Modelling LIGO with microwaves

LIGO, the Laser Interferometer Gravitational-Wave Observatory, uses a Michelson Interferometer set-up to detect tiny movements of a mirror caused by space stretching when a gravitational wave passes. Whereas LIGO depends on the interference of laser light, our version uses microwaves of wavelength 2.8 cm. Figure 1 shows a photograph of the assembled apparatus and Figure 2 the layout.

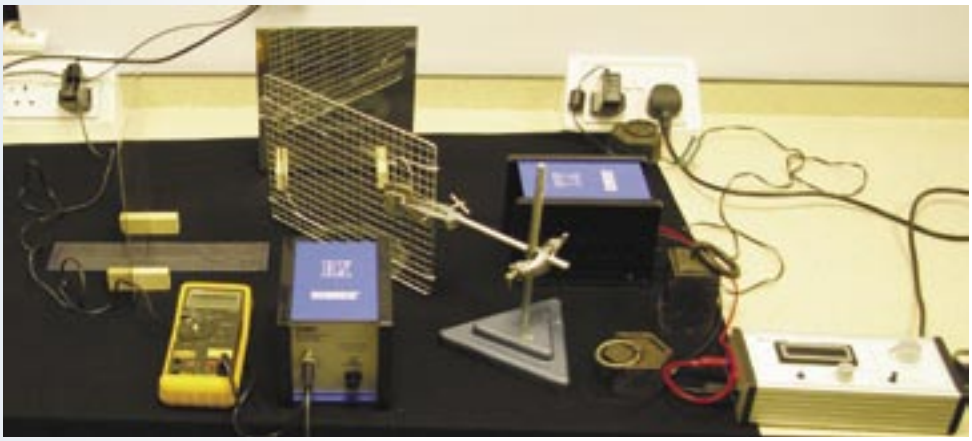

Figure 1 *- Microwave Michelson Interferometer.*

The equipment used is standard school microwave kit apart from a beam splitter and (optional) a sheet of Lycra®. The microwave transmitter and receiver are placed at right angles to one another. A metal reflector is placed around 50 cm in front of each. The beam splitter - we found that a barbecue grill with a 12 mm mesh was ideal - is placed at an angle of 45 degrees to the transmitter and receiver as shown in figure 2. A voltmeter is connected to the output of the receiver, giving a reading that is proportional to microwave intensity.

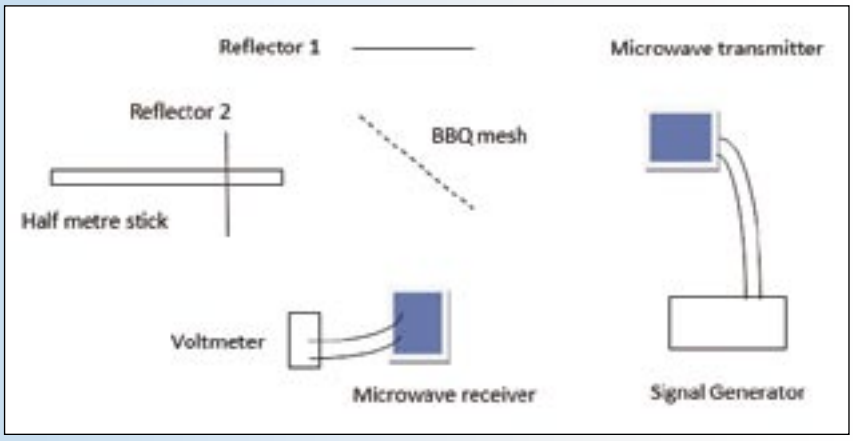

Figure 2 *- Diagram of layout.*

Figure 3 helps us to understand how interference occurs.

Some of the microwave radiation - ideally 50% - passes through the beam splitter, reflects from reflector 2 then reflects off the mesh and travels towards the receiver (blue path). The rest of the radiation is reflected by the beam splitter, strikes reflector 1 and is then reflected towards the receiver (red path). Interference then occurs at the receiver. If we move one of the reflectors and plot the voltmeter reading versus displacement, a series of maxima and minima can be found. Maxima (or minima) should be half a wavelength apart. An alternative approach is to determine the position of maxima using a half metre stick. Call the first maximum m=1 and plot y versus m where y is the position of the reflector. The gradient should equal one half wavelength (Figure 4). We suggest that you experiment with the relative positions of the reflectors to try to get as low minimum values as possible.

