Light-Enhanced Gravitational Constant G

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Abstract

Einstein's geometric theory of gravity was paraphrased by John Wheeler in essentially two statements: Spacetime tells matter how to move, and matter tells spacetime how to curve. With matter including light, the first statement have been widely explored and evidenced in various types of experiments. Though not as obvious, however, in the second statement, matter should in principle include light, as proclaimed by Einstein's Special Theory of Relativity. This current research aimed to put the second statement under strict quantitative examination using light as the effective gravitating mass. The results showed, however, that even a dim light, of almost negligible equivalent effective mass, played overly significant role in Newton's gravitational formula, i.e., the enhancement of the gravitational constant. Thus, though replete with successes on gargantuan scales, the General Relativity theory appears to be untenable when confronting influence from tiny bits of photons.

Introduction and Motivation

In Newton's description of gravity, the gravitational force is caused by matter. More precisely, it is caused by a specific property of material objects: their mass. In Einstein's theory and related theories of gravitation, curvature at every point in spacetime is also caused by whatever matter is present. Here, too, mass is a key property in determining the gravitational influence of matter. But in a relativistic theory of gravity, physical mass cannot be the only source of gravity.

It is well known that the equivalence between mass and energy, as expressed by Einstein's formula $E = mc^2$, is the most famous consequence of Special Relativity. In it, mass and energy are two different ways of describing one physical quantity. If a physical system has energy, it also has the corresponding mass, and vice versa. In particular, all properties of a body that are associated with energy, such as its temperature or the binding energy of systems like nuclei or molecules, contribute to that body's mass, and hence act as sources of gravity. That is, Special Relativity links mass with energy, and energy with momentum. Up to this day, numerous successful tests of the General Relativity theory have been achieved, in which mass, including light, was shown to be guided precisely by the theory-predicted invisible warp of the spacetime[1].

On the other hand, efforts spent on quantitative measurements of spacetime warp effects (i.e., gravitation) rendered by light, have been scarce, at least to the best knowledge of the authors. This did not seem to have posed too serious a problem since it is normally taken for granted that as long as the light energy gets large enough (in fact, very large according to Special Relativity, to reach the equivalence of the mass of a physical object in daily life), its effective mass role would become more and more obvious. However, this notion might just have been an unwarranted myth.

Light-influenced Cavendish Measurements and Results

In this experimental investigation, two sets of multi-path laser beams, a ring of cold fluorescent light, and a white LED light source, respectively, were employed to act as the effective mass to cause extra gravitational attraction in-between two predetermined balls made of lead. For the multi-path laser beam setup, variation in laser intensities and colors were particularly attempted. Then, Newton's gravitational law was applied to exploit any possible delicate change in the gravitational constant owing to such added effective light mass.

The adopted sensitive measuring device was a computerized Cavendish balance (Model: TEL-RP2111 of TEL-Atomic, Inc., USA, originally manufactured by ASONIK of Poland, see Fig. 1 and Ref. 2), widely used in the academic world. The radius and mass of the big lead (Pb) ball were 2.82 cm (0.0282 m) and 917 g (0.917 kg), and those of the small lead ball were 0.67 cm (0.0067 m) and 14.5 g (0.0145 kg). The latter was confined in the central housing. All following experiments were conducted in the dark, unless otherwise stated.

The first experimental setup was as shown in Fig. 2 in which the added nine zig-zag laser beam paths from a diode-pumped solid-state (DPSS) Nd-YAG blue (473 nm, 8 mW, 1 mm dia.) laser, through bouncing back and forth between two mirrors far out, were positioned in-between the big and small lead balls in such a manner that the grazing on two sides of the central housing owing to diverging laser beams was minimized to paltry (see, Fig. 2 for photograph). To prevent any electric charge-caused spurious forces, the whole Cavendish balance, as well as the laser and optic table, were connected to the soil ground on the first floor. With laser, light blocker, attenuator, and optics all installed and aligned on the optic table, a careful Cavendish calibration, via the driven resonance method[2], was performed to reach a gravitational constant G of the value 6.877×10^{-11}

Nm^2kg^{-2}, as compared to the now globally accepted value of 6.674 x 10^{-11} Nm^2kg^{-2} (i.e., 3 % off).

