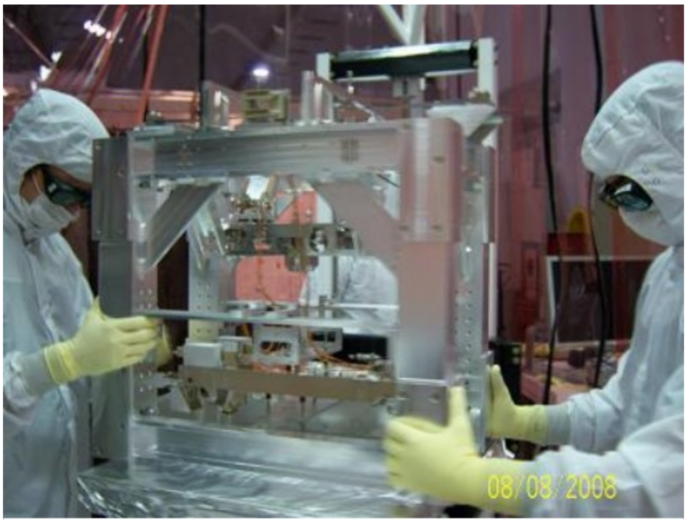
9. Past Research and Achievements

My PhD research has centered primarily on the **detection of gravitational-waves**. First predicted by Albert Einstein in 1916, gravitational-waves are oscillations in the gravitational force field. Albert Einstein also showed the equivalence of the force of gravity with the structure and fabric of space and time itself. So to be more precise, **gravitational-waves are oscillations in the structure of space-time**.

In addition to predicting the existence of gravitational-waves, Einstein also predicted that, because the strength of these waves is so small (modifying km scale lengths by **less than the diameter of a proton**), **no one would ever be able to detect them**. Although indirect evidence has been observed (resulting in the award of the 1993 Nobel Prize in Physics), **today there has still been no direct detection of gravitational-waves.** During my PhD research, I have worked for the Laser Interferometer Gravitational-wave Observatory (LIGO) project, operated jointly by Caltech and MIT. LIGO has built and operated 3 gravitational-wave detectors in the United States.

A laser interferometer gravitational-wave detector is a modified Michelson interferometer, with arms that are **4km long.** An extremely stable laser beam is split by a beam splitter and sent down the two arms, reflected, and recombined. By carefully measuring the phase of the recombined light, it is possible to **detect gravitational-waves**. It is expected that sources of gravitational-waves will be **colliding black holes and neutron stars, spinning neutron stars and possibly other unknown sources**.

For almost 2 years, I lived on site at the LIGO Hanford Observatory in Washington state. While there, I participated in the “Enhanced LIGO” project, which was a project to upgrade the LIGO detectors beyond their initial design sensitivity. **I was an integral part** of the on-site commissioning effort during the upgrade. **I applied my knowledge of control systems, electronics, optics, and lasers** to facilitate in the upgrade of the 4km gravitational-wave interferometer.



Installation of the LIGO OMC. I am pictured on the right.

I was the local expert of the new Output Mode Cleaner (OMC) subsystem which was installed for the Enhanced LIGO upgrade. The **OMC is a 4 mirror optical resonator** cavity which is designed to remove so-called “junk light” from the output interferometer beam. This allows the gravitational-wave signal to be detected with higher efficiency than would be possible normally. I helped build and install the OMC, and I **designed and commissioned** many of the cavity locking and automatic alignment **control systems** which maintain the cavity in **optimum performance** with respect to the laser signal emitted from the interferometer.

Thanks in part to the work that I performed at the LIGO observatory, the interferometer at Hanford became the **most sensitive gravitational-wave detector ever**. By the end of my time at LIGO, the detector could measure the gravitational-waves from the collision of two neutron stars at a distance of **65 billion light years**.

Since the end of the Enhanced LIGO upgrade I have worked **modeling** the transmission of various laser **noise sources** to the readout channel of laser interferometers. This includes numerical **computer modeling of optical signals and control systems.**

During my time at MIT **I have developed a software package for mode analysis, beam propagation, and modematching** in the MATLAB software environment. This software, called “a la mode” is being used by researchers not only in the field of gravitational-waves, but also atomic physics.

I have also modeled and developed **novel new alignment techniques** for mode cleaner cavities like the OMC used in LIGO. The **new techniques I have developed** describe how to **optimally align a laser beam** containing a signal into a mode cleaner cavity and has **applications to many fields** that use optics, not just gravitational wave detection. Such fields include quantum optics, cavity optomechanics.