



On the Theoretical Possibility to Generate Gravitational Waves Using Electromagnetic Waves

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ABSTRACT

This paper demonstrates that according to a consequence of General Theory of Relativity, a high amount of electromagnetic waves, such as ultraviolet light, injected between two or more parallel reflective surfaces must generate through multiple reflections gravitational waves having a significant power which are radiated into space. The emitted gravitational waves have the same frequency as the incident electromagnetic waves and are directed along the normal to the reflective surfaces. This paper derives, an equation connecting the radiated gravitational power with the electromagnetic energy injected between reflective plates. The radiated gravitational power can be enhanced and focused on a point using multiple reflective calottes.

Indexing terms/Keywords

gravitation; gravitational radiation; generation of gravitational waves using electromagnetic waves; light generates gravitons during reflection; light encapsulated in a sphere generates gravitation only on sphere's surface

Academic Discipline And Sub-Disciplines

Physics, Relativity, General Theory of Relativity

SUBJECT CLASSIFICATION

TYPE (METHOD/APPROACH)

Theoretical

1. INTRODUCTION

Based on the acceleration involved, the reflection of electromagnetic waves on a reflective wall (mirror) can be considered the most violent process in the Universe, which in addition involves a quadrupole-type oscillation of matter. Such type of oscillations must cause emission of gravitational waves.

In this article, the generation of gravitational waves during reflection of electromagnetic waves is deduced as a direct consequence of Einstein's General Theory of Relativity (GTR).

In addition, an intuitive demonstration of the possibility to generate gravitational radiation using electromagnetic waves is presented in appendix 1.

2. METHODS

For avoiding any ambiguity, Einstein's field equations and some important known demonstrations are summarized in the next section.

2.1 Einstein's field equations

Einstein field equations [1] are:

$$R_{ik} - \frac{1}{2} \cdot g_{ik} \cdot R = -\frac{8\pi G}{c^4} \cdot T_{ik} \quad (1)$$

where the indices of coordinates in the 4D space-time continuum, i and k take values from 0 to 3. The values 1, 2 and 3 indicate space coordinates (for example $x_1=x$, $x_2=y$, $x_3=z$ when using Cartesian coordinates and $x_1=r$, i.e., radius, $x_2=\theta$, $x_3=\varphi$ when using spherical coordinates). The index value of zero is reserved for the temporal coordinate, which takes the form $x_0 = c \cdot t$, where 'c' is the speed of light in vacuum and 't' is time, R_{ik} , g_{ik} and T_{ik} are tensors; R_{ik} is the curvature tensor of second order or Riemann's tensor, the tensor that defines the space metric, g_{ik} , is also called the metric or fundamental tensor, R is Ricci's scalar curvature of space and G is the universal constant from Newton's Law of gravitation. T_{ik} is the energy-momentum tensor of matter (also known as the stress-energy tensor).

2.2 A basic feature of electromagnetic waves

For electromagnetic waves, which propagate freely through space, the components of the energy-momentum tensor are given below.[2]

$$T_{00} = \frac{1}{8\pi}(E^2 + H^2), T_{0i} = -\frac{1}{4\pi}(\vec{E} \times \vec{H})_i, T_{ik} = -\frac{1}{4\pi}(E_i E_k + H_i H_k) + \frac{1}{8\pi} \delta_{ik}(E^2 + H^2) \quad (2)$$

where $i, k=1, 2, 3$ and $\delta_{ik}=1$ for $i=k$ and $\delta_{ik}=0$ for $i \neq k$. The invariant of the energy-momentum tensor of the electromagnetic field is a null scalar [2]:

$$T = \sum_{i=0}^3 e_i T_{ii} = 0 \quad (3)$$

The values of factors e_i are: $e_1=e_2=e_3=-1$ and $e_0=1$. [3]

It is known that 'contraction', (i.e., the multiplication of covariant field Eq. (1) with the metric tensor expressed in counter-variant form, which is labeled g^{ik} , followed by a summation), provides a new form of Einstein's field equations which is given below. [4]

$$R = \frac{8\pi G}{c^4} T \quad (4)$$

where R is the invariant of curvature R_{ik} (also known as Ricci's scalar curvature).

