Detection of Gravitational Waves by Sequential Field Imaging through Fourier Transform Heterodyne

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Abstract

We suggest using the experimental setup given in [15] by carrying out the following change: We will increase the distance, equally and sufficiently, between the mirror and polarized beam splitter present on one side and between the other mirror and beam combiner present on other side in the experimental apparatus shown in FIG 1 below which is actually Figure 5 in [15] taken with thanks. We then suggest to carry out imaging after suitably predefined regular time intervals and compare these images of transverse amplitude, phase, (and intensity) of coherent electromagnetic field. It is our guess that the images will be identical as long as no gravitational waves pass through the apparatus and cause changes in the distance between the mirror and polarized beam splitter present on one side as well as in the distance between the other mirror and beam combiner present on other side in the experimental apparatus shown in Figure 5 in [15] due to squeezing and stretching of space-time fabric. So, the changes that will be observed will occur in the images only due to the passing of gravitational waves through the apparatus. Due to passing of the gravitational waves through the apparatus the squeezing and stretching of the paths for rays will cause the change in the images of transverse amplitude, phase, (and intensity) to be taken at regular intervals. The observed changes in the images will offer a conclusive proof for the existence of gravitational waves!

1. **Introduction:** Experimental detection of gravitational waves is a big challenge of this time and enormous efforts are on world over by people working in highly sophisticated gravitational wave detection laboratories. Gravitational wave laboratories will be leading laboratories in the coming future to offer new important insights in our study of large scale phenomena. Detection and study of gravitational waves of different types and of different intensity and frequency will make revolutionary contributions to our knowledge about galactic dynamics. It will add greatly to our knowledge about astrophysical sources and about processes driven by strong gravitational fields. Objects of fundamental importance, such as astrophysical black holes, merge and radiate with luminosity larger than the entire electromagnetic universe, and these events will become clearly detectable only through a tool for detection of gravitational waves that are mainly associated with detectable amplitude with such unimaginably huge events [1]. When observed with gravitational waves these intrinsically interesting astronomical sources such as massive black holes and their merger, extremely compact stellar binaries and their collisions, supernovae

events etc will surely yield many new surprises. Thus, the discovery potential associated with detection of gravitational waves is immense.

Gravitational radiation was detected indirectly in 1974 by J. Taylor and R. Hulse, who observed its effects on the orbital period of a binary system containing two neutron stars, one of them a pulsar (PSR 1913 + 16). Efforts to detect gravitational waves directly have been severely challenged by the extreme weakness of the waves impinging on the Earth. However, as the 21st century begins, observations of the gravitational waves from astrophysical sources such as black holes, neutron stars, and stellar collapse are expected to open a new window on the universe [2].

There are two major gravitational wave detection concepts: acoustic and interferometric detection [3]. The acoustic method deals with a resonance response of massive elastic bodies on gravitational wave excitations. Historically the acoustic method was proposed first by J. Weber [4] where he suggested to use long and narrow elastic cylinders as Gravitational Wave Antennas. Although a significant progress has been achieved in fabrication and increasing sensitivity of such type of detectors [4, 5, 6] the interpretation of obtained data is still far to claim undoubtedly the detection of gravitational waves. On the other hand a considerable attention has been shifted recently to more promising interferometric detection methods. The interferometric gravitational wave detector like Laser Interferometer Gravitational Wave Observatory (LIGO) and VIRGO [7, 8] represents a Michelson interferometer with a laser beam split between two perpendicular arms of interferometer. The principles of operation of such type of detectors are reviewed in Refs [9, 10, 11, 12, 13]. The action of gravitational waves on an interferometer can be presented as relative deformation of both interferometer arms. A gravitational wave with dimensionless amplitude h induces the opposite length changes $\frac{\delta l}{l} = \frac{1}{2} h \cos(\Omega t)$ in each arm of the Michelson interferometer, where l stands for the length of each of the arm, Ω for the gravitational wave frequency. These length changes produce opposite phase shifts between two light beams in interferometer arms, when interference occurs at the beam splitter of Michelson interferometer. The resulting phase shift of a single beam of light spending time τ in the interferometer can be written as [13]

$$\delta\phi = h \frac{\omega}{\Omega} \sin\left(\frac{\Omega \tau}{2}\right), \qquad (1)$$

where, ω is the light frequency. This phase shift results an intensity signal change of the light from interferometer beam splitter hitting the photo detector.

