A theoretical gravitational wave detector

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Abstract: Measuring gravitational waves is of fundamental significance for many areas of physics. Here we can broaden our knowledge about gravitation and the theory of general relativity, which is deduced from the theory of special relativity, is to be tested. Both the gravitation and the theory of relativity are important parts of physics. Unfortunately, though, measuring gravitation waves with the help of interferometers is very, very effort-full. The more important it is to find more simple methods for the measurement of gravitational waves. In this paper I introduce a further but only theoretical method. Perhaps in the more distant future there will be possibilities to realize it.

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At present it is tried to detect gravitational waves [1, 2, 3, 4, 5] with the help of interferometers [6, 7, 8, 9, 10]. Many problems arise, though. [11, 12]. The greatest problems arise because of thermal fluctuations and because of seismic vibrations [13, 14, 15, 16]. The essential reason for these problems is, that the length changes, which the gravitation waves cause at the interferometer, are very small. This is due to the low strength of the gravitation. For this reason the still best measurable sources for gravitational waves [17, 18, 19, 20] are exploding stars. At these explosions characteristic wave patterns arise at the gravitational waves with characteristic frequencies. The hope now is to filter out these wave patterns, at the corresponding frequencies. For this purpose the interferometer must have a resolution as high as possible. A good way to obtain a high resolution is to make the arm length of the interferometer as long as possible. But even with grate arm lengths [GEO 600, Ligo, Virgo, Tama] the numerous problems are hard to be solved, as it has show to be. For this reason the interferometer will be installed in space now; this is the famous LISA project. With LISA three satellites will be brought in an orbit around the sun in that way that they form an interferometer with an enormous arm length. One may expect that LISA will provide excellent results.

It is assumed in principle that gravitational waves appear almost frequently. Being able to measure them would reveal a new window to physics and especially to astrophysics. Here, gravitational wave detectors would be a completely new type of observation instrument, something as a new kind of telescope. The problem, here, is the very high cost for such detectors, though. The more important it seems to be, developing new and more economical methods for gravitational wave detecting. There already are such approaches [21].

At this paper another alternative method for the measurement of gravitational waves is introduced. The idea introduced here is based on angle changes. Every one-sided length change - as gravitational waves are causing - causes angle changes. If e.g. one changes the length of one side in a triangle, then all angles change in this triangle.
Of course, angle changes, which are caused by gravitational waves, are exactly as small as the length changes, which the gravitational waves cause. For this reason the angle isn't measured directly but the deviation, which is caused by the angle change, is measured. This deviation is all the bigger the longer the stretch is whose angle changes. What is meant can be seen at Figure 1.

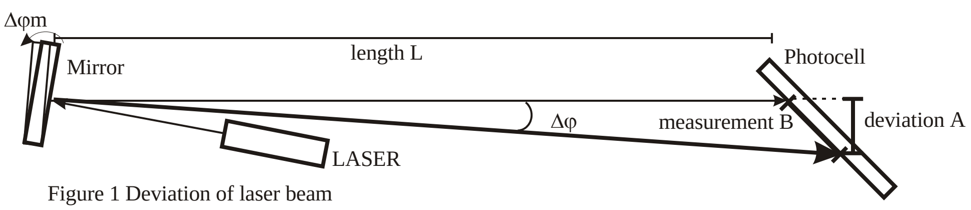

Figure 1 Deviation of laser beam

One immediately recognizes that the deviation (A) is all the bigger the bigger the stretch L is. It is sensible to measure the deviation of a laser beam, of course. Here, then, one could use the vacuum ways of the already available gravitational wave interferometers. At the GEO 600 the way L would then be great 600 meters long. To still amplify the effect, one can place the photocell in an angle to the laser beam: one recognizes (at Figure 1), that the length of the measurement B is greater than the deviation A.

How is the angle change taking place now? Let us have a look at Figure2. Here, the gravitational wave changes only the length in x direction. Through this the angle ($\varphi 1$), with which the laser beam (b1) comes from the laser, changes. The angle of the mirror ($\varphi m1$) changes in an analogous way. The changes of $\varphi 1$ and $\varphi m1$ lead now automatically to a change of the angle of reflection; or to a change of the angle, which the laser beam has after the reflection ($\varphi 2$). This is represented (exaggerated) in Figure 2b for a shortening of the x direction. One recognizes here that the change of the angle of the mirror even supports the angle change of the laser beam.

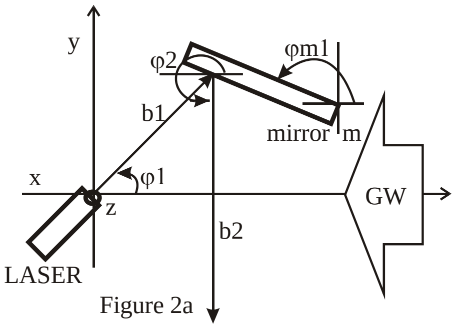

Figure 2a

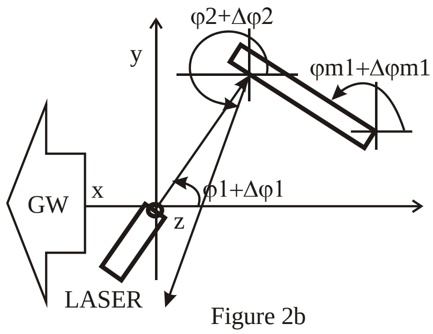

Figure 2b

Unfortunately, though, the effect (the deviation A) is here still much to small as it could ever be measured. So we must try to amplify the deviation of the laser beam. The most self-introducing idea actually works here: The laser beam simply is reflected repeatedly. At every reflection one more angle change is added. Two problems arise here: 1. The angle changes may not cancel each other out mutually. 2. The way covered by the laser beam altogether mustn't be too long since the gravitational wave only has a short effect (according to $c = L * f$). Many different constructions for reflection ways can be found, but I will not mention everyone in detail here, however.

