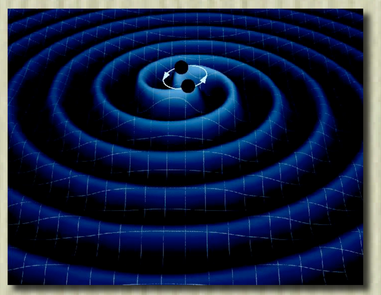
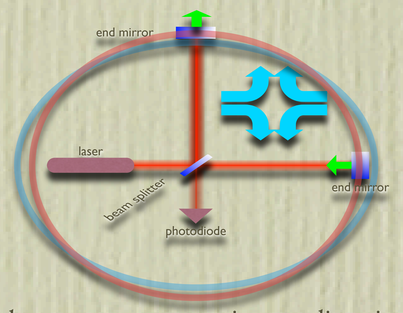
Improving the sensitivity of LIGO detectors to Gravitational Waves

Pinkesh Patel for the LIGO Scientific Collaboration

What is LIGO?

- LIGO is an **interferometer** designed to detect gravitational waves.
- **Gravitational waves** are **ripples** in the fabric of space and time.
- Predicted by Einstein's **General Theory of Relativity**.
- Similar to Electromagnetic radiation, except they are produced by **accelerating masses** and not charges.
- Produced in cataclysmic events like **neutron star mergers**.

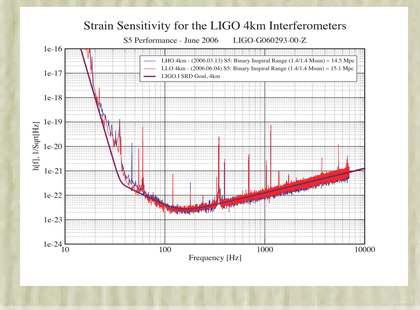




- As these waves pass through matter, they **squeeze** space in one direction and **stretch** it in the other.
- When passing through an interferometer, it will **elongate one arm**, while **shortening the other**, causing a difference in length.
- This **difference in length** is converted to a light signal at the **anti-symmetric port** and can be detected.

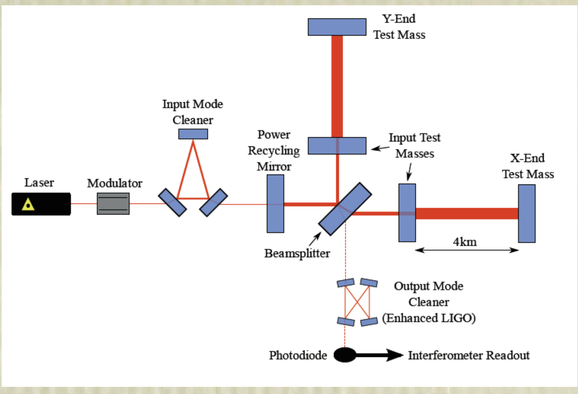
Why is it hard?

- Gravitational waves are **extremely weak**.
- The **typical strains** produced in the arms of the detector are of the order of 10^{-21}.
- In spite of Initial LIGO's success at achieving the most sensitive detector of gravitational waves, even more sensitive detectors are needed.
- We are limited by seismic, thermal, and shot noise sources.
- **Enhanced LIGO will reduce** shot and sensing noise sources.
- Below is the **best sensitivity curve** achieved in Initial LIGO.



Output Mode Cleaner

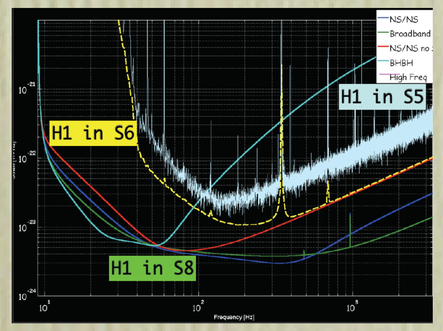
- The OMC is a four mirrored cavity, resonant with the same mode of the light resonating in the interferometer (The TEM 00 mode).
- It filters out all the other modes and transmits on the relevant mode to the photo diode.
- This ensures that we only feedback the motion of the test masses back to the test masses and other spurious scattered light is ignored.
- It is all in vacuum.



Enhanced LIGO

Enhanced LIGO are a series of upgrades which will help to double the strain sensitivity of the 4 km LIGO interferometers. These upgrades include -

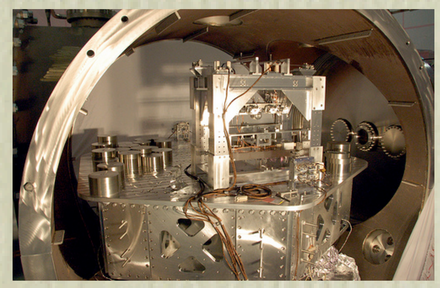
- **Increasing the Laser Power from 10 W to 35 W.**
- **Changing the sensing scheme from RF sideband to DC.**
- **Installation of an Output Mode Cleaner (OMC) to remove junk light.**
- **Move most of the new hardware into vacuum to avoid acoustic noise.**
- **Install and upgrade the Thermal Compensation System (TCS).**
- **Replace current earthquake stops with ones having fused silica tips.**



The figure above shows the expected improvement in Enhanced LIGO (S6) and Advanced LIGO (S8) from Initial LIGO (S5)

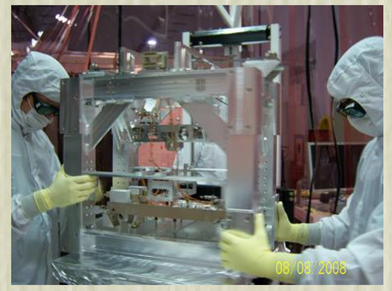
LIGO Hanford from above

The OMC in chamber

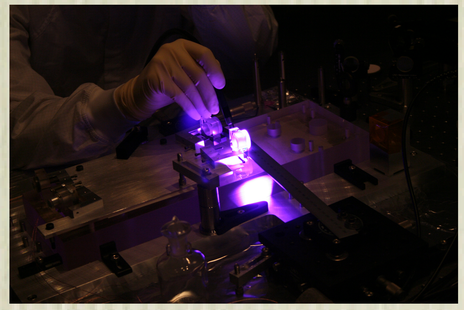


DC Readout

- The current implementation involves a readout scheme, in which RF sidebands are added to the main laser light. The light passing through the interferometer is beat with the sideband oscillator to demodulate the gravitational wave signal.
- DC readout involves shifting the main cavities a little off resonance, which leads to a linear relationship between the gravitational wave signal and the power at the anti-symmetric port.
- DC readout helps reduce many noise couplings which are present in the RF scheme.



The OMC in real life



Acknowledgements/References

- Enhanced LIGO, Rana Adhikari et al, LIGO-T060156-01-I
- The Path to the Enhanced and Advanced LIGO Gravitational-Wave Detectors, Josh Smith, P080127-00-Z.

LIGO was constructed b Caltech and MIT with funding from the US National Science Foundation and operates under the cooperative agreement PHY-0107417.

The poster was printed with funding and support from the Caltech GSC's academic committee and the graduate Dean's office.