THE STATUS OF GEO 600

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for the GEO600 group

TAUP
Sendai, Japan, 11th Sept 2007
LSC dcc no. LIGO-G070623-00-I
GEO600 location
GEO600 – a different optical layout

laser system  mode cleaner  interferometer

slave laser  second mode

master laser  first mode cleaner

power recycling  compensator

signal recycling  detector
GEO600 – birds eye view
The GEO600 Interferometer

2 sequential mode-cleaners (8 m round-trip)

12 W injection locked master-slave laser system

Output bench

P(t) Q(t)

BDIPR

MPR T=0.09%

MSR T=1.9%

BS

3.2 W

2.7 kW

600 m north arm (folded in vertical plane)

600 m east arm (folded in vertical plane)

MC2

MC1

MCn

MFe

MFn
The GEO600 Interferometer

No arm cavities, but folded arms:

- High PR factor (~1000)
- High power in BS substrate (~kW)
- Very low absorption of BS substrate (< 0.25 ppm/cm)
The GEO600 Interferometer

Triple suspensions:

Split-feedback
(3-stage hierarchical control: longitudinal + alignment)

Monolithic stages: ~100 fibre years on running IFO with ~5 partial ventings
Ultra-low mechanical loss suspensions at the heart of the interferometer

- Reduces thermal noise
- Adopted as a core component of the upgrades for Advanced LIGO and Advanced VIRGO

See following talk by A. Heptonstall – Development of fused silica suspension fibres for Advanced LIGO
The GEO600 Interferometer

Electro-Static Drives:

- Used for fast control of diff. arm length.
- Also used for fast auto-alignment (quadrants).

- ~3 mm gap between reaction mass and mirror
- 630 V bias, range 0-900V
- 900 V $\rightarrow$ 350$\mu$N $\rightarrow$ about 3.5$\mu$m @ DC
Charges on test masses

- Measured positive charging of test masses
- Discharged by using a UV-lamp, technique first demonstrated in Glasgow by Rowan et al. CQG. 14 1537–1541 (1997)

With UV-lamp + ESDs we can (positively and negatively) charge and discharge the test masses in a controlled way by electrons freed from the ESD electrodes.

Hewitson et al, in press, CQG LIGO-P070087-00-Z
The GEO600 Interferometer

Signal-Recycling:

- Shaping detector response \textit{trades bandwidth for sensitivity}
- Complex detector (resonance conditions with detuned SR)
- GW signal is spread over both quadratures $P$ and $Q$. 
The Last Two Years

Locked state and main activities at the site

Locked time [%]

Time [days]

S5 N&W ~190 days science time [57%]
S5 24/7 ~152 days science time [91%]
Noise hunting ~342 days
Infrastructure work
S5: 24/7 Mode

1. May - 15. October, 168 days

- Instrumental duty cycle: 94.3%
- Science time duty cycle: 91 %

- Longest lock: 102 hours
S5: 24/7 Mode

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Noise Projections Update

Noise projection to h 2007-09-08 00:12:00

- H
- MID AA FB Rot
- MID AA FB Tilt
- SR longitudinal noise
- Oscillator phase noise
- Oscillator amplitude noise
- Laser amplitude noise
- PR error
- Magnetic field
- High voltage amplifier
- RF noise
- Dark noise
- Model Shot 550Hz
- Sum of the noise

Frequency [Hz]

Strain [1/sqrt(Hz)]
Main Noise Reduction Topics

- Low-frequency (< ~200Hz):
  - Signal recycling feedback
  - Michelson auto-alignment feedback
- Mid & high frequency (> ~200Hz):
  - Detection noise (dynamic range of photodetector)
  - RF Modulation: phase noise and glitches
  - Acoustics / scattered light

Digital controls, ESD autoalignment, noise subtraction, ...

PD design, crystal oscillators, SMA connectors, RF power stabilization, acoustic shielding, larger optics, cleaner air, ...
Scattered Light Reduction

Graph showing frequency vs. strain, with two curves labeled:
- Red: Repetitive structures from end station scattering
- Blue: Scattering Removed

Y-axis: Strain [1/sqrt(Hz)]
X-axis: Frequency [Hz]
Acousto-Optic Phase Shifter...

...to suppress back-scattering from optics beyond

- Phase-modulate beam via excitation of substrate eigenmode
- Can handle large apertures and is polarization independent
- Place as first component on output beams in places where scattering cannot be avoided, e.g. photodiodes

Scattering provoked and suppressed at end station
Infrastructure Work

- New HV feedthroughs for electrostatic drives, improved ESD wiring
- Cleanroom: particle reduction by HEPA filters in main airconditioning stream
- Debugging of mains power routing done. Work ongoing on balancing of currents

We are ready for a long data run
Glitches and Vetoes

- Nullstream veto
- Noise projection vetos

Chi² veto
Statistical vetos
Reduction of Glitches

Comparizon of glitchiness of LIGO /GEO /VIRGO data with coherent waveburst showed GEO glitchiness around the average of all detectors (Sept. 2006). Since then we further reduced glitches.

H triggers in HACR mon: n=1067

Typical s5 in 2006

H triggers in HACR mon: n=392

End of June 2007
DC Detection: A New World

- From heterodyne (AC) to homodyne (DC) detection

- Anticipated advantages:
  - Reduced modulation noise coupling
    (in particular important for detuned signal recycling)
  - Better sensitivity (~20 to ~40 %)

- But pay attention to:
  - Larger power noise coupling: OK, but get optical filter for LO!
  - Output mode-cleaner: Alignment to power coupling, scattering
DC-Readout without OMC

**IDEA:**
Turning down the RF-modulation (*factor 10 is possible*)
Using an offset from dark fringe (*of the order 50pm*)
Dark port dominated by carrier light

**EXPERIMENT in GEO600:**

Locked to dark port power

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Nominal heterodyne

Heterodyne with only 10% modulation

Offset to dark fringe (~ 50pm)
Results from first Experiments with DC-readout

It works!

- Slightly better (10-20%) sensitivity than heterodyne at high frequencies (> ~2kHz)
- Not much worse sensitivity at mid frequencies
- Power noise coupling is not terrible!
The current plan is to start 24/7 run in October 2007
Run until Enhanced IFOs start science run (LSC: S6, ~early 2009)
2009 and beyond:
  Sequential upgrades in the GEO-HF frame, minimizing downtime (and take science data when possible) during construction of advanced detectors
GEO-HF and the AEI Prototype

- GEO-HF is the frame for sequential upgrades of the GEO600 detector

- Topics: high-power, squeezing, DC readout, digital controls, new mirrors to lower thermal noise, ...

- A new prototype will be built at AEI-Hannover serving as a platform for different types of experiments, including testing of GEO-HF upgrades
Summary

- We have ~1 year of S5 science data
- Noise and glitch reduction, infrastructure work, detector characterization work etc. done and ongoing, ready for
- Long observation from Oct. 2007 to the end of 2008...

Even in the highest Tension, just see what happens