Detecting Gravitational Waves by video shooting the Standing Wave Pattern and Diffraction Pattern

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Abstract

We propose two novel techniques for assuredly detecting Gravitational Waves through enhancement techniques proposed to make these ridiculously tiny waves detectable. Suppose that the Gravitational Waves are passing through the spacetime fabric, say, through a region bounded by two planes parallel to say X-Y plane, i.e. through a slab parallel to the X-Y plane. The first technique that we propose consists of continuously photographing the Standing Wave Pattern that we create in this slab which is bounded by two planes parallel to say X-Y plane, and through this slab these incredibly feeble waves are passing and causing stretching and squeezing in this region parallel to X-Y plane. We create Standing Wave Pattern in this slab parallel to the X-Y plane, which has extent simultaneously along X as well as Y axis, and we video shoot this region by fixing camera at a suitable height on say Z axis while Gravitational Waves are passing through it. Through this camera we video shoot the region of X-Y plane, to capture as large region as possible, where we have created the Standing Wave Pattern, which is present simultaneously along X as well as Y axis due to our special experimental arrangement. In the second technique we propose to create 2-dimensional Fraunhofer Diffraction Pattern due to a square shaped aperture, and also due to circular shaped aperture, kept parallel to X-Y plane in the slab through which Gravitational Waves will be passing causing stretching and squeezing of this region parallel to X-Y plane. Below this slab bounded by two planes parallel to X-Y plane we keep the screen on which 2-dimensional Fraunhofer Diffraction Pattern will be produced. As previous by fixing camera at a suitable height on Z axis we carry out photographing (video-shooting) of this 2-dimensional Fraunhofer Diffraction Pattern. Is there any simple way to enhance the extremely tiny local effects of stretching and squeezing of spacetime fabric when these waves pass through it? We suggest in this paper two novel techniques which propose to enhance the locally occurring effects on spacetime when Gravitational Waves pass through it through the technique of cumulative additions of such several tiny effects occurred locally into a big assuredly detectable and measurable effect!!

1. **Introduction:** The incredibly exciting news has just arrived about successful detection of Gravitational Waves at LIGO and it has given rise to lots of excitement

and enthusiasm all over the world! Experimental detection of Gravitational Waves was a big challenge of this time and enormous efforts were on world over by people working in highly sophisticated Gravitational Wave detection laboratories. These 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. How can we enhance the effects of stretching and squeezing of spacetime fabric when these waves pass through it? We suggest in this paper two novel techniques which propose to enhance these local and extremely tiny effects on spacetime through technique of cumulative additions of such several effects occurred locally into a big assuredly detectable and measurable effect!!

2. **Two Novel Techniques:** In the first technique we create Standing Wave Pattern in the slab bounded by two planes parallel to X-Y plane and take continuous photographs using ultrahigh speed camera of the Standing Wave Pattern containing successive maxima and minima, i.e. the maximum and minimum intensity locations present simultaneously along X and Y direction due to our experimental arrangement. The Standing Wave Pattern is a uniform intensity pattern made up of successive maxima and minima and these maxima (minima) are separated by distance equal to wavelength of the used laser light for their formation. When there are no Gravitational Waves passing through region parallel to X-Y plane this stationary pattern will remain as it is and will be identical both along X and Y axis, i.e. the separation between two successive maxima as well as minima along both the axes will be same. But when the Gravitational Waves will pass through the slab bounded by planes parallel to X-Y plane through this Standing Wave Pattern these waves will create reciprocal effect. The passing Gravitational Waves will create an elongation (stretching) along X axis while contraction (squeezing) along Y axis and vice versa. So, as an effect the distance between successive maxima along X axis will elongate while distance between successive maxima along Y axis will shrink in earlier photographs and there will be exactly opposite situation in the other photographs which are taken later. This variation in distance between successive maxima (minima) will be extremely tiny (local effect) but instead of measuring the variation in distance between successive maxima (minima) we have made the option available to measure the variation in distance between two maxima (minima) separated by say 1billion