Notes: Equation (4) was derived taking into account that:

1) The definition of the counter-variant metric tensor g^{ik} is based on the covariant metric tensor:

$$\sum_{k=0}^3 g_{jk} g^{ik} = \delta_j^i, \delta_j^i = 1 \text{ when } i=j \text{ and } \delta_j^i = 0 \text{ when } i \neq j. \quad [5]$$

$$2) g^{ik} \cdot R_{ik} = R. \quad [6]$$

$$3) g^{ik} \cdot T_{ik} = T. \quad [7]$$

As it can be seen from Eq. (3), the invariant T of the energy-momentum tensor T_{ik} is null for a free electromagnetic field. Based on Eq. (4), the scalar curvature R is null, i.e., according to GTR, electromagnetic waves propagating freely through space do not generate gravitational fields. [8]

The fact that electromagnetic waves, which propagate freely in space do not produce gravitational fields is a profound property of matter.

3. RESULTS

3.1 Demonstration

The possibility of generating gravitational waves using electromagnetic waves is demonstrated below.

Assume a packet of electromagnetic waves which freely propagate through space where there are no gravitational fields (see **Figure 1**). Assume this pack enters a massless sphere (see **Figure 2**). When the sphere's cover is closed, the waves are confined inside (see **Figure 3**). If the inner surface of sphere is perfectly reflective, an isotropic electromagnetic field is established inside the sphere in a short time (see **Figure 4**).

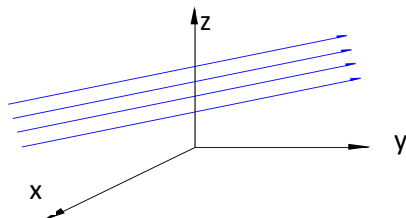


Fig.1: A pack of electromagnetic waves which freely propagates through space

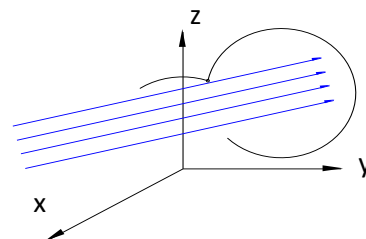


Fig.2: A pack of electromagnetic waves enters a massless sphere

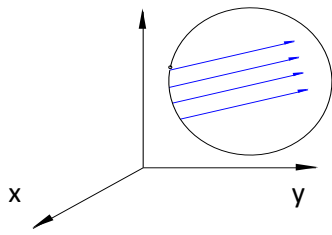


Fig.3: Electromagnetic waves confined inside a sphere

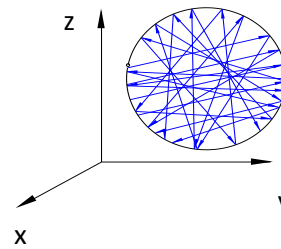


Fig.4: An isotropic electromagnetic field formed within the sphere

If the total energy of electromagnetic waves confined inside is E , then according to Einstein's formula, the relativistic mass of photons is:

$$M = \frac{E}{c^2} \quad (5)$$

According to Newton, such a mass must produce a gravitational field with potential:

$$\Phi = -\frac{G \cdot M}{r} \quad (6)$$

where G is Newton's gravitational constant and r is the distance from sphere's center ($r > r_0$, r_0 =sphere's radius).

On the other hand, according to Einstein's GTR, a concentrated mass M should modify the continuum space-time curvature; the space element being given by Schwarzschild's metric given below. [9]

$$ds^2 = \frac{r-\alpha}{r+\alpha} c^2 dt^2 - \frac{r+\alpha}{r-\alpha} dr^2 - (r+\alpha)^2 \cdot d\theta^2 - [(r+\alpha) \cdot \sin\theta]^2 \cdot d\phi^2 \quad (7)$$

where r, θ, ϕ are spherical coordinates, t is time, $\alpha = GMc^{-2}$. In the Schwarzschild metric, the fundamental metric tensor is therefore:

$$g_{ik} = \begin{bmatrix} -\frac{r+\alpha}{r-\alpha} & 0 & 0 & 0 \\ 0 & -(r+\alpha)^2 & 0 & 0 \\ 0 & 0 & -[(r+\alpha)\sin\theta]^2 & 0 \\ 0 & 0 & 0 & \frac{r-\alpha}{r+\alpha} \end{bmatrix} \quad (8)$$

Note: for a concentrated mass, the energy-momentum tensor takes the following form:

$$T_{ik} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & w \end{bmatrix} \quad (9)$$