In the next step, the blue-light laser was turned on for hours to become steady but with its beam terminated by the blocker just in front of the laser output. A new calibration measurement reached the G value of 6.772 x 10^{-11} Nm^2kg^{-2}, still very close to the globally accepted value (1.5 % off) (see, Fig. 3). Then, the blocker was removed and 9 paths of laser beams were formed along the two long sides of the Cavendish balance central chamber, and between the big and small lead balls without touching any of the above objects. This time the measured G value became 15.61 x 10^{-11} Nm^2kg^{-2}, about 130% increase from the previous laser beam-blocked one (see, Fig. 3). A measurement of temperature rise along the laser paths proved negligible. G values associated with 50 % and 90 % laser attenuation were then obtained to be 11.630 x 10^{-11} Nm^2kg^{-2} (72 % increase) and 9.237 x 10^{-11} Nm^2kg^{-2} (36 % increase), respectively (see, Fig. 3). Apparently, the presence of light beams between the two lead balls had caused enhanced attraction to an extent proportional to the laser beam intensity.

However, the added light mass could not have been responsible for such observed effect if the equivalent mass according to Special Relativity is to be resorted to. Namely, for a zig-zag range (i.e., distance between the zig-zag-path-forming mirrors) of about 18 cm (0.18 m), the total equivalent mass of photons within the zig-zag paths would have been minimal. To be precise, the energy of a single photon from such laser was $E = h\nu = hc/\lambda = 2.62$ eV, with h, ν, c and λ being Planck's constant, light frequency, light speed in air, and light wavelength, respectively. For a 8 mW (= P) laser, the number of photons emitted in one second was $P\cdot$ 1 sec/E = 1.9 x 10^{16}, which would have spanned a range of 3 x 10^8 m. Hence, for a zig-zag range of 18 cm, the number of photons in one zig path was about 1.1 x 10^4. For nine paths and with the relativity-equivalent mass of each photon being $m = E/c^2 = 4.7 \times 10^{-36}$ kg, the total equivalent photon mass introduced was roughly 4.7 x 10^{-31} kg, which apparently was too little to be responsible for any noticeable gravitational effect according to Newton's formula of gravitation.

Similar experiments using a He-Ne gas laser (632.8 nm, 7.6 mW, 1.5 mm dia.) instead were then carried out and the results are illustrated in Fig. 4. The calibration measurement in the dark with laser turned on but its beam blocked gave the G value of 6.763 x 10^{-11} Nm^2kg^{-1}(about 1.3 % off the globally accepted value of 6.674 x 10^{-11} Nm^2kg^{-2}). The G values obtained under 100 %, 80 %, and 50 % laser beam transmittance were 9.675 x 10^{-11} Nm^2kg^{-1} (about 43 % increase), 9.131 x 10^{-11} Nm^2kg^{-1} (35 % increase), and 8.838 x 10^{-11} Nm^2kg^{-1} (30.7 % increase), respectively. As is obvious, the similar trend of proportionality between enhanced attraction and laser beam intensity was reproduced, even though the blue laser was more efficient in modifying G than the red one at similar power levels.

Then, at a later phase of this research, the calibration was conducted again with the room lighting turned on and off to secure G values of 6.714 x 10^{-11} Nm^2kg^{-2} (about 0.6 % off the globally accepted value) and 6.763 x 10^{-11} Nm^2kg^{-1} (1.3% off the above current standard value), respectively. Subsequently, G values obtained for the 100 % laser beam transmittance case, with the room lighting on and off, were 7.586 x 10^{-11} Nm^2kg^{-1} (nearly 13 % increase) and 9.011 x 10^{-11} Nm^2kg^{-1} (33.2 % increase), respectively. Therefore, the previously evidenced phenomena in the dark remained under the full bright lighting, except that the light mass effect appeared to be less prominent.

