 kg at an angle of 21 degrees, and show a reduction in vertical stiffness to 70% of the value they would have under purely vertical load.”

*4: (Section 2.5.3) Same as above, especially for the effect #3. Figure 5 is unclear and incomplete to explain the pitch unstability. Explanation of “T” is missing.*

We have expanded the text in point 3 of section 2.5.3 , defined T and added some text to figure 5, and expanded the figure caption to better explain what the figure is showing. Modified text is as follows.

“3. The blade springs lie such that their long axis is close to being perpendicular to the longitudinal (x) direction. (see figure 1). They are narrow compared to their length to give a more compliant blade in the vertical direction, and this means that their lateral compliance, i.e. their compliance in the horizontal plane at right angles to their long axis, has a significant effect. Any lateral deflection of the wire caused for example by motion of the suspension in the longitudinal direction will lead to a lateral load on the blade tip, which will cause the blade tip to move laterally. That means in turn that the wire moves further laterally than would be the case with a laterally stiff blade. This is illustrated in figure 5, which shows the effect of a wire tension T acting at an angle. In the figure it can also be seen that the effective pivot point after a lateral translation is a smaller distance from the blade tip than the original flexure point. This in turn leads to a suspension that has less margin for stability in pitch than would be the case in a suspension with stubbier and hence laterally stiffer blades.”

Revised Figure 5 caption is as follows.

“The oblong represents a blade tip seen end on, i.e. looking horizontally along the long axis of the blade from its tip. Diagram A shows a wire attached vertically to the blade tip. Diagram B shows the effect of lateral translation of the blade tip caused by a horizontal component of the tension T applied by the wire. The dotted line represents the original position of the wire attached to the blade. The effective flexure or pivot point of the translated blade/wire system is not the same as the flexure point of the wire. It has now been raised, reducing the margin for stability.”

*5: (Section 3.3, Fig.8) 1) Is the peak height for the horizontal mode is correct?*

The figure has been checked and the peak height is correct for the aLIGO pendulum mode thermal noise.

*2) How much vertical-to-horizontal coupling is assumed here?*

A cross coupling of 0.1% is assumed (stated and now expanded upon in **Section 5. Expected performance**) and this has been included in the caption of fig 8 which now reads:

“Figure 8. Displacement thermal noise spectra for the monolithic stage of a single aLIGO monolithic suspension (adapted from Cumming et al. 2011a). The total noise is made up from the quadrature sum of contributions from the horizontal pendulum mode, the vertical mode with a vertical-horizontal cross coupling of 0.1%, the first two violin modes and silicate bonding of the attachment ears (see section 5 for comment on the cross-coupling value). The thermal noise requirement curve, which is defined from 10 Hz and above, is also shown. The requirements curve is for the quadrature sum of longitudinal and coupled vertical thermal noise, each of which is 10-19 m/√Hz at 10 Hz. Not shown is the thermal noise contribution from upper stages of the quadruple suspension, which falls below the noise from the monolithic stage by 10 Hz.”

*3) The contribution from “Bonds and ears” is misleading (or incorrect), since authors have stated that it is the main contribution to the loss angle in Sec. 3.1. From the figure, readers may get an impression that the contribution is negligible.*

Section 3.1 has been reworded to give the loss mechanisms in order of importance (fibre, weld and ear-mass silicate bond region) and that part now reads:

“In the aLIGO monolithic suspension the contributions to the loss angle, in order of importance, are from the fused silica fibre (Penn et al. 2006, Gretarsson et al. 1999, Cagnoli and Willems 2002), weld loss (Heptonstall et al. 2010) at the fibre/ear attachment point and mechanical loss associated with the with the ear-mass silicate bond (Cumming et al. 2011a).”

*6: (Section 4.1, Fig.9) Most important components in the assembly (the LED, the flag, and the coil) are not indicated.*

The figure and caption have been revised.

*7: (Section 5, Fig.12) 1) Some explanations are needed for the coupling assumption. How can the assumption (1/1000) be justified?*

We have added text to explain the assumption of 0.1% cross-coupling as follows.

“We take 10-3 as a conservative estimate of the cross-coupling factor. There is a small inherent cross-coupling of vertical to longitudinal due to the curvature of the Earth over the 4 km arm lengths of LIGO, since verticals defined by local gravity at each end of an arm are not parallel at a level of 6 x10-4 radians. Further cross-coupling will be introduced via mechanical imperfections in the suspension. However from analysis, these effects have been shown to be small (Husman et al 2000).”