wavelengths (a cumulative addition of local effect)! Thus, we create a provision to measure the cumulatively added much enhanced variation in distance. We create and perform video-shooting of this Standing Wave Pattern of maxima and minima before, during, and after the passing Gravitational Waves by following simple experiment!! The following FIG.1 depicts the apparatus and experimental arrangement required for this experiment to be carried out to capture the signature of Gravitational Waves. As shown in FIG.1 below, the laser source (1) emits the ray of light which moves parallel to X axis towards perfectly reflecting plane mirror (4) kept inclined by 45 degrees with the incident ray direction. The ray that reflects from mirror (4) then moves parallel to Y axis and reach to the perfectly reflecting mirror (7) kept perpendicular to Y axis to reflect back the ray of light along the reversed direction. The ray, reflected back from this mirror (7, traverse back the same journey to reach back to source. This leads to formation of standing waves in the region along X axis from source (1) to inclined plane mirror (4) and further along Y axis from inclined plane mirror (4) to plane mirror (7) kept perpendicular to Y axis. The locations for maxima (2), (4) and minima (3), (5) are also shown in this FIG.1

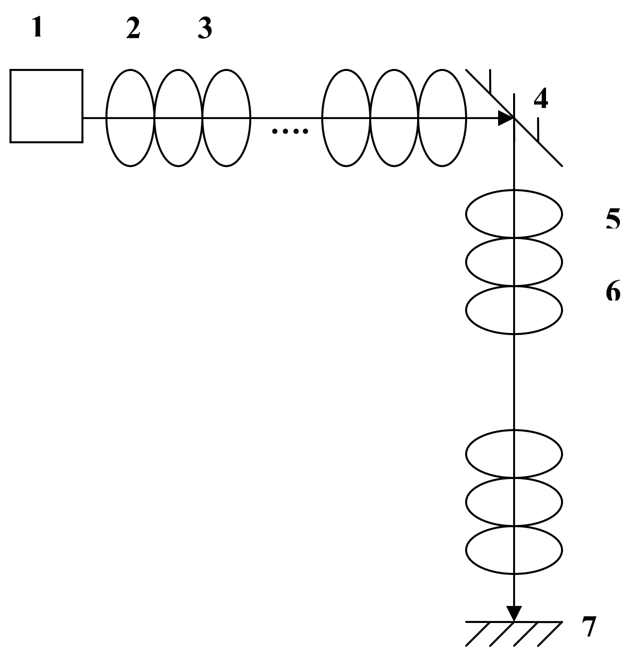

FIG.1

The following FIG.2, and FIG.3 depicts the effects of passing of Gravitational Waves through the region where we have created the Standing Wave Pattern shown in FIG.1. In FIG.2 we see the stretching effect along X axis and squeezing effect along Y axis. The exactly opposite (reciprocal) effect, i.e. squeezing effect along X axis and stretching effect along Y axis are depicted in FIG.3 when Gravitational Waves will pass through the region