As a further attempt, a ring of cold fluorescence light tube (of weight about 4.1 g) was mounted on the big ball in a horizontal plane passing the ball's origin (see, Fig. 5), and the experiments in the dark started after the light of ring had decayed to a dim, steady one with a measured radiation power of about 0.630 μW (= 10^{-6} W), taking at the distance between the two balls. Using the corrected big ball mass, the obtained G value was 14.03 x 10^{-11} Nm^2kg^{-2}, a 116 % increase from the value of 6.485 x 10^{-11} Nm^2kg^{-2} (about 2.8 % off the globally accepted value of 6.674 x 10^{-11} Nm^2kg^{-2}) obtained when the fluorescence light became fully depleted eventually. Then, under the full room lighting instead, the secured value was 11.24 x 10^{-11} Nm^2kg^{-1}, about 73.3 % increase. A careful power meter recording of the jitters in room lighting, which first bounced off the big ball and then onto the small ball, indicated a peak fluctuation of about 0.1 μW, much smaller than the fluorescent power impinging on the small ball, using the same detector.

The concern over the role played by possible electrostatic effect due to ions within the fluorescent tube can be dismissed since charges within the tube normally obey the quasi-neutrality property and field measurements indeed indicated so. Further, the light pressure exerted on the small ball by light emanated from the big ball was also minimal at such low power level. In fact, even if it existed, its effect should have been pushing the two balls further away instead of enforcing more attraction as observed.

As one other means of quantifying the influence of light on gravitation, the above cold light ring was replaced by a surface-mounted white-light LED (light-emitting diode). Using the then adjusted LED-laden big ball mass and with the LED turned off, the calibration run offered the G value of 6.582 x 10^{-11} Nm^2kg^{-2} (nearly 1.4 % off the globally accepted value). Then, at the LED power levels of 1.6 mW and 3.2 mW, the G values obtained were 29.090 x 10^{-11} Nm^2kg^{-2} (about 342 % increase) and 49.460 x 10^{-11} Nm^2kg^{-2} (about 651 % increase), respectively (see, Fig. 6). Temperature rise of about 2 - 3°C was obtained around the LED-mounted big ball, but such-caused Bernoulli type of gas flow and hence pressure drop were far too small to account for the observed enhanced attraction. The optical pressure on the small ball, exerted from the LED mounted on the big ball, and thus pushing away the two balls instead of attracting as observed, was about $2(I/c) \sim 10^{-8}$ N/m^2, with I the light intensity impinging on an unit area, c the speed of light, giving rise to a force of about

10^{-12} N. Obviously, it was negligible as compared to the gravitational attractive force, by the big ball on the small one, of about 10^{-10} N from Newton's gravitational formula.

Summary and Conclusions

Despite the above experimental evidence of influence on G values by light in the dark, a question naturally arises: how come in all Cavendish type of measurements in history, among which most were performed under daylight, such effects were never reported? The answer is just that in the brightness of daylight, the crucial role of light was essentially made unobservable since photonic effects from all points in the Cavendish system averaged out one another. This is supported by the fact that in the above calibration measurements, the secured G values were very close between situations with full room lighting and in the dark. Further, those extra light mass effects, as observed in the dark, remained in full brightness as long as the added light power levels were above the lighting fluctuations.

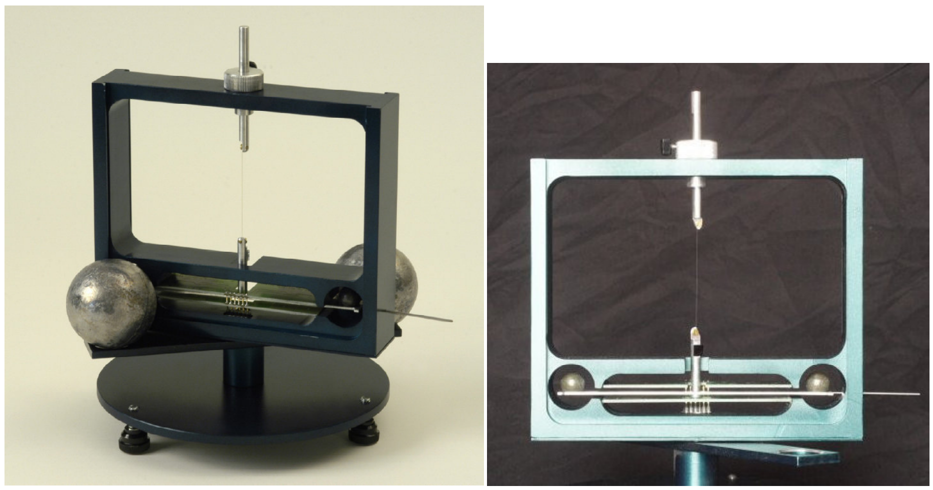
In contrast to all other modern theories of fundamental interactions, General Relativity is a classical theory, namely, it does not include the effects of quantum physics which describe the fundamental buildup of our universe. The quest for a quantum version of general relativity addresses one of the most fundamental open questions in physics. While there are promising candidates for such a theory of quantum gravity, notably string theory and loop quantum gravity, there is at present no consistent and complete theory. Now, there is something more.