The main problem of the acoustic and interferometric methods that they both deal with gravitational waves with extremely small amplitudes of the order $h \sim 10^{-21}$ [14] reached the Earth from deep space. One can see from equation (1) that for gravitational wave frequencies in the 1 kHz range, $\Omega \sim 10^3$ Hz, and for the light in visual frequency range, $\omega \sim 10^{14}$ Hz, one has the maximum phase shift of the order $\delta\phi \sim 10^{-10}$ for interferometer arms length of the order 150 kilometers. Such extraordinarily weak effect requires exceedingly high detector sensitivity for both acoustic as well as interferometric detectors.

2. **The Novel Technique:** As seen above one requires extraordinarily high sensitivity of detectors to conclusively capture signal called gravitational waves. Due to feeble change in the path difference that is produced when gravitational waves pass through the apparatus the light rays running in the two mutually orthogonal arms of the interferometer at LIGO produce undetectably small phase difference in these interfering waves at the moment of their reaching back to the beam splitter due to which these rays come back to interfere almost destructively at beam splitter and do not have detectable amplitude for the detectors to detect. Because of the extraordinarily high sensitivity the detectors required to have in order to conclusively capture the signal called gravitational wave nobody has yet succeeded in this task even though many gravitational waves would have passed through the setups like the one at LIGO installed at different locations. It could be very much likely that this enormous requirement of sensitivity may not be possible to fulfill for our future apparatus also. Instead of direct detection we should try to imply the existence of gravitational waves through some indirect means. As because of extreme smallness of atomic dimensions it is impossible to photograph few atoms directly, similarly, because of extreme smallness of phase variation in two destructively interfering beams running in two orthogonal arms of interferometer at LIGO one gets no light at detector. But we have circumvented the first difficulty [16] by using scanning tunneling microscopy (STM)! In STM one measures tunneling current produced by free electrons in the surface of specimen tunneling on to the probe and flowing through the current meter. By scanning the surface (to be photographed) by a very sharply pointed probe and measuring very feeble current, which is changing from place to place, as an input for imaging software to produce (something like) image of the region of scanned surface containing few atoms. We propose on similar lines a method for detecting gravitational waves through imaging the amplitude and phase of electromagnetic field at regular time intervals using imaging setup used in [15]. Thus, our suggestion for detection of gravitational waves is based on making use of the detection process capable of directly imaging the transverse amplitude, phase, (and intensity etc) of coherent electromagnetic field as discussed in [15]. We suggest using the experimental setup given in [15] by carrying out the following change: We have to increase the distance, equally and sufficiently, between the mirror and polarized beam splitter present on one side and between the other mirror and beam combiner present on other side in the experimental apparatus shown in Figure 5 in [15] which we reproduce with thanks as FIG. 1 given below:. We then suggest to carry out imaging after predefined regular time intervals and compare these images of transverse amplitude, phase, (and intensity) of the coherent electromagnetic field. It is our guess that the images will be identical as long as no gravitational waves pass through the apparatus and cause changes in the distance between the mirror and polarized beam splitter present on one side as well as in the distance between the other mirror and beam combiner present on other side in the experimental apparatus shown in FIG. 1 due to squeezing and stretching of space-time fabric. So, the changes

that will be observed will occur in the images of amplitude, phase, (and intensity) of coherent electromagnetic field only due to the passing of gravitational waves through the apparatus. Due to passing of the gravitational waves through the apparatus the squeezing and stretching of the paths for rays will cause the change in the images of transverse amplitude, phase, (and intensity) that are taken at regular intervals. The observed change in the images will offer a conclusive proof for the existence of gravitational waves!