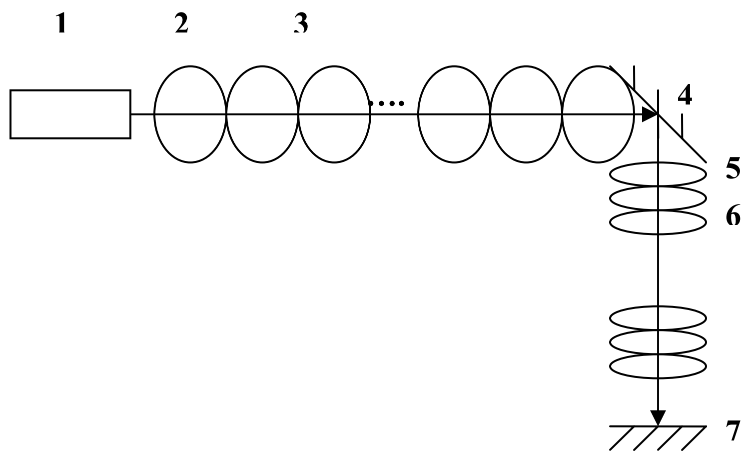

FIG.2

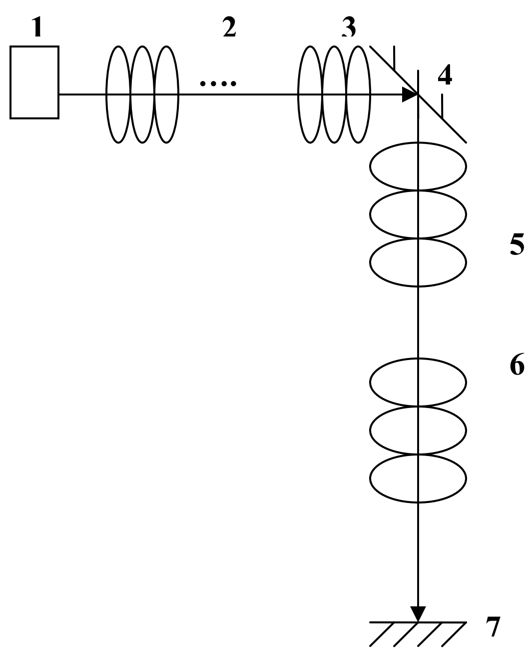

FIG.3

We now proceed to discuss the second technique that we propose to capture the signature of Gravitational Waves. In this technique we propose to create Fraunhofer

Diffraction Pattern instead of Standing Wave Pattern by keeping square shaped aperture in the fabric of spacetime through which Gravitational Waves will be passing. Suppose as previous that the Gravitational Waves are passing through the spacetime fabric, say, through the region bounded by two planes parallel to say X-Y plane, i.e. through the slab parallel to the X-Y plane. We now proceed to create 2-D Fraunhofer diffraction pattern which looks like Fourier transform of the field at the square shaped or circular shaped aperture kept parallel to X-Y plane in the above mentioned slab. When the Gravitational Waves will pass through this region, at that time there will be stretching along Y axis and squeezing along X axis occurring simultaneously and exactly reverse of this , i.e. stretching along X axis and squeezing along Y axis, again occurring simultaneously at a later time, and this process repeats periodically till the Gravitational Waves are passing through this region. The experimental arrangement that we need is very simple as depicted in FIG.4 below.