As it can be seen, all tensor components are null, except, T_{00} , which is equal to the energy density $w = c^2 \rho$ (ρ is the mass density). We have obviously an unacceptable contradiction: On one hand, according to Eq.4 the electromagnetic waves confined inside the sphere should produce no space-time curvature but according to Eq. 7, the mass of electromagnetic waves must produce gravitational effects. The above contradiction can be eliminated only by admitting that electromagnetic waves confined inside the sphere produce gravitational fields only during reflection on the reflective wall of sphere. In fact, this contradiction was observed as early as 1913 during debates between Nordstrom and Einstein [10] The single explanation given at that time was that "the electromagnetic radiation enclosed within a massless box having reflective walls would not acquire a gravitational mass although that radiation would exert a pressure on the walls of the box. These walls would become stressed and, simply because of this stress, the walls would acquire a gravitational mass". Today, it is very clear for everybody that such a massless wall cannot be stressed simply because in the absence of mass, such a stress can have no physical sense. So, while a sphere of condensed matter generates gravitational field in every point, a massless sphere full with electromagnetic waves generates a gravitational field only on its surface i.e., obviously during reflection of electromagnetic waves by the sphere surface. For understanding further why a photon is able to generate during reflection a graviton, one should be aware that in a way, the reflection of a photon on a reflective surface can be considered the most violent process in Universe even more violent than the head on collision of neutron stars because the acceleration of matter during normal reflection has a huge value due to the high speed of light:

$$a = \frac{\Delta V}{\Delta t} = \frac{-c - (+c)}{T} = \frac{-2c}{T} = -2cv \tag{10}$$

where ΔV is speed variation, Δt is the duration of photon-surface interaction, c is the speed of light in vacuum, T the oscillation period of wave and v is the frequency of electromagnetic wave. During reflection, the matter of photon obviously oscillates as a quadrupole (see **Figure 5**) and for this reason it must generate gravitational waves (it was demonstrated that only a quadrupole and not a dipole can generate gravitational waves. [11])

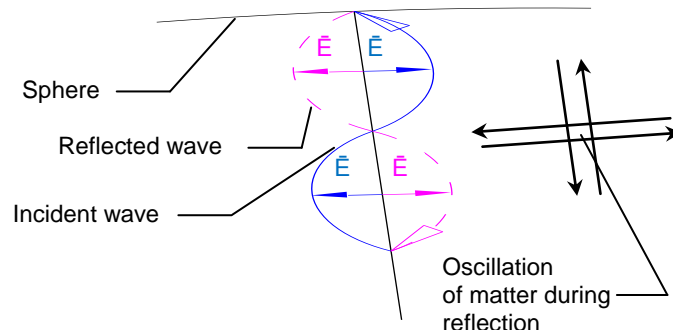


Fig.5: During reflection, the matter of a photon oscillates like a quadrupole

The direction of the electric field is perpendicular to the photon's travel direction. During reflection, the sense of the electric field is reversed and obviously the photon's matter also oscillates longitudinally due to the reflection process. A fundamental question arises: how to determine the direction of a graviton emitted during normal reflection of a photon by a reflective wall? Intuition would indicate the graviton is emitted in the direction of the incident wave. But the opposite is true. The inertia must oppose the cause, therefore the emitted graviton and incident photon must have opposite directions, see **Figure 6**. In this case, the graviton-photon interaction would tend to counter the deceleration process produced by reflection i.e., the graviton 'attempts to accelerate' the photon along the initial direction.

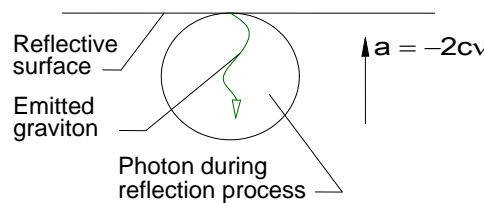


Fig.6: Inertia should determine graviton emission in the direction of reflected wave

This conclusion is supported even by the laws of energy and momentum conservation. Assume the mass of the emitted graviton is m_g . The energy balance in the reflection process is given by:

$$E_{if} = E_{rf} + E_g \tag{11}$$

where E_{if} is the energy of incident photon, E_{rf} is the energy of reflected photon and E_g is the energy of graviton.

