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LIGO Laboratory / LIGO Scientific Collaboration

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Report from the Thermal Noise Interferometer Technical Advisory Board Meeting

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The Thermal Noise Advisory Board met by telecom April 20, 2007 to discuss priorities for the TNI. Present at the call were Gregg Harry (chair), Andri Gretarsson, Sheila Rowan, Eric Gustafson, Bill Kells, Vincenzo Galdi, Innocenzo Pinto, Garilynn Billingsley, Michele Zanolin, and Eric Black.

The TNI Advisory Boards recommendations as priorities for the TNI for the next six months are to 1- get the most out of existing data, 2 – investigate whether measuring Gaussian noise from charging is realistic, 3- measure thermal noise from the optimized coating designed in Sannio, and 4- investigate whether it is realistic to measure suspension thermal noise. More details on each of these recommendations follow.

The highest priority activity for the TNI should be to fully understanding the existing data, especially the data on the LMA titania-doped tantala/silica coating. Key to this is to finish the re-evaluation of the TNI calibration, including making sure the cavity length change is the only important change to the previously used calibration and understanding how previous results will change with any calibration changes. A technical note should be written on what is learned about calibration and changes to previous results that is circulated among the TNI Advisory Board, coating mailing list, optics working group, core optics mailing list, etc. A crucial question to answer is whether the TNI results do agree with what is expected for thermal noise based on the Q measuring program.

Secondarily, existing data should be evaluated for thermo-optic noise. This may include fitting the thermal noise with both Brownian and thermo-optic noise included, to see if better fits might results, as well as setting limits on dn/dT for tantala and titania-doped tantala based on TNI data. Results from this should quickly be shared with the coating working group to better inform research on dn/dT at Embry-Riddle.

Based on the results of these studies, the question of coating new optics for follow up studies will be investigated. At least two possibilities will be considered, redoing the titania-doped tantala/silica coating to check how repeatable the thermal noise is, and increasing the reflectivity of titania-doped tantala/silica mirrors to reduce shot noise and thereby possibly uncover more thermo-optic noise. This will be evaluated and discussed at another TNI Advisory Board meeting in mid to late summer of 2007.

The second priority should be investigating the feasibility of directly measuring Gaussian noise from charge buildup on the optics. Such a measurement would be very valuable to the overall LSC effort to understand and reduce noise from charge. The LSC charge mitigation project was set up in response to numerous statements by the NSF LIGO Review Boards and is thus very important to LIGO. One concern is that charge noise is expected to be primarily a low frequency (< 100 Hz) issue and may not be visible in the TNI. However, the noise scales with the amount of charge so, at least on paper, any level of noise can be achieved with enough charge. The TNI team should investigate what level of charge might be needed for the noise to be measurable at the TNI. If it seems realistic, further planning should occur on how to introduce charge on the TNI mirrors, how to monitor it in situ, and any other changes to the TNI setup that may be necessary. Depending on the results of this study, direct measurement of charge noise may become the top priority for the next experimental program at the TNI. This will also be discussed at a late summer TNI Advisory Board meeting.

The next priority is to measure thermal noise from the tantala/silica coating designed by the Sannio group with layer thicknesses optimized to minimize thermal noise. There have been many delays in getting this mirror coated at LMA/Virgo, but we are told that following the LASTI optic which is being coated now, these optimized mirrors for the TNI are LMA's top priority. They should be available by June 2007. If this proves true, thermal noise measurements should be able to be done at the TNI in early summer and will be finished before the charging noise study is complete. Should there be further delays, any charging noise experiment should take priority over the optimized coating experiment.

The final priority for the next six months is to investigate the feasibility of directly measuring suspension thermal noise. Suspension thermal noise is the only major, limiting noise source for any generation of LIGO that has not been directly measured in a prototype interferometer, and as such it is very important to try to do so. However, as a low frequency noise source, it is very difficult to measure. This task has similar problems as the charging noise investigation, but it is important that the possibility of directly measuring suspension thermal noise in the TNI be investigated. This includes studying any hardware changes that might be necessary to do this, with an estimate of the cost in time, money, and manpower.