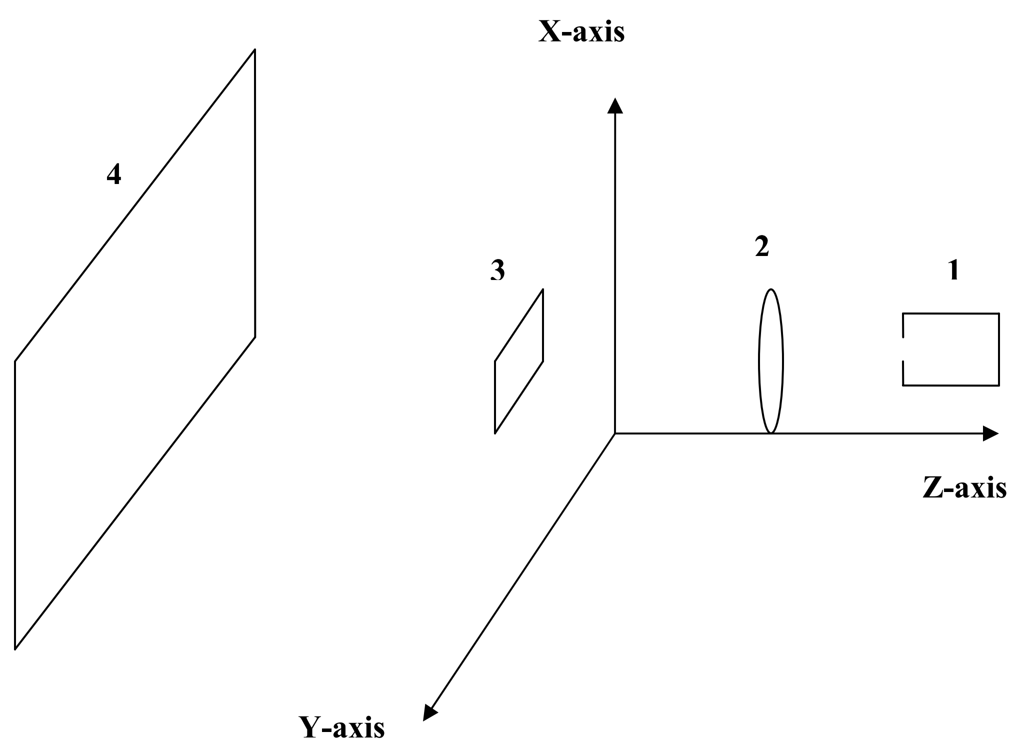

FIG.4

In FIG.4 there is taken a laser source (1), say Helium-Neon laser with wavelength $\lambda = 6328$ Angstroms. The ray running along Z axis falls on lens (2) which causes the focusing of light on the very small square shaped aperture (3) and creates Fraunhofer Diffraction Pattern on the screen (4) kept a meter or two away. When no Gravitational Waves will be passing through the slab parallel to X-Y plane in which we have kept the square shaped aperture there will be no stretching or squeezing and so the square shaped aperture will maintain its shape as it is and the Diffraction Pattern will be as shown in FIG.5 below.

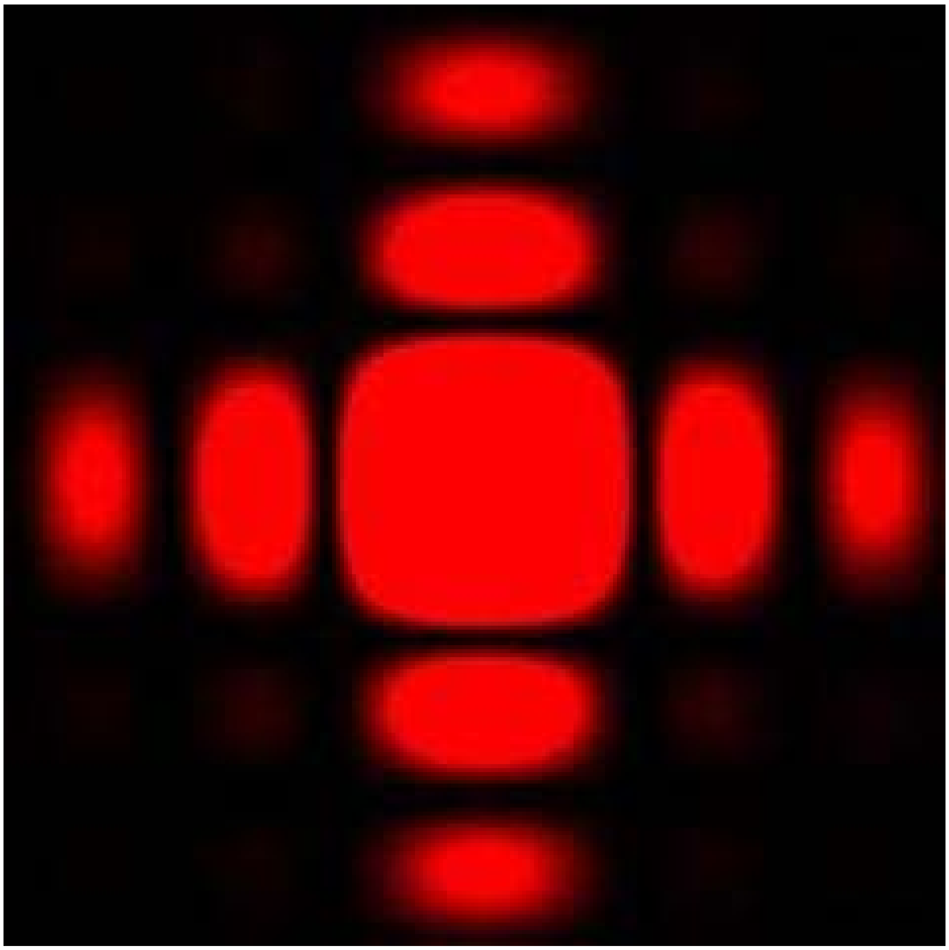

FIG.5

But, when Gravitational Waves will be passing through this medium there will be periodic stretching and squeezing and the square shaped aperture will take rectangular shape. It will become firstly a rectangle with lesser width and greater height producing the Diffraction Pattern as shown in FIG.6.

