Transmission and Bond Quality of Hydroxide Catalysis Bonds

using silicon windows

University of Glasgow
N.M.S Al-Kiyumi
2111539A@student.gla.ac.uk

Introduction and Aims

- Gravitational waves are deformations of spacetime as a result of asymmetrically accelerating mass [1] and were first detected aLIGO a century after they were predicted by Albert Einstein in 1916 [2]
- Currently, the advanced detectors uses hydroxide catalysis bonding to bond silica attachments (ears) to the sides of the silica mirrors with the silica suspension fibers welded to the ears [3]. This technique minimizes the thermal noise associated to the test masses and their suspensions in the detectors operating frequency band of 10 Hz to a few kHz [4]

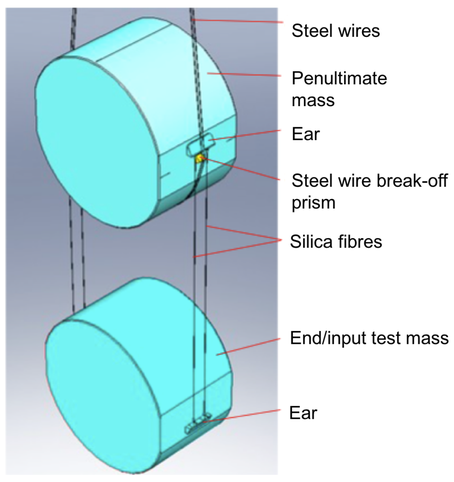

Figure 1: Schematic of the aLIGO monolithic suspension [5]

- For future generation detectors, with plans to go cryogenic, silica is no longer a suitable since it has shown to have a broad mechanical dissipation peak centered at 40K [6,7]. However, silicon has the desirable thermo-mechanical properties needed in order to operate in cryogenic regime [6,8]
- Silicon is transparent in the infrared region and a laser set-up using an infrared source (1550nm laser) was constructed as a method of assessing the bond quality of silicon-silicon bonds using the hydroxide catalysis bonding technique.

Method

1. Building a laser transmission set-up in order to obtain a transmission map of the bonded area of two silicon windows bonded together via hydroxide catalysis bonds
2. Bonding 3 pairs of silicon windows to each other via hydroxide catalysis bonds
3. Obtaining transmission maps using the laser set-up with curing time
4. Obtaining thermal images with curing time

Hydroxide Catalysis Bonding (HCB)

- Hydroxide catalysis bonding forms between silicate-like networks
- Silicon surfaces need to be oxidised prior to bonding
- Bond is formed using a diluted aqueous alkali solution (e.g.NaOH)

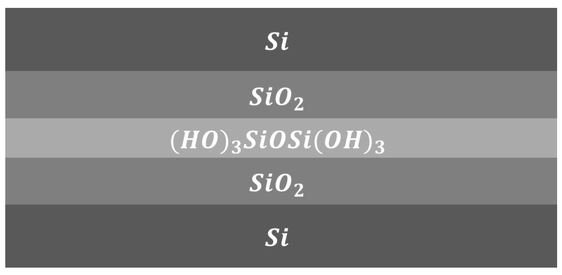

Figure 2: Bonded oxidised silicon sample showing siloxane chains formed from the reaction with the hydroxide solution

Transmission set-up

- The laser set-up was built with the aim of scanning the surface of a bonded sample

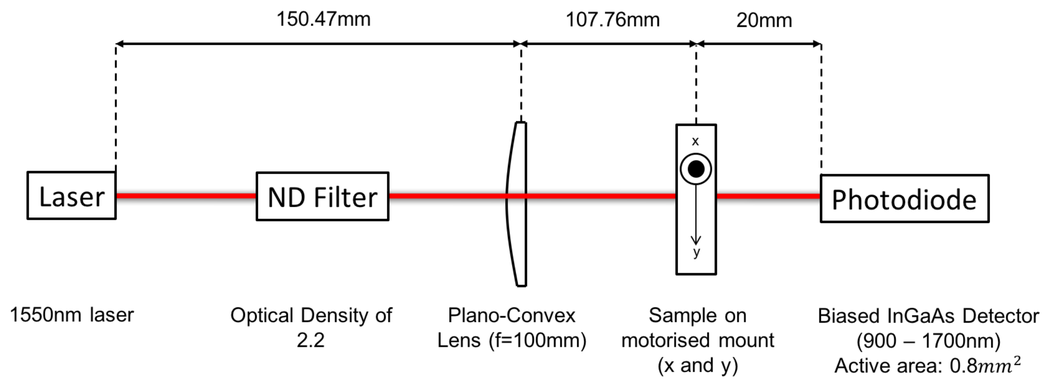

Figure 3: Schematic of the laser set-up used to obtain the transmission map of a bonded area

Beam diameter

- The beam diameter (mm) of the laser against the distance from the lens (mm) was obtained
- The minimum diameter is 0.13mm which means that the scanning resolution can be this small