Based on Eq. (11), reflection causes a red shift i.e., the frequency of the reflected wave is smaller than the frequency of incident wave, $\nu_{rf} < \nu_{if}$. This red shift is obviously extremely low and cannot be observed visually. On the other hand, according to the law of momentum conservation:

$$h \cdot \nu_{if} / c + h \cdot \nu_{rf} / (-c) + m_g (-c) = 0 \tag{12}$$

where ν_{if} is the frequency of incident photon, ν_{rf} is the frequency of reflected photon and m_g is the mass of graviton. Equation (12) shows that the direction of radiated gravitational wave is opposite to the incident electromagnetic wave and that the propagation speed of gravitational wave is c , fact, which was already demonstrated for weak gravitational fields. [12]

The energy of a graviton emitted in this manner can be easily evaluated using dimensional analysis. The graviton energy should depend on Planck's constant, h , frequencies of incident and reflected electromagnetic wave, $\nu_{if} > \nu_{rf} \approx \nu_g$ (ν_g - frequency of gravitational wave), c - speed of light and G - gravitational constant:

$$E_g = \chi^* \cdot G^\alpha \cdot h^\beta \cdot \nu_g^\delta \cdot c^\epsilon \tag{13}$$

where χ^* is a constant.

One can easily find that $\alpha = 1, \beta = 2, \delta = 3, \epsilon = -5$ i.e.,

$$E_g = \frac{\chi^* \cdot G \cdot h^2}{c^5} \cdot \nu^3 \tag{14}$$

The value $h_{gv} = \frac{\chi^* \cdot G \cdot h^2}{c^5}$ can be taken as a universal constant showing that during normal reflection of photons, the gravitons are emitted as energy quanta. The energy of gravitons is proportional to the cube of light frequency. Equation (14) can be written in a new form (15),

$$E_g = \frac{\chi^* \cdot G}{c^5 \cdot h} \cdot h^3 \cdot \nu^3 = \frac{\chi^* \cdot G}{c^5 \cdot h} \cdot E_e^3 = h_{ge} \cdot E_e^3 \tag{15}$$

Eq. (15) reveals a connection between radiated gravitational energy and electromagnetic energy: The radiated gravitational energy is proportional with the cube of electromagnetic energy, and the proportionality constant is $h_{ge} = \frac{\chi^* \cdot G}{c^5 \cdot h}$ which obviously can also be considered a universal constant.

3.2 The enunciation of conversion theorem and equation of the radiated gravitational power

According to the above demonstrations, the following theorem can be stated:

‘During normal reflection of an electromagnetic wave on a reflective surface, electromagnetic energy is partially converted into gravitational energy. The frequency of the emitted gravitational wave is equal to the frequency of incident wave. The energy of emitted gravitational wave is proportional with the cube of frequency of electromagnetic wave. The direction of gravitational wave is opposite to that of the incident electromagnetic wave’.

Assume two packs of electromagnetic waves 1, 2 having the same frequency and continuously reflected by two parallel reflective surfaces (mirrors A, B) separated by a gap, $d = \lambda$ (see **Figure 7**). Assume the incidence angle is zero, each pack has the same number of photons, n , and total energy E . Obviously such equipment continuously generates gravitational power because reflection of pack 2 on mirror A and of pack 1 on mirror B is instantaneously followed by reflection of pack 1 on mirror A and of pack 2 on mirror B.

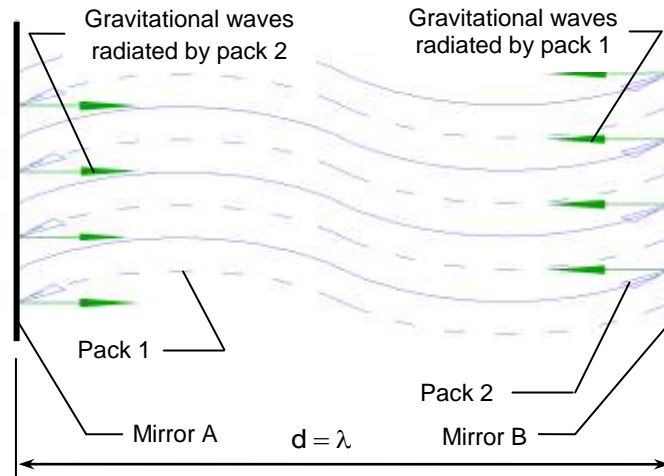


Fig.7: Two packs of electromagnetic energy which continuously radiate gravitational waves through multiple reflections

The radiated gravitational power P_g is calculated dividing the right hand side of Eq. 14 by wave period $T = \lambda / c$ and multiplying by n , the number of photons in a pack and by 2 because both packs are reflected simultaneously.

$$P_g = 2 \cdot n \cdot \frac{1}{T} \cdot \frac{\chi^* \cdot G \cdot h^2}{c^5} \cdot \nu^3 = \frac{2n\chi^* Gh^2 \nu^2}{c^5} \cdot \nu^2 = \frac{\chi^* G}{c^5} \cdot E^2 \cdot \nu^2 \tag{16}$$

Eq. (16) shows that the radiated gravitational power generated by electromagnetic waves reflecting between two parallel mirrors separated by a gap λ is proportional to the square of incident wave energy and its frequency. In addition, as Figure 7 shows, gravitational energy is directed along the normal direction pointing away from the mirror surface. If $(q+1)$ reflective surfaces are placed at distances $d = \lambda$ (see **Figure 8**), and 2 packs of electromagnetic waves with energy E are inserted between each pair of reflective surfaces, the total power of gravitational radiation increases by a factor of q .