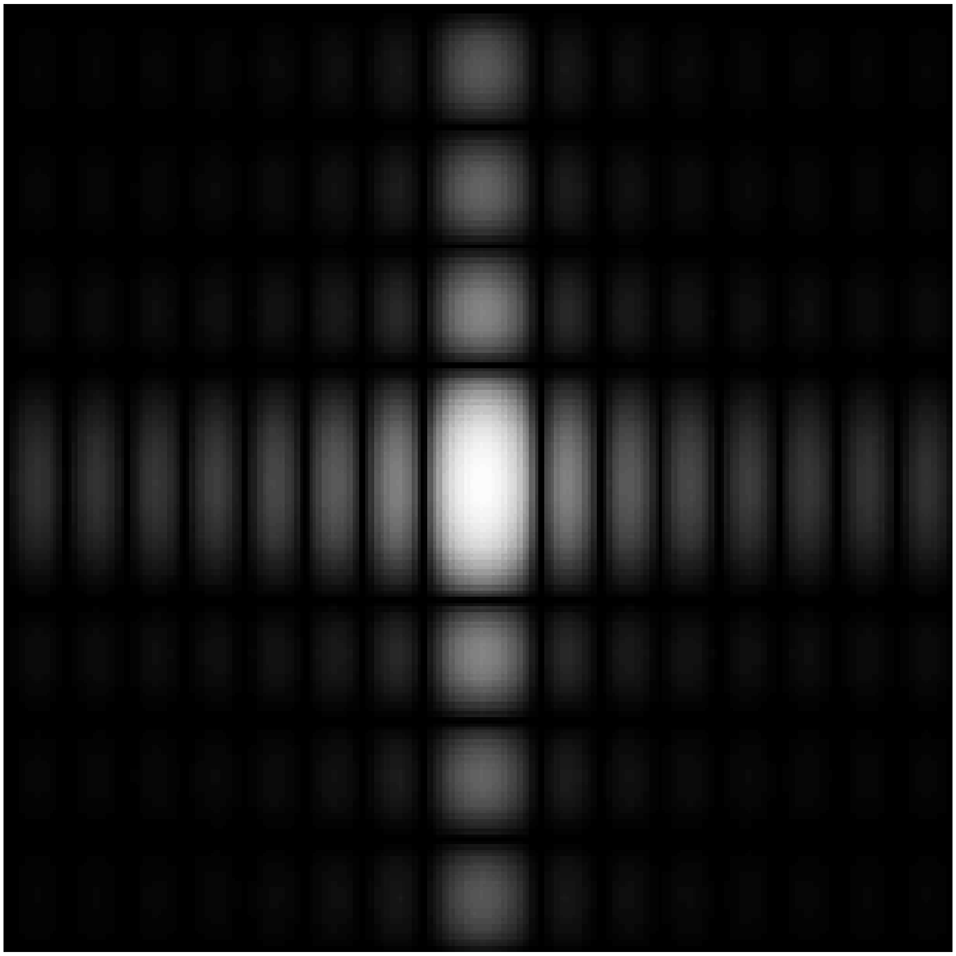

FIG.6

We then get the rectangular aperture with greater width and lesser height producing the Diffraction Pattern as shown in FIG.7 given below.

