AN EXPERIMENT TO SHOW THAT THERE IS GRAVITATIONAL INTERACTION AMONG PHOTONS, BECAUSE THEY HAVE NON-NULL IMAGINARY GRAVITATIONAL MASSES

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An experimental arrangement, using two petawatts laser beams, is proposed here in order to show that the two laser beams interact gravitationally between them, due to the photons have non-null *imaginary* gravitational mass.

Key words: Imaginary Gravitational Mass, Gravitational Interaction, Petawatts laser, Photons.

INTRODUCTION

In a previous paper [1] we have show that *photons* should have *imaginary* gravitational mass, $m_{gp(imaginary)}$, given by

$$m_{gp(imaginary)} = +\frac{4}{\sqrt{3}}\left(\frac{hf}{c^2}\right)i \qquad (1)$$

where f is the frequency of the photon. Thus, the gravitational forces, F_{pp}, between *two* photons separated by a distance r, at the free space, can be expressed by

$$F_{pp} = -G\frac{m^2_{gp(imaginary)}}{r^2} = -G\frac{\left[+\frac{4}{\sqrt{3}}\left(\frac{hf}{c^2}\right)i\right]^2}{r^2} = -\left(\frac{16}{3}\right)\left(\frac{hf}{c^2}\right)^2\frac{G}{r^2} \qquad (2)$$

It is then expected that the gravitational forces, between two parallel laser beams, curve the laser beams mutually, approaching them progressively.

Here it is proposed an experimental arrangement to check the phenomenon above.

THEORY

Assuming that the *total imaginary gravitational mass* of each laser beam is given by $M_{gp(imaginary)} = Nm_{gp(imaginary)}$, where N is the number of photons in each laser beam, and $m_{gp(imaginary)}$ is the imaginary gravitational mass of *one* photon (Eq. (1)). Then, the gravitational forces F_y between the two laser beams will be given by

$$F_y = -G\frac{M^2_{gp(imaginary)}}{r^2} = -G\frac{\left[+N\frac{4}{\sqrt{3}}\left(\frac{hf}{c^2}\right)i\right]^2}{r^2} = -\left(\frac{16}{3}\right)\left(\frac{hf}{c^2}\right)^2\frac{GN^2}{r^2} \qquad (3)$$

The acceleration a_y produced by the force F_y upon a *central photon* in one of the laser beam (See Fig.1) can be then expressed by $|a_y| = |F_y/m_{gp(imaginary)}|$. Consequently, the trajectory of the photon will have a deflection Δy (and *also* the trajectory of the laser beam), which can be expressed by the following equation:

$$|\Delta y| = \tfrac{1}{2}|a_y|t_y^2 = \tfrac{1}{2}\left(\frac{|F_y|}{|m_{gp(imaginary)}|}\right)t_y^2 \qquad (4)$$

where $t_y = t_x = x/c$ (See Fig.2).

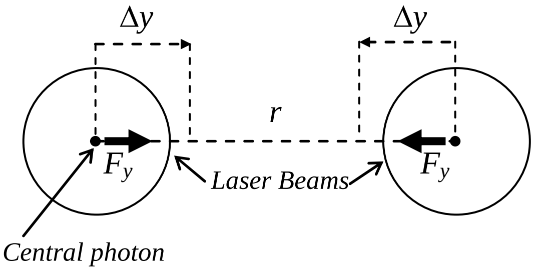

Fig.1 – Displacement Δy of the trajectory of the laser beams due to the mutual *gravitational* interaction of the laser beams.

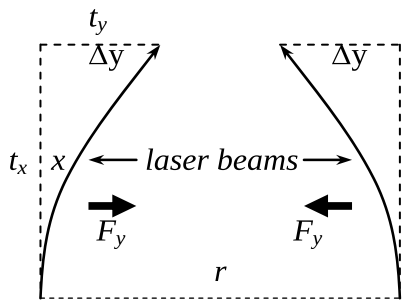

Fig.2 – Top view of the displacement Δy of the trajectory of the laser beams.

By substuting equations (3) and (1) into Eq. (4), we get

$$|\Delta y| = \tfrac{1}{2}\left(\frac{\left|-\left(\frac{16}{3}\right)\left(\frac{hf}{c^2}\right)^2 \frac{GN^2}{r^2}\right|}{\left|+\frac{4}{\sqrt{3}}\left(\frac{hf}{c^2}\right)i\right|}\right)\left(\frac{x}{c}\right)^2$$

$$= \frac{2}{\sqrt{3}}\left(\frac{hf}{c^2}\right)\left(\frac{GN^2}{r^2}\right)\left(\frac{x}{c}\right)^2 \qquad (5)$$

Since $Nhf = Pt_L$, where P is the power of the laser beam and t_L the pulse duration, then Eq.(5) can be rewritten as follows

$$|\Delta y| = \frac{2}{\sqrt{3}}\left(\frac{hf}{c^2}\right)\frac{G(Pt_L/hf)^2}{r^2}\left(\frac{x}{c}\right)^2 =$$

$$= \frac{2}{\sqrt{3}}\frac{G}{hf}\left(\frac{Pt_L x}{c^2 r}\right)^2 \qquad (6)$$

SUGGESTED EXPERIMENT

Equation (6) shows that the value of Δy is only relevant if the distance x is very great (thousands kilometers) and also if the laser beams have very great energy (Pt_L).