In this paper we suggest to use the Fourier transform heterodyne imaging (FTH). The main idea in brief behind the suggestion in this paper is to capture and measure the variation that will occur in the Fourier transform heterodyne images for amplitude, phase, and intensity taken at regular time intervals on a computer. We will need to increase the distance between beam splitter and mirror on one side and beam combiner and mirror on the other side to achieve perceptible changes in the successively taken images. The changes in the Fourier transform heterodyne images taken on computer should occur while gravitational waves will pass through the modified apparatus in which the above mentioned increase in distances is carried out. It is our guess that if we carry out the process of Fourier transform heterodyne imaging on computer for amplitude, phase, and intensity in succession after a suitable time intervals and after increasing the distance between beam splitter and mirror on one side and beam combiner and mirror on the other side (so as to make this distance suitable for producing detectable changes in the amplitude, phase, and intensity) then (as STM technology has made us capable of imaging few atoms) Fourier transform heterodyne imaging technique developed in [15] should make possible the detection of gravitational waves indirectly through recording the variation in images through Fourier transform heterodyne imaging on the computer.

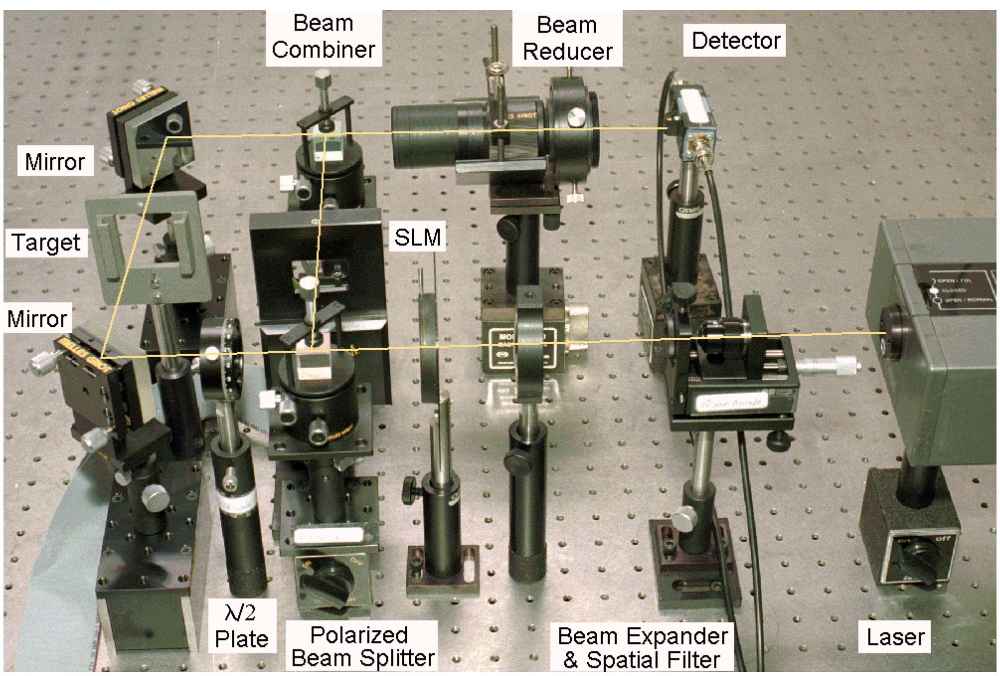

FIG. 1

As mentioned above we sufficiently increase the distance between beam splitter and mirror on one side and beam combiner and mirror on the other side as shown in FIG. 1, so as to make this distance suitable for producing detectable changes in the images for amplitude, phase, and intensity due to passing of gravitational waves through the apparatus. We carry out imaging for imaging transverse amplitude and phase at suitable intervals using the setup of **FTH experiment,** 3.0, shown in the experimental schematic, Figure 4, in [15].

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