To model LIGO, we mounted our equipment on a sheet of Lycra, secured at the transmitter end using weights. We then positioned the reflector such that we had a minimum reading on our meter. The Lycra represents space, so a gravitational wave can be simulated by carefully stretching then relaxing the material. When this was done, we observed the reading on the meter rise and fall. Our equipment allowed the transmitted wave to be modulated and the receiver had a built in speaker. By modulating the microwaves using an audio frequency, we could hear the sound level rise and fall as the "wave" passed. We felt this was a satisfactory analogue to the "chirp" heard by the LIGO team when they detected their first wave.

We think that microwave Michelson Interferometer experiments could form part of an Advanced Higher project. In a future issue we hope to write about finding the refractive index of materials using the apparatus. Initial results are encouraging. We are sure, too, that many physics teachers share our excitement in the discovery of gravitational waves. Here is what we hope is an effective way to explain what's going on to your senior phase students.

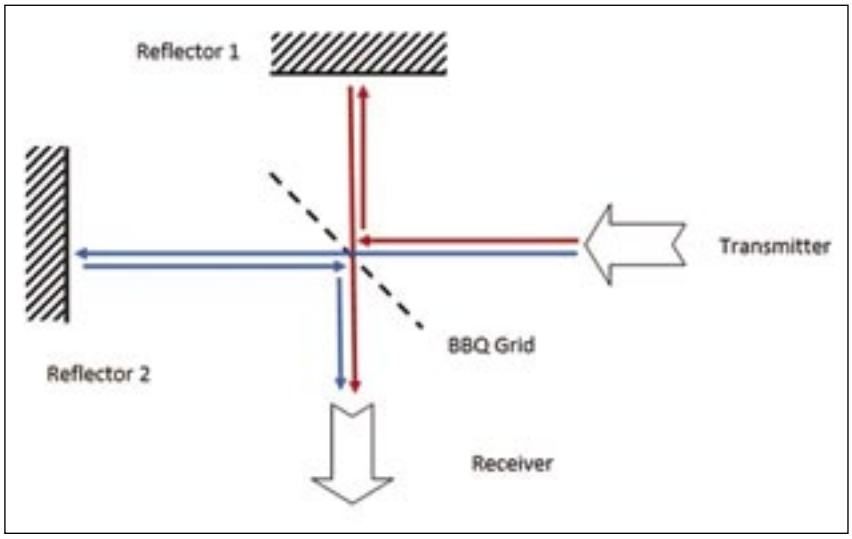

Figure 3 *- Beam paths in the interferometer.*

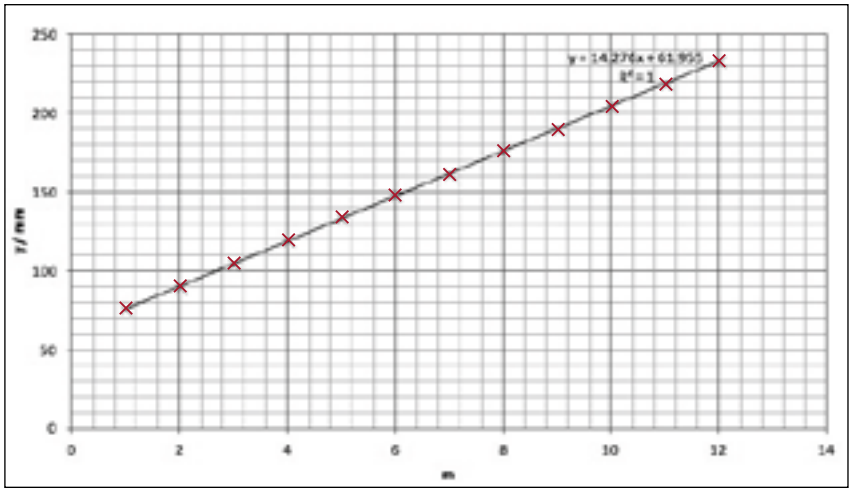

Figure 4 *- graph showing position of consecutive maxima/minima.*