Recently, it were developed powerful lasers called *Petawatt lasers*. These lasers are used for study of basic science, generating such high-energy quantum beams as neutrons and ions, but only a few facilities in the world have this type of laser. Petawatt lasers in the world have had relatively a small output (to *a few tens of joules*). However, in 2015, the Institute of Laser Engineering (ILE), Osaka University, has succeeded to reinforce the Petawatt laser "LFEX" to deliver up to *2 petawatts* in the duration of one *picosecond*, i.e., pulses with energy of about *2000 joules* * [2].

Consider two laser beams each one with this energy $(Pt_L = 2000\,joules)$ and frequency $f = 6.3\times10^{14}\,Hz$. If they are on the Earth's surface (separated by a distance $r = 0.5m$), and are projected to the Moon surface in such way that the distance x is

$$x = d_{Earth/Moon} - r_{Earth} - r_{Moon} =$$

$$= 385{,}823.433km - 6{,}371.0km - 1{,}737.1km$$

$$\cong 377{,}715.33km \cong 3.77715\times10^8\,m$$

Then, Eq. (6) tells us that in this case, we have

$$|\Delta y| = \frac{2}{\sqrt{3}}\frac{G}{hf}\left(\frac{Pt_L x}{c^2 r}\right)^2 \cong 0.05m \qquad (7)$$

This displacement can be easily measurable. Therefore, this experiment is feasible, and can be used in order to prove that photons interact gravitationally among them because they have *imaginary* gravitational masses, as expressed by Eq. (1).

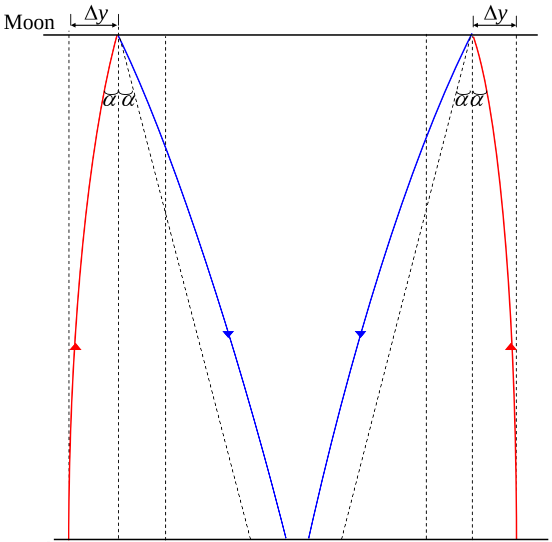

Fig. 3 – Petawatt lasers sent from a telescope on Earth (in red). Laser beams reflected (in blue) from **reflectors** on the Moon surface.

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* In 2016, a team of Chinese physicists working in the Superintense Ultrafast Laser Facility (SULF) in Shanghai announced success in creating a laser beam generating 5.3 petawatts power. The researchers are now upgrading their laser and hope to beat their own record by the next year with a laser of 10 petawatt. They intend to build a 100 Petawatt laser up to 2023.

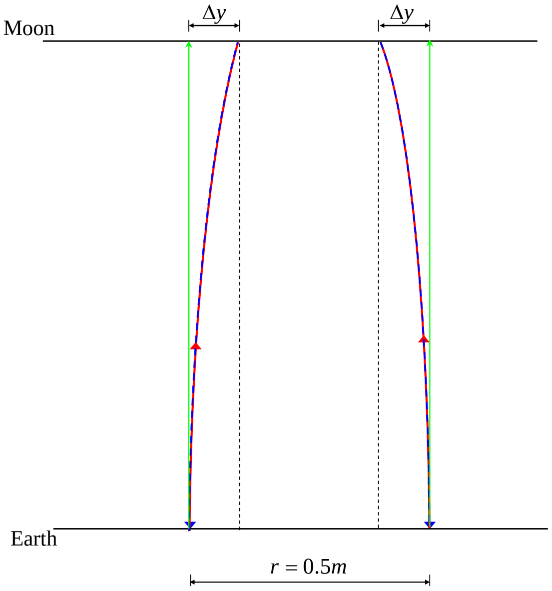

Fig. 4 – Petawatt lasers sent from a telescope on Earth (in red). Laser beams reflected (in blue) from **retroreflectors** on the Moon surface. The laser beams in green has low-power their function is only for reference in the case of a telescopic observation of the retroreflectors on the Moon surface.

Retroreflectors are optical devices that return any incident light back in exactly the direction from which it came.

References

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[Accessed 16 April 2019]