What this experimental study presented is that, other than being seemingly incompatible with orthodox quantum theories, the large-objects-focusing General Relativity theory may have also fallen short on small things. Namely, it is uncongenial to the role played by lights on a daily scale in the familiar classical world surrounding us all.

References

1. In special relativity, energy is closely connected to momentum. Just as space and time are, in that theory, different aspects of a more comprehensive entity called spacetime, energy and momentum are merely different aspects of a unified, four-dimensional quantity that physicists call four-momentum. In consequence, if energy is a source of gravity, momentum must be a source as well. The same is true for quantities that are directly related to energy and momentum, namely internal pressure and tension. Taken together, in general relativity, it is mass, energy, momentum, pressure and tension that serve as sources of gravity: they are how matter tells spacetime how to curve. In the theory's mathematical formulation, all these quantities are but aspects of a more general physical quantity called the energy–momentum tensor.

2. TEL-RP2111 Computerized Cavendish Balance User's Manual, TEL-Atomic, Incorporated. Website: http://www.telatomic.com/.



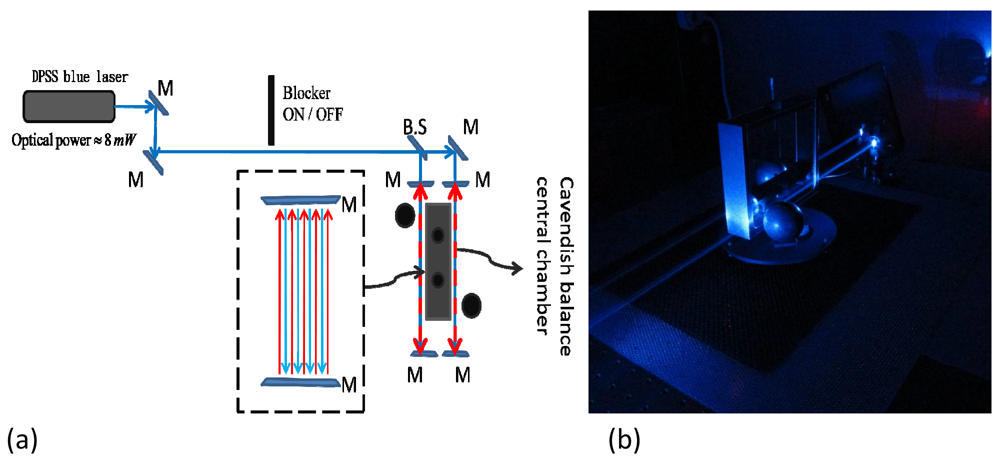
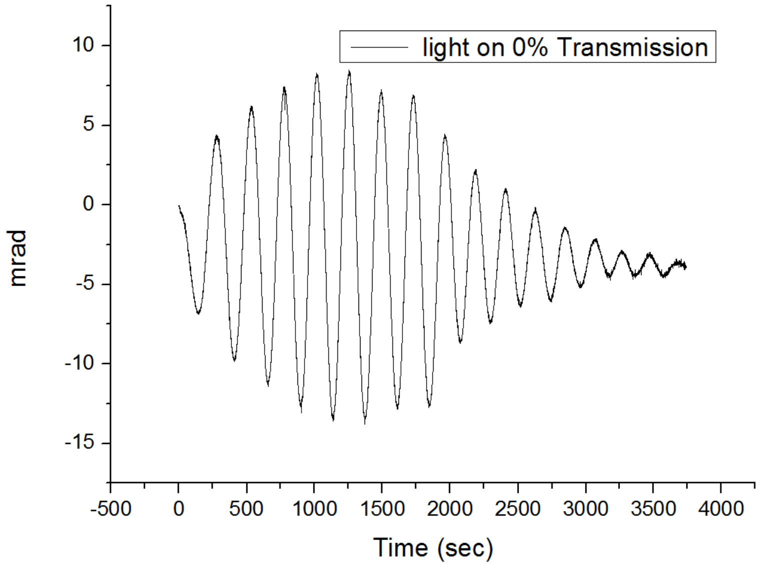