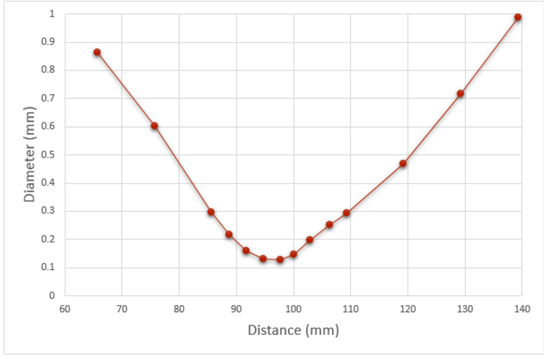

Figure 4: Beam diameter (mm) against distance from lens (mm)

Results

Transmission and thermal images of the silicon-silicon sample one week after curing were obtained (the triangle was purpously scratched before oxidation)

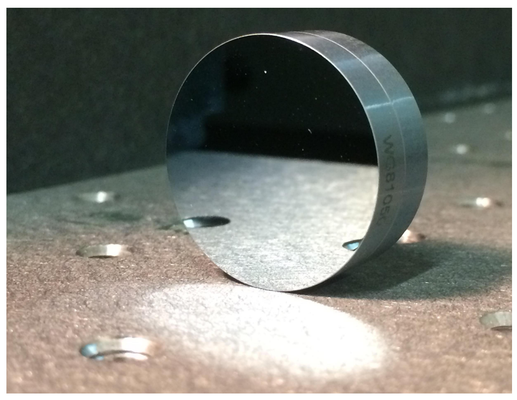

Figure 5: Bonded silicon sample

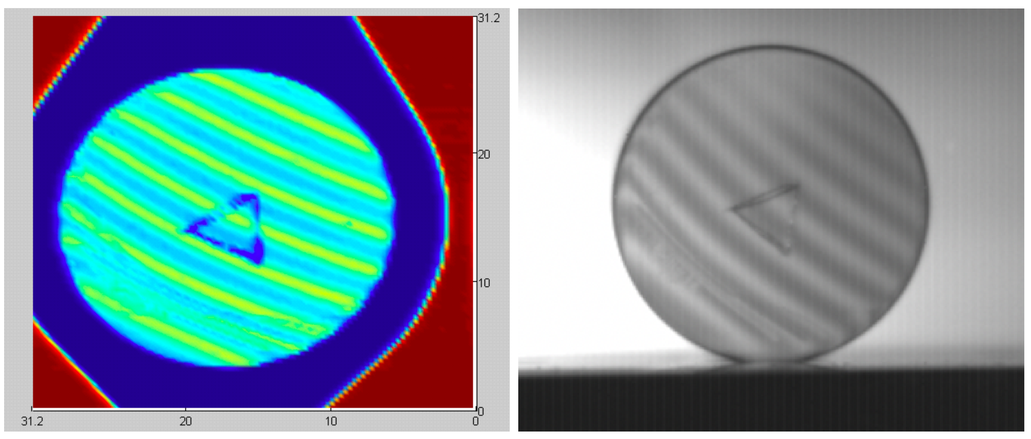

Figure 6, 7: 6) Transmission image of the silicon sample showing distinct features towards the bottom left of the bond, 7) Thermal image of the silicon sample with features shown in the same region

Conclusion

- The fringes and the shape scratched onto the sample surface before bonding were clearly seen in both the transmission and the thermal images
- The transmission and thermal images showed the same pattern of fringes implying that the fringes shown is due to the bond
- The fringes are present due to variation in thickness of the bond creating regions of constructive and destructive interferences (bond is probably of order microns thicker on one side than the other)
- The transmission set-up proved to be a successful method of accessing the bond quality of silicon bonds as the bond features show up

References

1. Beveridge, N. L. (2012). Characterisation of silicon-silicon hydroxide catalysis bonds for future gravitational wave detectors. University of Glasgow.
2. Abbott, B. P. et al. (2016). Observation of Gravitational Waves from a Binary Black Hole Merger. Physical Review Letters, 61102, 1-16.
3. van Veggel, A. A. et al. (2009). Strength testing and SEM imaging of hydroxide-catalysis bonds between silicon. Classical and Quantum Gravity, 26(17), 175007
4. Beveridge, N. L. (2011). Low-temperature strength tests and SEM imaging of hydroxide catalysis bonds in silicon. Classical and Quantum Gravity, 28(22), 229501.
5. van Veggel, A. A. and Killow, C. J. (2014). Hydroxide catalysis bonding for astronomical instruments. Advanced Optical Technologies, 3(3), 293âĂŞ307.
6. Rowan, S. et al. (2003). Test mass materials for a new generation of gravitational wave detectors. In Proceedings of SPIE - The International Society for Optical Engineering, 4856, 292-297.
7. Braginsky, V. B. (1987). Systems with Small Dissipation. American Journal of Physics, 55(12), 1153.
8. Beveridge, N. L. et al. (2012). Dependence of cryogenic strength of hydroxide catalysis bonded silicon on type of surface oxide. Classical and Quantum Gravity, 30(2), 25003.