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Date: Tue, 03 Sep 2002 04:15:03 -0700
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Subject: Fwd: Re: Thank you

For the DCC.

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Subject: Re: Thank you
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X-Mailer: Microsoft Outlook Express 5.50.4807.1700

Hi Barry, Gary, Ken, Alan,

The following is the report for some of the major activities for which I was mainly involved in during my stay at Caltech this summer.

Take care!

Seiji

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1. TNI

(1) Locking of the arm cavity
We had difficulty in locking the arm cavities with the reason, which we suspected might be related to the existence of the 21Hz bouncing mode of the pendulum. Actually there existed a relatively large 21Hz component in the local suspension sensor signals. Shanti and Eric realigned the suspension sensor/actuator head to minimize this coupling, but it did not reduce the coupling significantly. Then we tried to lock the arm cavity with a reduced incident laser power and a correspondingly increased electronic gain, suspecting that the scattered light of the resonant light might be coupled to the local suspension sensors.

We succeeded in locking the arm cavity with the reduced light power, and the lock holding time was found to be longer for less light. After doing some diagnostic check, we concluded the following mechanism is the case for this. The bouncing mode of the test mass is excited purely seismically, which is coupled to the longitudinal motion of the mirror by either a slight misalignment of the mirror or a vertical-to-orientation cross coupling. This motion is controlled by the length servo system, thus it appears in the servo loop signals. Since the optical gain is relatively high with the maximum laser power (and the electronic gain is set to be low correspondingly), the demodulation signal is saturated due to the 21Hz component, although the feedback signal is not saturated because of the higher voltage range of the filter/amplifier. Thus decreasing the laser power reduces the 21Hz component at the demodulation signal and avoids the saturation. Incidentally it turned out that the coupling between the resonant laser light and the local suspension sensors did not take place.

We also implemented the gain boost at lower frequencies so that we can immediately increase the gain after the lock acquisition to further reduce the 21Hz component at the demodulation signal. With the help of this system the lock acquisition is possible with up to half the maximum laser power and the lock is held for more than several hours.

(2) Noise Estimate

a. Shot Noise
The spectrum of the demodulation signal was measured with the flashlight shone onto the photodetector with various DC photocurrents. Then the noise was converted to displacement using the optical gain of the interferometer, which was measured independently. Using the actual photocurrent when the arm cavity was locked, the shot noise was estimated to be about 10^-18 m/rHz.

b. Photodetector Noise
The photodetector noise including the demodulation process was estimated. The demodulation signal without any light on the photodetector was measured and converted to the equivalent displacement noise using the optical gain of the interferometer. It was a factor of 2-3 lower than the shot noise.

c. Filter/Amplifier Electronic Noise
The electronic noise of the filter/amplifier used to lock the arm cavity was measured and its input equivalent noise was converted to the equivalent displacement noise using the optical gain of the interferometer. It was factor of 3 lower than the shot noise at 1kHz.

d. Intensity Noise
The intensity noise of the laser light appears at the output of the interferometer, coupling with the deviation of the operating point of from the dark fringe. This deviation was measured by modulating the intensity of the light and measuring the corresponding signals at the output of the interferometer. It was measured to be 2x10^-12 m. The intensity noise of the laser light was measured independently and it was converted to the equivalent displacement noise using the obtained deviation. It was 1x10^-18 m/rHz at 1 kHz. To make sure that it is not limiting the current sensitivity of the interferometer, we intentionally deviated the operating point from the dark fringe by injecting the DC offset into the demodulation signal. We found no change in the sensitivity, which indicated that the intensity noise was not limiting the current sensitivity.

e. Shot Noise and Electronic Noise in the MC Servo
The modulation depth of the MC servo was temporarily increased by a factor of 3 and the electronic gain was reduced correspondingly, which would reduce the frequency noise of the light coming out of the MC due to the shot noise and electronic noise in the MC servo. The sensitivity of the arm cavity servo was not changed at all by this. It indicates that the current noise of the arm cavity servo is not limited by the frequency noise due to the shot noise and electronic noise in the MC servo.

(3) Calibration of the Arm Cavity Servo System

The arm cavity servo was re-calibrated by referring the coil-magnet actuator efficiency to the laser PZT efficiency. A signal was injected into the PZT path of the MC servo loop, resulting in the imposed frequency noise of the light coming out of the MC. This noise can be measured at the resulting voltages applied to the PZT of the laser. This noise is controlled by the arm cavity servo;

it appears at the feedback voltage to the suspension actuator. The coefficient from the laser PZT feedback signal to the arm cavity feedback signal was measured and they were related. Since we had known the efficiency of the Laser PZT by using the modulation-sweep-cavity method, we were able to calibrate the suspension actuation efficiency successfully. It turned out that the old calibration obtained by the fringe counting method was off by a factor of 1.7, resulting that the sensitivity curve obtained with this new calibration is a factor of 1.7 better than before.

(4) Current Sensitivity and limiting Noise

The sensitivity of the arm cavity is now 1x10^17 m/rHz at 1 kHz, which is a factor of 10 worse than the sensitivity obtained in May. We found that the noise spectrum was non-stationary and fluctuating even around 1 kHz, which made us suspect that the noise might be caused by scattered light. A lens which was inserted for the reflected light of the arm cavity inside the vacuum tank to focus the beam to the photodiode could be causing the scattered light because it is the only significant configuration change which was made between May and now. Unfortunately we did not have time to open the tank and investigate the scattered light problem, we should check this as soon as possible.

2. 40m RSE

(1) Gain and Phase Margin Check for Short-term Locking

After we locked the MC servo with the feedback path only to the PSL for less than 0.3 sec at maximum, we had difficulty in incorporating the path to the MC suspension. We felt that we had to make sure that the PSL path is optimized before checking the MC path. Usually when the lock is stable we can easily measure the transfer function of the servo by injecting the swept sine signal into a summing junction in the loop and measuring the signal before and after the summing junction. Unfortunately we cannot do this during 0.3 sec of locking. Thus we injected monochromatic signal instead and monitored by an oscilloscope the signals before and after the summing junction when it is locked using the transmitted signal as a trigger signal. This gives us satisfactory information whether the gain is optimal and the phase margin is enough. We found that it is a very useful diagnostic method in the process of optimizing the overall servo system. Actually we found with this method that the gain of the PSL path was unexpectedly low, which reminded us that the polarization of the light injected into the MC, which had been rotated by 90 degrees to avoid serious damages on the coating of the mirror due to locking in the air, was not restored properly after we evacuated the tank.