Fig. 2. (a) The installed nine zig-zag laser paths on each side of the small-balls-enclosing house of the Cavendish Balance. 10 mW DPSS blue laser of wavelength 473 nm, polarization >100: 1, was employed in this case; (b) Photograph of the laser grazing experiment setup.

$$G = 6.772 \times 10^{-11} Nm^2 kg^{-2}$$

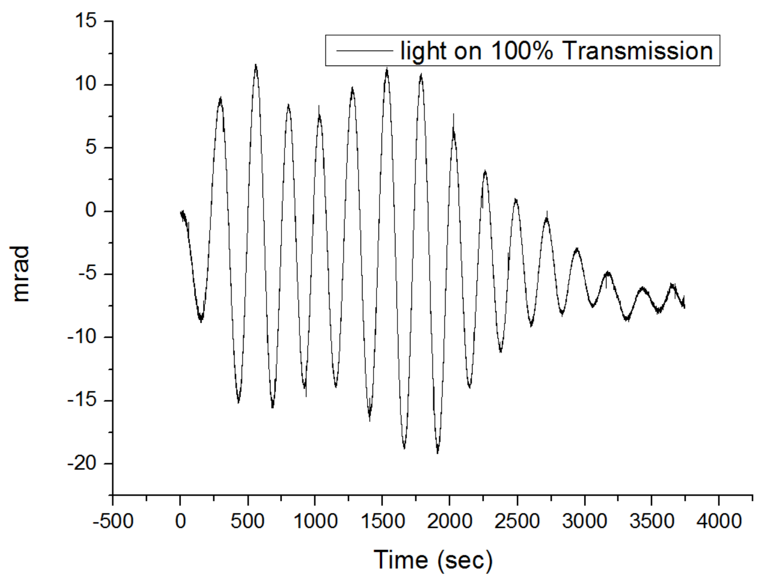
$$\mathrm{T} = 241.836\mathrm{s}$$



(a)

$$G = 15.61 \times 10^{-11} Nm^2 kg^{-2}$$

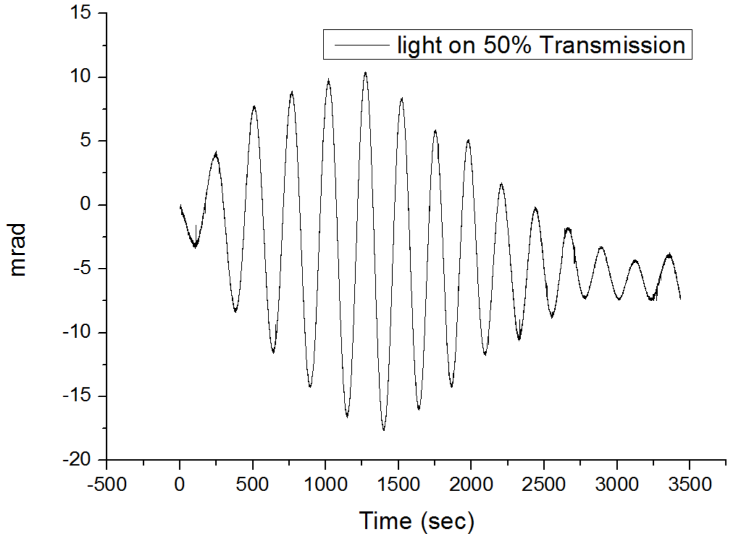
$$\mathrm{T} = 248.318\,\mathrm{s}$$



(b)

