Advanced LIGO status

Sheila Dwyer for the LIGO Scientific collaboration
LIGO DCC G1700585
LIGO interferometers

Hanford, WA (H1)

Livingston, LA (L1)

Photos: LIGO Lab

Sheila Dwyer for the LSC G1700585
## Advanced LIGO timeline

<table>
<thead>
<tr>
<th>Event</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation/ Locking</td>
<td>June 2015 (Livingston) February 2016 (Hanford)</td>
</tr>
<tr>
<td>Commissioning (15-9 months)</td>
<td>O1 (3 months)</td>
</tr>
<tr>
<td>Commissioning (9m)</td>
<td>Observing (9 months)</td>
</tr>
<tr>
<td>Commissioning (1 year +)</td>
<td></td>
</tr>
</tbody>
</table>

- **Relevant Dates:**
  - **June 2015** (Livingston)
  - **February 2016** (Hanford)
  - **June 2015** (Livingston)
  - **November 2016** (Livingston)
  - **December 2015** (Hanford)
  - **January 2016** (Hanford)
  - **July/August 2017** (Hanford)**
First observing run (O1) noise performance

Commissioning efforts from Feb-Nov 2016 mainly focused on scattered light and high power.
Scattered light

Mitigation strategies:
1) Reduce amplitude of light in spurious path
2) Reduce motion of scattering objects

1) Light scatters out of main interferometer beam (Anti reflection coatings, imperfections in optics)

2) Scatters off of less well isolated objects (baffles)

3) Light re-enters interferometer creating spurious interferometer
Scattered light improvements at Livingston

- Replaced Faraday isolator at detection port
- Improved alignment of ghost beams on baffles
- Planning underway for further improvements to baffling at both LIGO sites after second observing run (O2)

Plot: L Barsotti

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Increased laser power at Hanford

- First observing run operated at 20 Watts input power
- High power stage turned on at end of first observing run
- Interferometer operates stably with 50 Watts of input power
- Increased laser noise:
  - Intensity noise (fixed)
  - Higher order modes
Higher order mode coupling to gravitational wave signal

- **Laser table**
- **Input mode cleaner**
- **Interferometer**
- **Output mode cleaner**
- **Only 00 modes detected**

### Mitigation strategies:
1. Reduce amplitude of higher order modes
2. Reduce couplings to 00 mode in interferometer

- **Angular jitter** (water cooling, acoustic noise)
- **Beam size jitter** (High power oscillator)
Increasing power at Hanford

- Difficulties with beam size and angle jitter at high power
- For second observing run we are running at 30 Watts, small improvement at high frequencies
- Possible solutions:
  - Fix anomalous absorption spot in one test mass (ITMX) (to reduce couplings)
  - Changes to laser (70 Watt amplifier rather than high power oscillator)
  - Additional mode cleaner cavity
Duty cycle improvements

• Both sites have improved duty cycle
  – Tilt meter at Hanford helps with wind
  – Improvements in angular controls at both sites

• Duty cycles 60% and 75%, improved since start of run
Second observing run

- Started in November, possible extension to August
- Time volume collected so far is comparable to O1
- Expect to be joined by VIRGO in summer (F Sorrentio and J Casanueva Diaz talks)
Current Hanford noise budget

- Control noise
- Unknown noise
- Scattered light
- Laser beam angle and size jitter
- Quantum noise

Displacement sensitivity [m/√Hz]

Frequency [Hz]
Commissioning plans before O3 (~1 year)

• Increase laser power to 50 Watts for both sites
  – Attempt to clean Hanford ITM absorption spot (possibly break during run)
  – 70 Watt amplifier installation (Livingston first) as a substitute for high power oscillator

• Scattered light mitigation
  – New baffles for both sites

• Replacement of signal recycling mirrors
  – Reduce thermal noise from temporary mirrors

• Necessary vacuum maintenance will take ~3 months at Hanford

• Squeezing
Squeezed light and squeezed vacuum

\[ \Delta X_1 \Delta X_2 \geq 1 \]

Coherent state of light

Vacuum fluctuations

Squeezed light

Squeezed vacuum
Commissioning before O3: Squeezing

- Installation of in vacuum squeezer at Livingston soon after end of O2
- Frequency independent squeezing for now (filter cavity can be added later)
- Installation at Hanford possible before third observing run
Conservative sensitivity projections

Higher power: 107Mpc
Higher power and squeezing: 120 Mpc
Third observing run goal: 120-170 Mpc
Summary

• Second observing run underway since November
  – Time volume collected to date is similar to O1, 5 months to go
• Goal for next observing run is 50% sensitivity improvement (or better)
• Start date of third run will be determined by sensitivity progress (expect a year of downtime).
Towards design sensitivity

Scattered light reduction control noise

Increase laser power
Inject squeezed states of light
The reach of ground based gravitational wave detectors