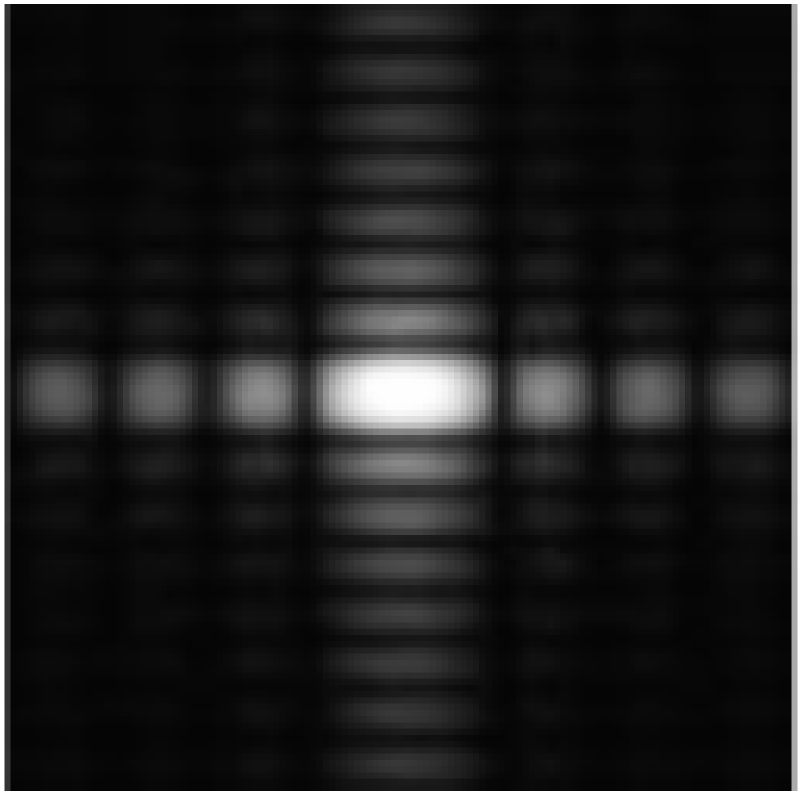

FIG.7

This process will continue to take place periodically and can be captured using very high speed femto-photography.

We can use circular aperture (an extremely tiny hole) in the place of square shaped aperture. It is obvious to check that the Diffraction Pattern in this case will be as shown in FIG.8 when no Gravitational Waves will be passing through the slab parallel to X-Y plane in which we have kept the circular shaped aperture as there will be no stretching or squeezing and so the square shaped aperture will maintain its shape as it is and the Diffraction Pattern will be as shown in FIG.8 below.

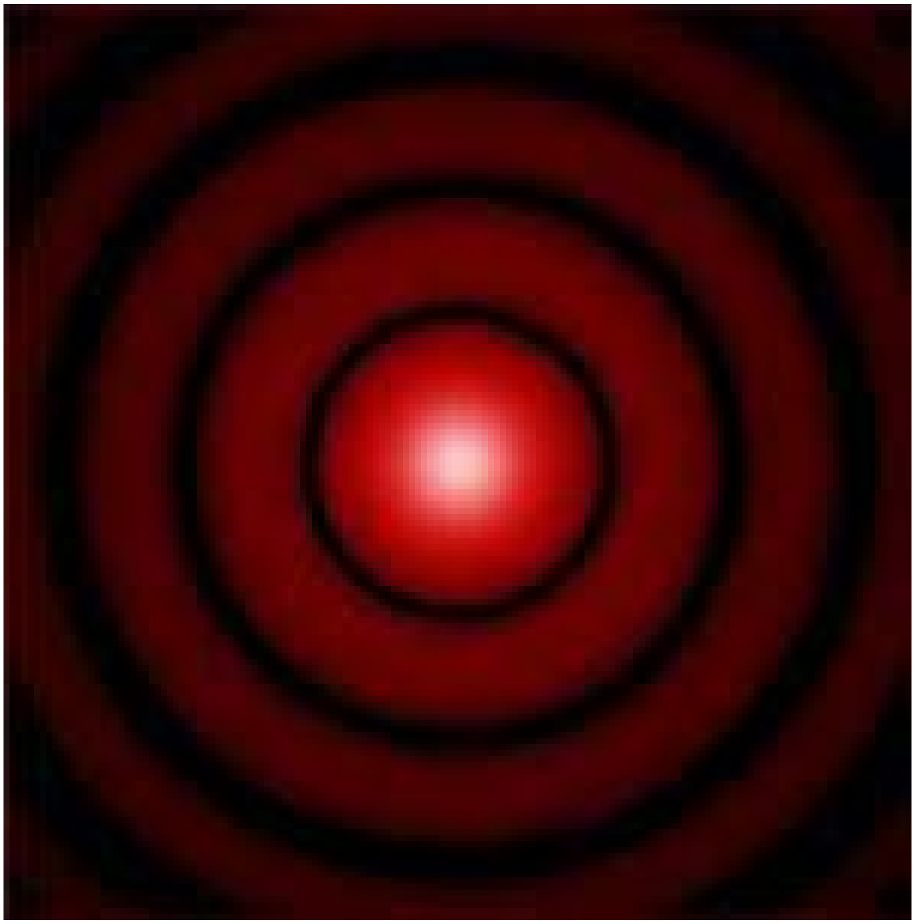

FIG.8

But, when Gravitational Waves will be passing through this medium there will be periodic stretching and squeezing and the circular shaped aperture will take elliptical shape. It will become firstly a ellipse with producing the Diffraction Pattern as shown in FIG.9.