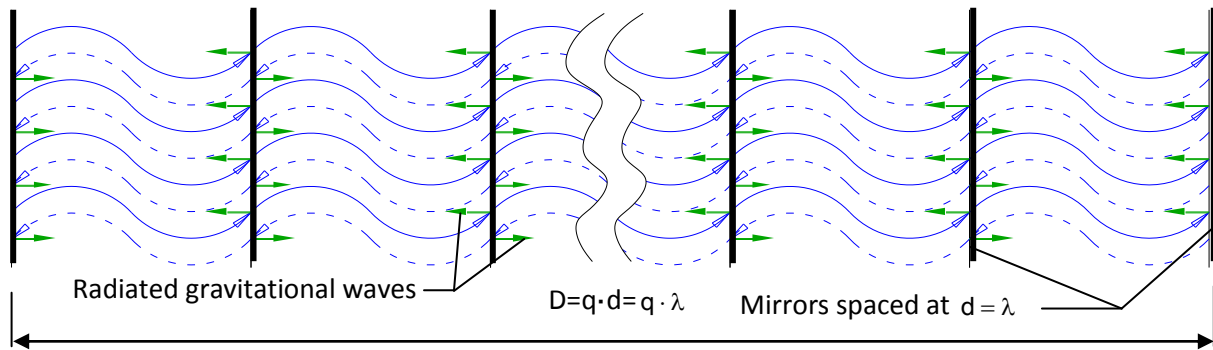


Fig.8: Equipment with multiple reflecting surfaces for increasing the power of gravitational radiation

To greatly boost the power of gravitational radiation a large number of pairs of mirrors must be used. For example, assume ultraviolet light having $\lambda = 50\text{nm}$, injected between $q=10^6+1$ reflective layers forming a multilayered structure with a total thickness, $D = 5\text{ cm}$.

In this situation Eq. (16) becomes:

$$P_{gm} = q \cdot P_g = \frac{q\chi^* G}{c^5} E^2 v^2 \tag{17}$$

4. DISCUSSIONS

4.1. The magnitude of radiated gravitational power produced in this way

Assume the reflectivity coefficient $R=1$ for all the $(q+1)$ reflective layers from Figure 8. During reflection, the electromagnetic energy E is consumed. While the number of photons remains the same, the wave length must increase, i.e. the light enters the visible spectrum and then infrared spectrum, microwave and lower frequencies. For this reason, in practical applications, the distance d must exceed the wavelength of injected light which usually is ultraviolet light. When the wave length of electromagnetic waves reaches the maximum possible length allowed by the gap between mirrors, $\lambda = d$, the wave can no longer exist between the reflective surfaces and is absorbed by the electrons from the surface of mirror. Thus, the energy of remaining electromagnetic waves is converted into heat. This is the reason for which the equipment must be intensively cooled.

Eq. (17) shows that although (G/c^5) is an extremely small number, the quantity $(q \cdot \chi^* \cdot E^2 v^2)$ can be highly enough if the frequency v , electromagnetic energy E and the number of reflective surfaces, q is high. As shown in Appendix 1 (Eq. (25)), the approximate value of χ^* is $\chi^* \approx 512/5 = 102.4$. Simple calculations done using Eq. (17) show that for large values of q ($q \approx 10^6$ or more), frequency of ultraviolet light ($v \approx 0.75 \times 10^{15}\text{Hz} \dots 3 \times 10^{16}\text{Hz}$) and for high amounts of electromagnetic energy ($E > 1\text{kJ}$ or more) injected between every pair of plates, the radiated gravitational power becomes significant (Table 1). Obviously the gravitational radiation becomes very intense if it is generated and focused by the equipment presented in **Figure 9**.

Intense research is necessary in solid physics and in the field of nanotechnology for finding reflective materials having high reflectivity coefficients. An intense technological research is also necessary for developing ultraviolet sources with very high power.

