

LSC Six-Month Progress Report

LIGO-M000045-00-M

Organization German/British Collaboration for the Detection of Gravitational Waves (GEO 600)

Report Date 02/15/2000

Attachment A - Report to the LSC from the GEO/Cardiff group

The Cardiff group consists of the following members:

Name	Position	% FTE on LSC
B.S. Sathyaprakash	Staff	80%
R. Balasubramanian	Postdoc	100%
D. Churches	Postdoc	100%
I. Taylor	Postdoc	100%

We are working on the development of software to search for (1) in-spiral waves from coalescing black holes/neutron stars (Churches) and (2) unstructured bursts using time-frequency analysis (Balasubramanian). The latter should also be helpful in recognising instrumental and environmental transients.

We have delivered to ASIS a set of codes for in-spiral searches. These codes generate waveforms using the post-Newtonian approximation to $(v/c)^5$ order. The codes have been written in the LAL standard.

We have completed a study on the effect of non-Gaussian noise on time-frequency searches. A document describing the outcomes of this study was submitted to the ASIS in early January.

Our milestones for the next six months are:

1. Frequency domain templates (SPA, irSPA) (by the end of March)
2. Time-domain T-approximant templates with eccentricity (by the end of June)
3. Time-domain T-approximant templates for spinning binaries (by the end of June)
4. Template placement algorithms for point-mass, spinless binaries (by the end of September)
5. Recoding of Steger's code for curve detection (by the end of April)
6. Testing of time-frequency code on a beowulf system with simulated coloured Gaussian noise with the initial LIGO power spectrum. (by the end of April)

Over the last few years we have also developed better theoretical models for in-spiral searches which when used in data analysis searches should greatly enhance LIGO's chance of detecting in-spiral events. These models will be implemented in our search software over the next year.

Attachment B - Isolation/Suspension/Thermal Noise

Participation Univ. Glasgow
Hough 50%
N Robertson 30%
Ward 30%
Plissi 100%
Rowan 25%
Strain 40%
Cagnoli 80%
Torrie 100%
McIntosh 80%
Husman 50%
Sneddon 80%
Craig 80%

Univ. Hannover
Danzmann 5%
Aufmuth 20%
Lueck 30%
Mossavi 100%
Kloevekorn 100%
Weidner 100%

MPQ-Garching
Ruediger 10%

Item - Task 8 - a) Suspension systems under development

Over the last six months there have been significant developments in a number of areas relevant to the design of LIGO II. The first GEO triple pendulum suspensions, but not yet using silica fibers, have been tested in terms of mode frequencies and control and have been installed in the vacuum system at Ruthe, near Hannover. Based on this, a quadruple mass suspension system for LIGO II has been designed and modeled and made available to the isolation teams working in this area.

Research in silica fibers and ribbons is progressing well with fibers of breaking stresses up to 5 GPa having been produced. A demonstration system of a 10 kg mass hung by four silica fibers of diameter ~200 microns, welded to 'quartz' ears silicate bonded to fused quartz inserts, has been completed, and the mass has been hanging in laboratory atmosphere for the past 3 months. Low mechanical losses in silica fibers have been demonstrated and welding of the ends of the fibers to the quartz ears has been shown to introduce no extra mechanical loss.

Item - Task 8 - b) Required performance of suspension system

Measurement on subsystems and modeling of the GEO suspension/isolation system has indicated that overall vertical isolation should be $\sim 2 \times 10^6$, and overall horizontal isolation should be greater than 6×10^9 at 50 Hz. Reduction of approx. a factor of 10 for horizontal rms micro-seismic noise around 0.3 Hz has been achieved using feedforward.

Item - Task 8 - c) Further relevant research

Modeling of silica ribbons for LIGO 11 has been continuing and preliminary measurements have been made of the breaking strengths of ribbons manufactured in an rf furnace. An oxy - hydrogen system for producing ribbons is also under development. Another area of crucial importance being investigated for future detectors is potential mechanical losses (and hence increased thermal noise) resulting from the mirror coatings on the silica test masses. Experiments are underway on a fused silica test mass of

Corning 7940, figured and coated to have ultra-low optical loss at 1.06 microns by General Optics. Measurements suggest that the coating is increasing the loss factor from a figure of $\sim 6 \times 10^{-8}$ for the fundamental mode where the coating is not significantly flexed to a value of $\sim 3 \times 10^{-7}$ for a mode where the coating is flexed. This appears to be a very significant extra loss and comparisons with an uncoated control mass are currently being carried out to establish whether the loss is definitely associated with the coating. In collaboration with the Galileo group at Stanford and the MSU group we have been measuring the loss factors of some crystalline materials. Excellent results for HEM sapphire have been obtained with losses as low as 4×10^{-9} having been demonstrated. Better polishing of the sample of YAG mentioned in the previous report has reduced its mechanical loss from $\sim 4.5 \times 10^{-8}$ to 1.4×10^{-8} .

