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Comments on "Mechanical noise from optical contacting"
by Rai Weiss

In the memo 7488a.tex an idea has been presented that optical contacting may produce noise due to the release of potential energy which is the consequence of nonperfect contact between the two contacted surfaces. The amount of potential enery and the relaxation time for this release are not known. Rai Weiss assumes the maximum possible energy release on the least favourable time scale of 1 year and arrives at a potentially worrisome result $10^{-17} m/Hz^{1/2}$. We have no concrete data strongly supporting or denying these assumptions. However it is worth remembering that the Glasgow interferometer has optically contacted mirrors and has achieved sensitivity which is already 10 times better then the predicted number.

In the absence of data on the two crucial numbers on the potential energy in the joint and on the relaxation time and also on the relaxation process, I would like to share some information which Alex and myself obtained while we were studying the Q factors of test masses. I believe this information gives a strong clue that the noise in optically contacted joints is very small.

The experimental setup of our measurement is reported in J. Phys. E: Sci. Instrum. 21(1988)453 – 456. As reported in this paper, we measured the mechanical Q value of a cylinder of fused silica made by optically contacting two cylinders together and we found that losses calculated from this measurement agreed to within measuring error (5%) with bulk losses of a whole (noncontacted) piece. We also came across a puzzling piece of information, which was not put in the paper, because we had no time to pursue it further, but it now appears to me that it may be an important clue to the relaxation time in the contacting joint. We contacted the pieces in air and left them there for about three weeks. Then we got the Q measuring experiment ready and measured the Q of the contacted piece in air. The result was about 11000. We then evacuated the chamber with the experiment and obtained only slightly better Q in accordance with our estimate of how much the air should damp our particular piece. We left the piece in vacuum for two days and repeated the measurement. To our surprise the Q was now higher - 19000 and did not improve in the next day. This result indicates that at least one relaxation time in the contacting joint is shorter then 2 days and longer then a few hours. If this relaxation time can be identified also as the energy relaxation time, the available energy after one year is completelly negligible almost irespective of what kind of relaxation process one could imagine.

The other piece of information which may be a clue in the question of noise in optically contacted materials is the following. At the end of 1986 the Caltec and Glasgow gravity wave prototypes used mirrors joined to the masses with vacuum grease so as to prevent stresses induced by differential thermal expansion between the masses, made of brass, and silica mirrors. I had the idea that the excess noise in the interferometers of the time ($10^{-17}m/\sqrt{Hz}$) was in fact thermal noise in the harmonic oscillator mode where the grease acted like a very lossy spring between the testmass and the mirror. In order to test this idea, I tried to detect this mode. The task was difficult since the transfer function of the interferometer was not known to sufficient accuracy to measure a very low Q mechanical resonance in the testmass - mirror joint and the mirror is so precious that no transducer could be applied to it to measure its relative motion with respect to the testmass. I, therefore, applied a piezo to the testmass and carefully measured its frequency spectrum (resonances and their Q's). I then removed the mirror and measured the frequency spectrum again. Resonances have moved and their Q factors changed considerably. I identified the first longitudinal resonance and used a simple one dimensional wave model on this resonance - i.e. I considered the mass as a thin bar with free ends when the testmass had no mirrors and the mass was modeled as a thin bar with a harmonic oscillator attached to its end for the case when the mirror was glued to the testmass. The mass of the harmonic oscillator is the mass of the mirror and the spring and the damping constants were determined so that the model would best fit the observed frequency and Q factor shifts. To my surprise I obtained a very low Q resonance at about 5kHz and the ordinary thermal noise in this resonance could explain the measured noise in the interferometer. When the mirror contact was changed to optical contact, the noise in the Caltech interferometer did not improve drastically, until the mode cleaner was introduced in the system. My argument was,therefore, not convincing. However the Glasgow group reported that their noise performance definitly improved after they changed the grease for optical contact (Glasgow report to the 13^{th} *Texas meeting in Chicago* 1986). This gives yet another clue that mechanical losses may introduce "thermal noise" in a nonobvious manner. In this respect Alex and myself have measured losses in different types of joints and we found that for example a layer of a few microns of Glasgow glue joining two fused silica cylinders 3/8 inch thick dissipate almost as much energy as the two blocks together when the glued cylinder oscillates in its first longitudinal mode. When the same two fused silica cylinders were glued with a comparable layer of cyanoacrilate (crazy glue) the losses increased 24 fold. We could not repeat this experiment with the vacuum grease contact, but the previous experience with test masses and mirrors indicates that in this case the losses would be even greater possibly by more then an order of magnitude. It is remarkable that no losses beyond bulk losses in fused silica were detected when the two cylinders were optically contacted. This is again not a proof, but a clue that the noise in optically contacted joints might indeed be very small.