Detection of Gravitational Waves using High Energy Well Regulated Pulsed Laser, Photo detectors, and a Counter

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Abstract

We propose novel technique for detecting gravitational waves using facilities at LIGO with certain changes and additions in the present setup. We suggest replacing the perfectly reflecting mirrors fixed at the ends of the arms of interferometer by exactly identical photo detectors. We propose to use high energy laser to ensure well defined quantized form for the radiation. We make provision to determine maximality of incident intensity of light packet falling on the photo detector and further make provision to check whether this peak intensity is simultaneous in reaching both the detectors. Simultaneity of reaching of peak intensity is used to provide high inputs to something like logical AND gate. These provisions like logical AND gate will be sending high output if and when peak intensity will hit both the photo detectors simultaneously. This high output of logical AND will be used to operate a counter to go one count up. We suggest utilizing the simultaneous arrival of light packets with exactly equal peak intensity at detector to give an up count in the counter. These light packets are running in two orthogonal arms, originally emerged from a pulsed laser source and split into two beams by beam splitter, We propose to measure counts that will be shown by the counter after a sufficiently long interval of time. Now, if over this sufficiently long period any gravitational waves will pass through the apparatus they will cause stretching and squeezing of interferometer arms in a reciprocal way and the pulses directed towards photo detectors from beam splitter will not reach these detectors simultaneously with exactly equal peak intensity. This will be causing turning on of the logical AND lesser number of times leading in effect to lesser number of counts that will be recorded by the counter. From this record of lesser number of counts, less than the expected number when no gravitational waves reach the apparatus, we can conclusively infer that gravitational waves have certainly passed through the apparatus! Instead of laser one may consider using a well regulated uniform beam of particles, like electrons, to fall on beam splitters with relevant replacements in the detection apparatus in place of perfectly reflecting mirrors and again using same methodology for the detection.

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 wave and this may be one of the important reason that we have not yet succeeded in this task even though many gravitational waves would have passed through our apparatus installed at different locations.

   Instead of usual journey of light signals going in mutually orthogonal directions from the beam splitter and reflecting back from perfectly reflecting surfaces of mirrors installed at ends of these arms to recombine if we will cut this journey of light half way by replacing the mirrors fixed at the ends of mutually orthogonal arms by detectors to determine when these signals hit at peak intensity and if we also make a further provision to determine whether both these signals hit the detectors simultaneously at peak intensity and a still further provision to record such event of simultaneous hitting of light signals at peak intensity through an up count in the counter provided as additional accessory and testing this impinging of uniform light pulses at peak intensity each time producing up counts with each simultaneity in hitting the detectors with peak intensity will not keep us away for long from conclusively capturing the arrival of gravitational waves. The strongly guessed difference between measured number of counts and expected number of counts (when not any gravitational wave has reached the apparatus) will reveal us the arrival and passing of gravitational waves through the apparatus.

   Instead of light pulses from well regulated high energy laser light source one may consider using well regulated uniform particle beam, e.g. a uniform beam of well separated electrons emitted with perfect uniformity from an electron gun, for these experiments to firmly ensure particulate nature of the hitting beam. Such change could be more suitable to record the discrete events of knocks of beams on the exactly identical suitable detectors. Adjusting the hitting events of discrete particles in exact synchronization on the detectors at exactly identical times when no gravitational wave is passing through the apparatus will help to determine the mismatch in the hitting events through variation (reduction) in expected counts in the counter when some gravitational wave will pass through the apparatus. Instead of photo detectors we will need to choose and fix suitable and exactly identical particle detectors in the place of perfectly reflecting mirrors to achieve same results that we expect to obtain with the help of light pulses of laser.

The main idea in brief behind the suggestion in this paper is to capture the variation in the time interval between two successive knocks at peak intensity of well separated uniformly emitted and propagated pulses of laser or two successive knocks of discrete particles from a uniformly emitted and propagated beam of particles from a particle source separated initially by a fixed distance from each other to hit simultaneously on the detector. We aim capturing the nonuniformity that enters in the distance between successive pulses/particles in the beam of pulses/particles that result in variation in the time interval of two successive knocks.

3. Why this modification? : The present setup at LIGO tries to capture the phase difference that results due to path difference that will occur between two interfering waves reaching back after reflection from perfectly reflecting mirrors to beam splitter and interfere destructively when no phase difference is introduced due to absence of gravitational wave. On arrival and passing of gravitational wave through the apparatus when the phase difference will be created due to effect of generated path difference due to squeezing and stretching that gets introduced in mutually orthogonal interferometer arms. But one more possible reason for failure in getting any phase shift so far may be because of the following reasoning: It may be a fact that due to squeezing and stretching of *space* the resulting path difference may be causing creation of desired phase difference, but simultaneously occurring dilation and shortening of *time* associated with squeezing and stretching of *space* may be causing the reciprocal effect on the laser signal used in the experiment to *nullify this effect* resulting in *zero (effective) phase shift*, i.e. the effect of gravitational waves on *space* may be getting nullified by its simultaneous effect on *time* resulting effectively in *null phase shift* for laser signal.

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