The experiment to measure the off-resonance thermal noise spectrum in a small suspended sample of fused silica is continuing at Hannover.

Attachment C - Progress Report for GEO on Lasers August99 – February 2000 for LSC

Over the last six months there have been a number of significant developments in the Laser work relevant for LIGO2:

We stabilized the monolithic nonplanar ring oscillator to an ULE reference cavity and achieve an error-point noise of less than $1\text{mHz}/\sqrt{\text{Hz}}$ in the Fourier frequency range between 10Hz and 2kHz. A measurement of the out-of-loop frequency noise with a separate rigid analyzer cavity however showed fluctuations of approx. $1\text{Hz}/\sqrt{\text{Hz}}$. To find the origin of this excess noise we used one of the GEO modecleaners as the analyzer cavity and found the same high out-of-loop frequency noise. After that we stabilized the laser to the first GEO modecleaner and analyzed the achieved frequency stability with the second modecleaner. First measurements indicate a 2-3 orders of magnitude smaller out-of-loop noise than in the case when the laser was stabilized to the rigid reference cavity. Hence the excess noise enters the system via the rigid cavity path. To reduce this coupling we continued the work on the suspension of the rigid reference cavity.

The 12W laser was operated over more than 2 weeks to measure the long term behavior of its output power. The injection locking loop was very stable and no significant power degradation was found.

A low-thermal-expansion rigid spacer for the 12W slave-laser was designed, fabricated and will be tested within the next 6-month period.

Measurements of cross coupling between the different laser parameters (frequency, intensity, pointing) and the servo-loops used for the stabilization of these parameters were taken. A significant coupling between the frequency-loop feeding back to the laser PZT and the laser pointing as well as the laser intensity noise were found. An other cross coupling effect between the intensity actuator and the laser frequency was analyzed and used in the new current-lock scheme to stabilize the laser frequency and simultaneously achieve a reduction of the laser power noise. More investigations will show if this locking scheme can replace the PZT actuator and by that avoid the PZT cross coupling.

Attachment D - Advanced Detector Configurations

Participation Danzmann 5%, Hough 5%, Schilling 20%, Winkler 10%,
Strain 40%, Skeldon 20%, McNamara 10%, Robertson 10%,
Freise 100%, Clubley 20%,
Weidner 20% Emme 40%

Item - Task 8 - b) 1. Automatic alignment of the dual recycling system (30m) for all 12 degrees of freedom

This work has been given a lower priority than points 2 and 3. The last 2 degrees of freedom of automatic alignment will be implemented at a convenient stage in the work.

Item - Task 8 - b) 2. and 3. Investigation of dual recycling with increased recycling factor and analysis and reduction of measurement noise with dual recycling.

Power recycling gain is lower than expected, this is being investigated. As a result of the lower power recycling factor the performance is limited by electronic noise in the photodetector circuit. The effect of scattered light on sensitivity is also under investigation.

Item - Task 8 - b) 4. Development of control systems for dual recycling on GEO

This R&D task is completed. The system designs are being prepared for implementation on GEO and so become part of task 8 - a).

Item - Task 8 - b) 5. Development of output modecleaner designs for GEO

An outline design study has been completed. There has been no further work on the implementation of an output modecleaner on GEO 600.

Item - Task 8 - b) 6. Planning of dual recycling/ RSE experiments (10m) and initial preparation of the interferometer

The experiment has been divided into 3 phases:

- i) preparation,
- ii) signal recycling experiments on the existing prototype
- iii) dual recycling experiments on the new 10m prototype system that is to be built in a new, clean laboratory currently under construction.

Progress in each area is as follows:-

- i) The first stage of the preparatory work was conversion of the 10m interferometer to infra-red light. This is almost complete. Performance close to the typical sensitivity and reliability obtained with green light has been achieved with IR. Some work on laser/pre-stabilisation automation is needed. The noise spectrum is not yet fully understood and some further investigation is needed. This work is running close to the schedule set last year.
- ii) The experiments on signal recycling are scheduled to start in October 2000.
- iii) Construction of the new facility (to be available in late 2001 for DR/RSE experiments) started a few weeks behind schedule. Some measures have been taken to compress the construction schedule and the interferometer should be available roughly on time.