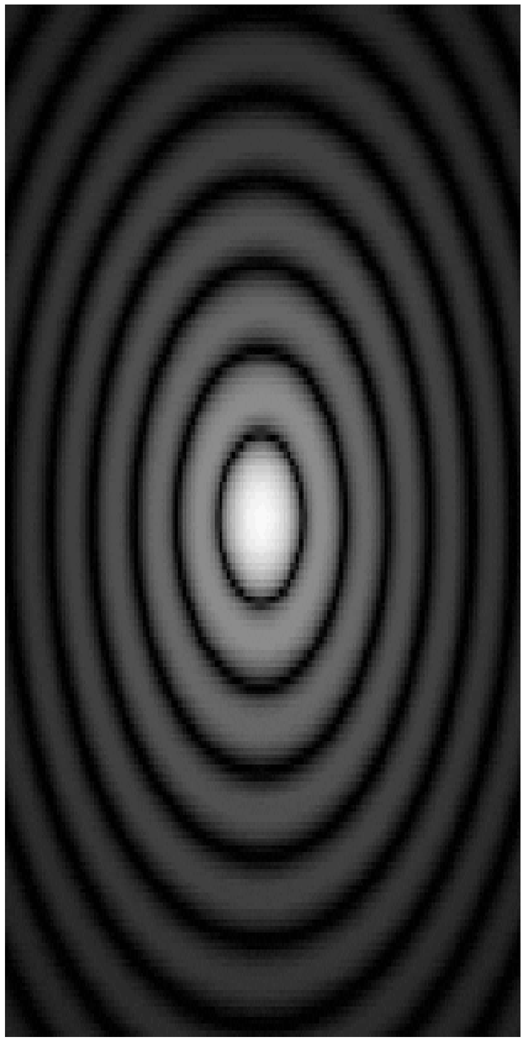

FIG.9

We then get the elliptical aperture producing the Diffraction Pattern as shown in FIG.10 given below.

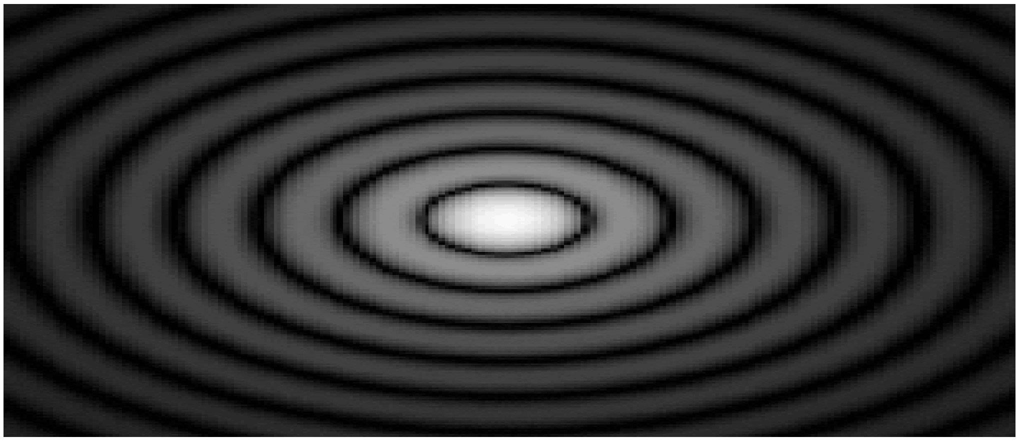

FIG.10

This process will continue to switch periodically and can be captured using very high speed femto-photography.

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