Table 1. The gravitational power generated through multiple perpendicular reflections of ultraviolet light

Energy E, J	10^3	10^6	10^8	10^{10}
Frequency of electromagnetic waves, Hz	The radiated gravitational power $\frac{dE}{dt}$, W			
$v = 3 \times 10^{16}$ (ultra violet)	1.88×10^{-8}	1.88×10^{-2}	1.88×10^2	1.88×10^6

The values of radiated power given in the table 1 show that in the future, gravitational radiation produced in this way could be used for practical applications.

4.2 Design of equipment which further concentrates the artificial gravitational radiation

Using the above results it is possible to further increase the intensity of radiated gravitational waves if the waves are focused in one point (see Figure 9).

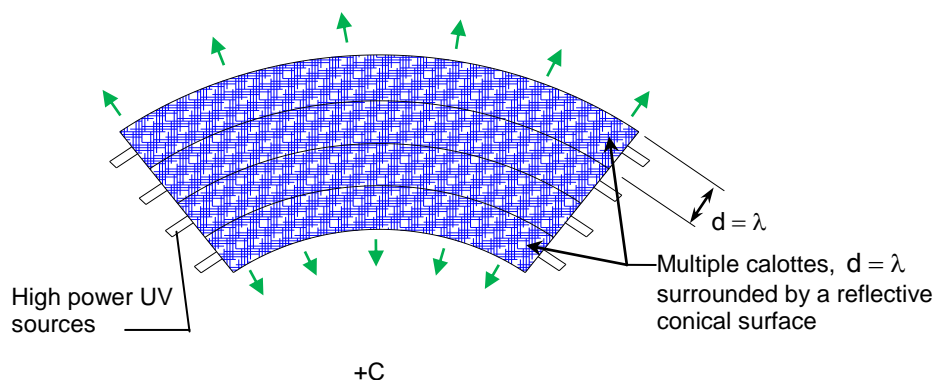


Fig.9: Equipment composed of (q+1) reflective calottes generating an enhanced artificial gravitational field in point C

The equipment is made of (q+1) reflective calottes separated by a gap $d = \lambda$. The highest intensity of radiated gravitational field is obtained in the calottes center, C.

The existence of the gravitational force in Newton's sense can be tested using a Cavendish balance.

5. CONCLUSIONS

1-This paper demonstrates the theoretical possibility of generating gravitational waves using electromagnetic waves. To eliminate any possible mistake, this demonstration is strictly based on the accepted GTR paradigm.

2-To summarize, electromagnetic waves with high energy, which are reflecting between two or more reflective parallel surfaces (mirrors) can generate gravitational waves (radiation).

3-The radiated gravitational waves are propagating in the direction normal to the reflective surfaces.

4-The propagation sense of radiated gravitational waves is opposite to that of incident electromagnetic waves.

5-The radiated gravitational power is significant if the gap between reflective parallel surfaces is comparable to the wave length of photons.

6-Multiple reflective calottes having a common center can be used for increasing the intensity of gravitational radiation.

7-Cavendish balances can be used for proving the emission of artificial gravitational waves

produced by as discussed above.

8-During multiple reflections, the frequency of ultraviolet radiation, which is injected between plates, decreases progressively until becoming visible light, infrared or microwave radiation. Infrared or microwave radiation is absorbed by electrons from the reflective surfaces and transformed into heat.

9-The mastery of artificial gravitation generated in this way will be important for industrial, medical and transportation application.

10-Fundamental research in solid physics will be necessary for improving the reflectivity of materials. At the same time, intense technological research is necessary for developing sources of ultraviolet light with high power.

11-Generation of gravitational radiation for practical applications is a difficult objective and needs sustained research and important resources.

6. APPENDIX 1-A SIMPLIFIED DEMONSTRATION OF THE POSSIBILITY OF GENERATING GRAVITATIONAL WAVES USING ELECTROMAGNETIC WAVES

The starting point of the following demonstration is a GTR prediction validated by astronomical observations. According to GTR a system formed by two planets generates gravitational waves.

The approximate power of gravitational radiation generated by two planets having masses m_1 and m_2 , respectively (see **Figure 10**) rotating with angular velocity ω on a circular orbit with diameter d is [13]:

$$\frac{dE}{dt} \approx -\frac{32G}{5c^5} \cdot \left(\frac{m_1 m_2}{m_1 + m_2} \right)^2 \cdot d^4 \cdot \omega^6 \quad (18)$$

where G is the universal constant of gravitation and c is the speed of light. There are more accurate expressions for the radiated gravitational power [14, 15], but simplicity makes Eq. (18) preferable here.