The way most simply to be realized appears to me to finally be the following: One constructs a trapezium with four mirrors (as to be seen at Figure 3) and sends a laser beam inside.

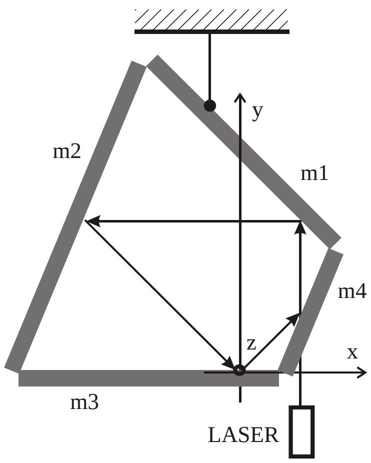

Figure 3a Top view

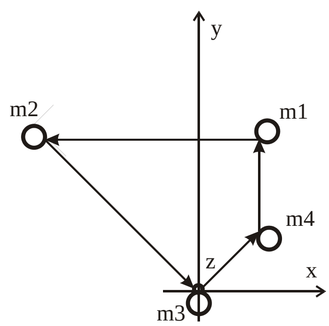

Figure 3b Micro reflector

Everything becomes most simple, if the mirrors and the laser beam are put in a way so that the laser beam always returns to its starting point, as to be seen at Figure 3a, the top view. At Figure 3a the laser beam propagates only on the x-y-plane. Actually, the laser beam gets a tiny angle in z-direction. This way the laser beam propagates in z-direction through the cavity, which the four mirrors form, and finally it reaches the other end of the mirrors, after numerous reflections, where it beams out of the

construction. The number of reflections results by the length of the mirrors in z-direction (Lz) and by the angle of the laser beam in z-direction (φz). If φz is very small many reflections can result even if Lz is small. As long as the mirror-construct doesn't deform, the laser beam will leave the construction with an unchanged angle at one of the four reflection mirrors. As soon, though, as a gravitational wave deforms the mirror-construct (e.g. the x direction is shortened) the angles of the trapezium and these of the laser beam change. Since the angles then don't fit any more, the laser beam will deviate more strongly with every reflection from both its original way and its angle. And this adds up to an almost considerable deviation, due to the grate number of reflections. The size of the mirrors plays only a subordinate role here. Actually it is most favorably if the mirrors are as small as possible so that the way covered altogether is as small as possible. If e.g. the laser beam propagates only 0.01 meters with every reflection-triangle, then it can be reflected hundreds of times within one single wavelength of a gravitational wave.
Unfortunately, the angular displacement, which results from every reflection cycle, has the same order of magnitude as the length change, which is caused by the gravitational waves. Since these angular displacements add themselves up linearly, about 10^{15} reflection cycles would be necessary to get a measurable result. Of course, this is far too much. However, one can prevent the linearity by bending the mirrors, because with every angle change the position, on which one the laser beam hits on the mirror, also changes. If the mirror is bent, then together with the position the reflection plane also changes and this strengthens the angular displacement additionally. But also here a measurable effect only then would result if the bend of the mirrors were extremely great. At such great bends, however, the laser beam gets lost very soon. So, one must take a very, very fine particle ray or gamma ray instead of the laser beam, and instead of the mirrors one would need bent reflectors at atomic level perhaps (see Figure 3b). Perhaps a semiconductor material could be doped correspondingly? If this would be archived, then the angle of the ray, sent out by that semiconductor, would change by a gravitational wave.
It is important here that the reflection construct (mirror trapezium) is so small (can be constructed such small) that it can be seen as almost dot-like in comparison with the deviation way L (of Figure 1). This has significance, because at the reflections inside the reflection construct the laser beam changes not only its angle but also its position. These inside-deviations had to be taken into account at a more extensive mirror construct, and that would lead to many practical problems. Our small, compact reflection construct, instead, produces essentially only a clear angle change, as soon as it is influenced by a gravitational wave.
Other influences however can be isolated very well. The temperature can relatively easily be kept low and constant because of the low size.
Seismic influences can be controlled by a simple, one-dimensional suspension (e.g. with a wire, as indicated at Figure 3) because any seismic oscillation, which propagates only through a simple wire, can be measured easily and be either re-calculated or compensated.
In addition, the position of the suspended reflection construct can easily be controlled and hold (e.g. with the help of little laser momenta beamed on position-correction-areas). Such position corrections hardly have influence on the angle changes inside the reflection construct, caused by gravitational waves.

Of course, the idea introduced here is an only very theoretical possibility. On the other hand such ideas can be often realized in a surprising way, too. Here then one would have a gravitational wave detector in pocket size.

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