Other experiments that the TNI could pursue were also discussed. These tasks will likely be pursued, if they are pursued at all, after the next meeting of the TNI Advisory Board in the summer, so will be revisited then. The following list of tasks is in rough priority order, with comments.

Direct measurement of thermal noise from silica-doped titania/silica coating. This coating, developed with CSIRO, is the fallback coating for Advanced LIGO and as such it would be useful to have direct proof that the thermal noise is improved over Initial LIGO levels as Q measuring indicates. Development of this coating with CSIRO is still ongoing, the optimal concentration, annealing temperature, and other parameters have not been determined yet, so it would not make sense to do a TNI measurement right away. If our confidence in the Advanced LIGO baseline coating, titania-doped tantala/silica with optimized thicknesses, continues to grow, the priority of an experiment with silica-doped titania will decrease.

Direct thermal noise measurement of titania-doped tantala/silica coating with optimized thicknesses. This is the Advanced LIGO baseline coating, and it is a very high priority to measure its thermal noise with the TNI before coating Advanced LIGO optics. However, it is premature to pursue at this time, before a direct measurement of an optimized tantala/silica coating. The optimization process is still evolving as well, and some aspects of the optical properties of titania-doped tantala (scatter, dn/dT) are not fully characterized. Assuming these loose ends are tied up acceptably, perhaps a year from now, this experiment becomes one of the highest priorities.

Coating thermal noise versus position across the face of the optic. This is a test of how uniform the thermal noise from a coating is within a given coating. It is very important to understand how repeatable coating thermal noise will be, and measuring statistically independent sections of a single coating is a way to study this without having to make many expensive and time consuming coating runs. There are concerns that the additional hardware necessary to do this experiment will be difficult to develop. This should be pursued at a preliminary design level at a moderate priority.

Direct measurement of non-Gaussian noise, in general and from various particular mechanisms including silicate bonds and charge buildup. This is an interesting, important, and understudied topic that deserves to be investigated. However, valuable bench measurement can and should be done prior to any attempt to study this with the TNI. The group at Embry-Riddle is interested in doing these bench measurements and has the right background to be successful in this. Thus the burden will be taken off of the TNI team and they will be able to focus on experiments that can only realistically be done there, namely the other listed studies. Depending on the outcome of the bench tests, targeted experiments on non-Gaussian noise at the TNI might be valuable. These experiments would likely be in collaboration with the Embry-Riddle group, and utilize the experience and techniques (both hardware and software) that they develop. Any experiment at the TNI along these lines will likely be a year or more away, so will be discussed at further TNI Advisory Board meetings.

Thermal noise from silicate bonds. An experiment where one or more silica ears are silicate bonded to the face of a TNI optic close to the spot to maximize thermal noise from the lossy bond seems realistic. Current understanding is that the silicate bond is very lossy so is a potential thermal noise problem when used on LIGO optics, and direct measurement of thermal noise would thus be useful. However, the current Advanced LIGO design has the bond connecting the core optics to the suspension sufficiently far away from the spot that even a very lossy bond is not predicted to cause an increase in thermal noise. Unless the Advanced LIGO design changes, this experiment is only valuable as general research into this important bonding technology. This is worthwhile, but does not rise above the other suggested experiments in priority.

Measuring the change in coating thermal noise with a change in spot size. One of the critical ways that coating thermal noise is kept low in Advanced LIGO is to increase the laser spot size. Verifying with direct thermal noise measurements that this works as predicted is valuable. However, this has already been done to some degree by the comparable measurements on tantala/silica coatings at the TNI and in Japan by Kenji Numata with different spot sizes. The results are as expected (baring changes from the re-evaluation of the TNI calibration) and as such do not require follow up studies. There is some value is doing this measurement on mirrors coated in the same coating run, to guarantee the same coating properties. There are indications, though, that the changes necessary to the TNI to significantly change spot sizes are significant. All this together makes this a low priority experiment.