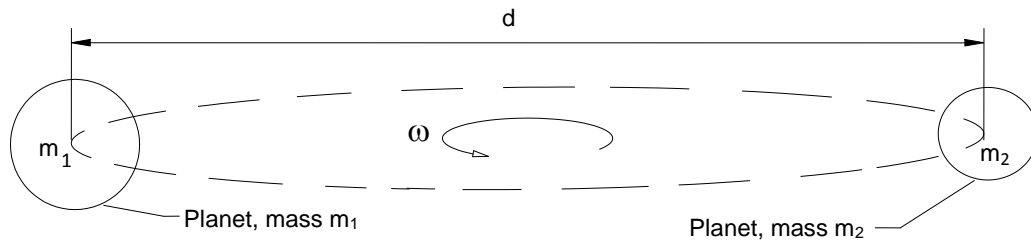


Fig.10: Two planets orbiting round the common center of mass generate gravitational waves

Planets having identical masses equal to m , create gravitational waves, which are uniform and propagate through the space-time continuum as symbolically illustrated in **Figure 11**. For this case, Eq. (18) takes the following form:

$$\frac{dE}{dt} \approx -\frac{8G}{5c^5} \cdot m^2 \cdot d^4 \cdot \omega^6 \tag{19}$$

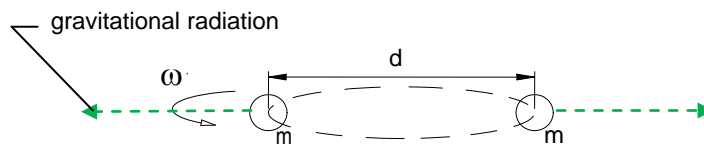


Fig.11: Uniform gravitational waves produced by two equal masses moving on circular trajectories

The minus sign indicates that the system loses energy through gravitational radiation. As a result of this continuous emission of energy in gravitational form, the distance d between planets decreases and as a result the pair of bodies collapses. [13] (Note: Due to the low amount of radiated power, the collapse process takes billions of years).

According to Einstein's formula, the relativistic energy of a body having mass m is $E = m \cdot c^2$. Therefore, the Eq. (19) is equivalent to:

$$\frac{dE}{dt} \approx -\frac{8G}{5c^9} \cdot E^2 \cdot d^4 \cdot \omega^6 \tag{20}$$

If the two bodies of condensed matter moving on circular trajectories with velocity V are replaced by two photon packs, i.e., energy pulses having the same relativistic energy as the planets and moving with the speed of light on a circular trajectory having the same diameter, d (see **Figure 12**), the gravitational power radiated by these packs of photons must be far greater than the power radiated by the pair of planets because the frequency of rotation would obviously increase. Assume that the electromagnetic waves from the two packs have the same frequency, ν , and each pack has energy E .

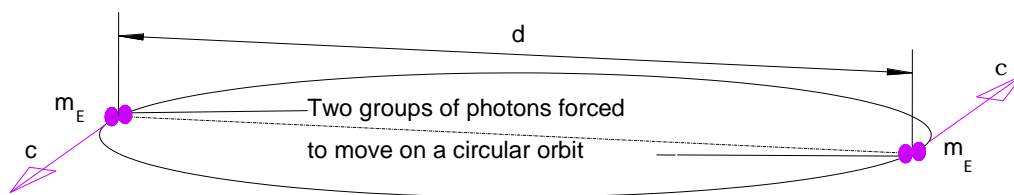


Fig.12: Two photon packs of mass m_E , which follow a circular path (inside an optical fiber for example) must generate gravitational radiation

Also assume the two photon packs are constrained to move on circular trajectories inside a fiber optic coil or wave-guide having diameter d , and the two packs always remain diametrically opposed, see **Figure 13**.

Taking into account that $c = \omega \cdot d / 2$, Eq. (20) becomes:

$$\frac{dE}{dt} \approx -\frac{512G}{5c^3} \cdot \frac{E^2}{d^2} \tag{21}$$

It is important to note that a greater amount of electromagnetic energy E and a smaller diameter d boosts the power of gravitational radiation, $|dE/dt|$. Assume the coil of optic fiber is made from a perfectly flexible, transparent and non-dispersive material, which therefore does not absorb electromagnetic energy and does not scatter the photon packs.