*2)(Same as Fig.8) Put aLIGO requirement for comparison.*

The aLIGO requirements are now shown in figs 8 and 12.

*8: It is better to show some experimental (performance) data, in order to make readers believe this system would really work.*

We have revised section 5, and added another figure, figure 12. The old figure 12 has now been renumbered as figure 13 and figure 13 has become figure 14. The revised text is as shown below. We have also revised the caption for figure 13 (what was figure 12). We have added one more reference to support this section (Shapiro 2011).

“The expected thermal noise performance was shown in figure 8 in section 3. As noted in section 3.1, we have seen good agreement between measured and modeled losses for violin modes in prototype monolithic suspensions, which gives us confidence in the thermal noise modeling. A direct measurement of thermal noise performance will require a full interferometer with good sensitivity.

As there are no local sensors at the test mass stage, we must rely on a dynamical model of the suspension in order to predict the residual motion until global sensing becomes available. We are able to excite and measure 22 of the 24 rigid-body, resonant modes from the top stage of the suspension. Thus measuring the response of the top stage sensors to excitation in all six degrees of freedom at the top mass and comparing against the predicted response from our model is sufficient to confirm the model's accuracy in predicting the response at all stages to drive at all stages (Shapiro 2011). Figure 12 shows the measured response of the top mass chain to actuation at the top mass in the longitudinal direction for two first article suspensions, compared against our model. We see that the agreement is very good. We have repeated such measurements in all degrees of freedom and have confirmed agreement with our model for all 22 low frequency modes of the quadruple suspension. In addition we have confirmed that we can lower the quality factor of all these modes to a suitably low value (Q ~ 10) for global feedback to operate.

With this affirmed dynamical model, we can then predict the response of the test mass to residual seismic motion at the suspension point, with active damping loops engaged. Using this response, we predict the displacement of the test mass by taking as the input to the suspension point the current expected noise performance on the final stage of the internal two-stage isolation system, the BSC-ISI (Matichard et al. 2010) from which the suspension is hung. Figure 13 shows this expected performance in the X (longitudinal, parallel to the cavity axis) and 10-3 x Z (vertical, parallel to local gravity) directions, where 10-3 is the assumed cross-coupling factor betweeen the vertical and longitudinal directions. We also show the quadrature sum of X and 10-3 Z. We take 10-3 as a conservative estimate fo the cross-coupling factor. There is a small inherent cross-coupling of vertical to longitudinal due to the curvature of the Earth over the 4 km arm lengths of LIGO, since verticals defined by local gravity at each end of an arm are not parallel at a level of 6 x10-4 radians. Further cross-coupling will be introduced via mechanical imperfections in the suspension. However from analysis, these effects have been shown to be small (Husman et al 2000). Motions in the other degrees of freedom are estimated from modeling to give less longitudinal motion than the X and Z contributions. Also shown in figure 13 is the seismic noise requirement for the quadruple suspension in conjunction with the BSC-ISI.

The high-Q, resonance seen at 9 Hz is one of the 2 undamped modes of the suspension. (The other is a roll mode at ~13 Hz.) The noise at 10 Hz is just above our requirement of 10-19 m/rtHz, due to a combination of the shoulders of the 9 Hz resonance and an enhancement of residual noise on the internal isolation system around 10 Hz caused by bending modes of the vacuum chamber support structure upon which the BSC-ISI is mounted. As these two features are limiting the performance, several options are being explored to reduce their contribution including local feedback at lower stages of the suspension (for the 9 Hz mode), feed-forward control on the BSC-ISI, and external mechanical stiffening / damping (for the support structure resonances). Contributions to the above displacement prediction notably do not include higher-order, non-rigid body, high-Q modes of the suspension (specifically the first fundamental or "violin" modes of the suspension fibers, at ~500 Hz) as well as technical noise contributions such as actuator and sensor noise. We require displacement due to technical noise to be a factor 10 below the expected residual seismic motion at 10 Hz and modeling of those noise sources using the most up-to-date configuration of their design is ongoing.”

Comments from the second referee.

*Figure 12 could be improved, both in quality of the graphics (very difficult to read), and in content of the the caption (poor)*

We have modified the text in the figure (which is now figure 13) to improve clarity, and revised the caption.