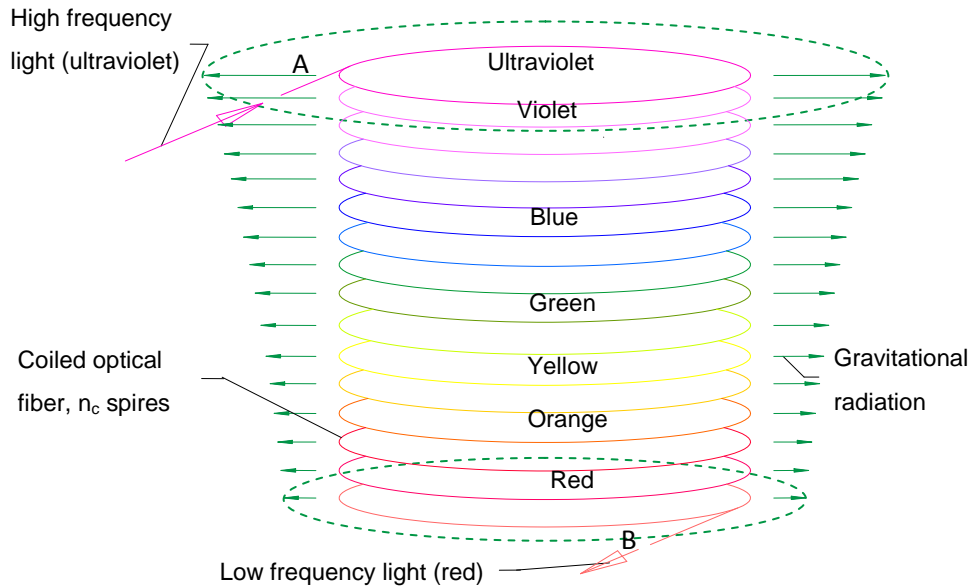


Fig.13: A coiled optical fiber must generate a gravitational field having a cylindrical shape.

Also assume photon packs with frequency ν_i and total energy E_i are periodically injected into this coil, which has an enormous number of spires n_s having diameter d . If the injection period, T^* is given by:

$$T^* = \frac{1}{2} \cdot \frac{\pi \cdot d}{c} = \frac{\pi d}{2c} \quad (22)$$

the total power of gravitational radiation would increase up to an approximate value of

$$\frac{dE}{dt} = -\frac{512G}{5c^3 d^2} \sum_{i=1}^{n_c} E_i^2 \quad (23)$$

because n pairs of photon packs will rotate simultaneously inside the coil. It has been assumed the electromagnetic energy E_i and frequency ν_i remain approximately constant within a spire 'i', although both these values decrease gradually as the electromagnetic energy passes through one spire after another and is gradually converted into gravitational radiation. The distribution of gravitational radiation would be cylindrical and the radiated power would obviously decrease from the first to the last spire due to gradual E_i reduction. The period of gravitational waves emitted by every spire would be exactly equal to the injection period T^* , because two photon packs, which are diametrically opposed, rotate inside each spire. Within a spire, the speed of light is a constant (somewhat less than the speed of light in vacuum, c , depending on the spire material). As a result of energy conversion, the frequency of photons decreases causing a 'red-shift'. In this scenario, pulses of visible light with high frequency (violet for example) injected into extremity A would gradually decay to blue, green and yellow and finally exit through extremity B as pulses of red light (see again Figure 13). Currently, it is impossible to manufacture such a coil due to technological limitations, especially the transparency and length requirement. But it is important to note the idea that one should not seek to generate gravitational waves using bodies of condensed matter that are large and move slowly. It is more useful to use light (or electromagnetic radiation in general), which has an unmatched speed. In optical fibers, light is propagating through multiple total reflections. Assume that the optical fiber is perfectly flexible and the diameter d (see again Figure 12) can be reduced to a very small value, $d = \lambda$, where λ is the wave length of light propagating through the optical fiber. In this case Eq. (21) becomes:

$$\frac{dE}{dt} \approx -\frac{512G}{5c^3} \cdot \frac{E^2}{d^2} = -\frac{512G}{5c^3} \cdot \frac{E^2}{(\lambda)^2} = -\frac{512G}{5c^3} \cdot \frac{E^2}{(c/\nu)^2} = -\frac{512G}{5c^5} \cdot E^2 \cdot \nu^2 \quad (24)$$

This equation gives an initial value for constant χ^* from Eq.16:

$$\chi^* = \frac{512}{5} \quad (25)$$

ACKNOWLEDGMENTS

This represents original research belonging to authors



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