$G = 11.63 \times 10^{-11} Nm^2 kg^{-2}$

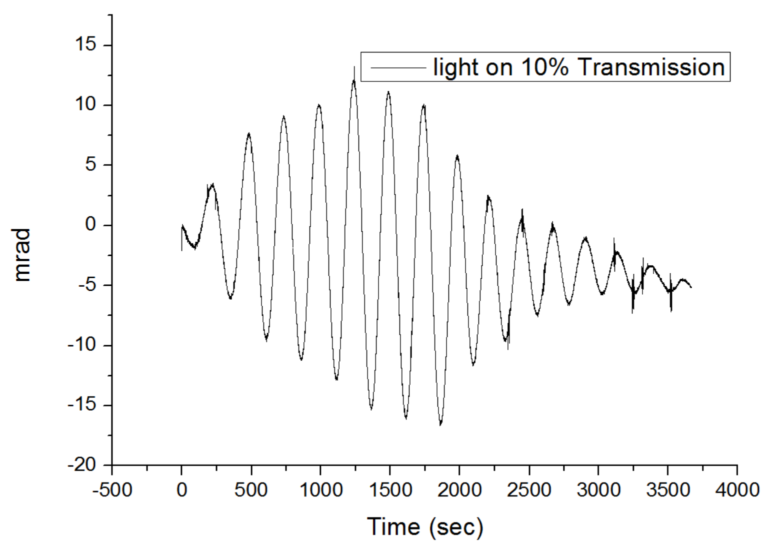
$T = 250.854$ s



(c)

$G = 9.237 \times 10^{-11} Nm^2 kg^{-2}$

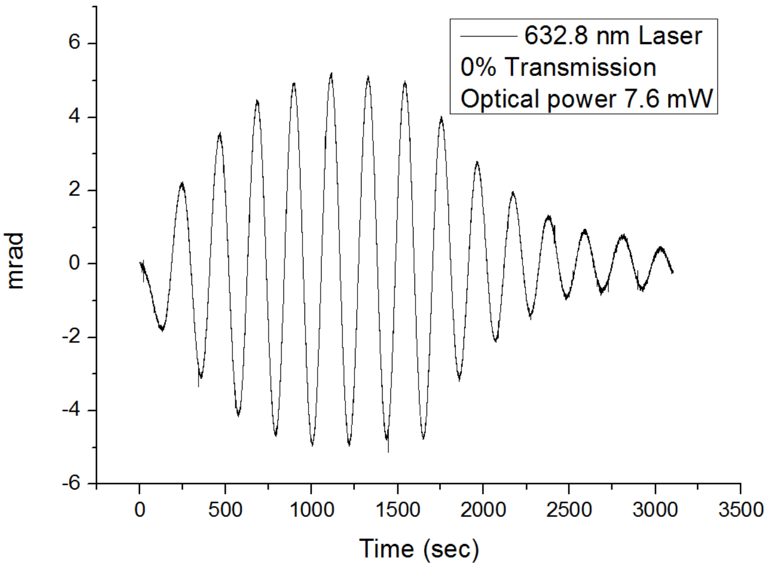
$T = 253.036$ s



(d)

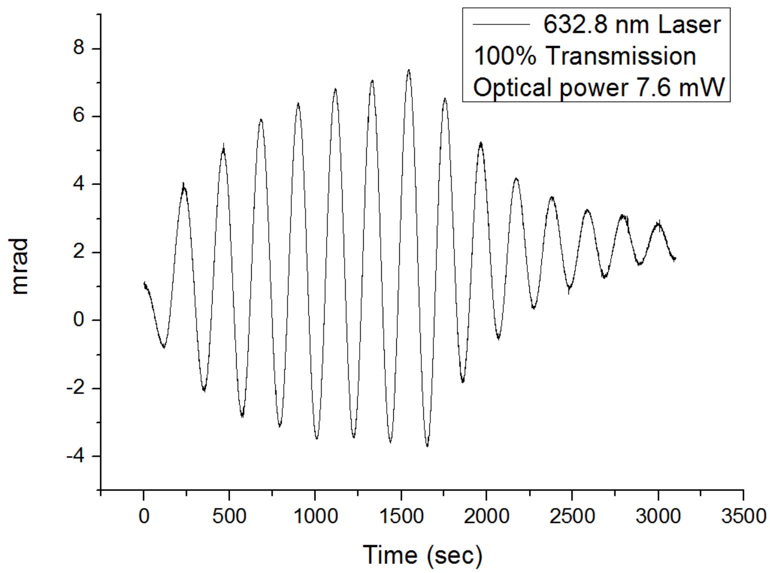
Fig. 3. Results of the blue laser grazing experiment, with (a) laser beam on but blocked; (b) laser beam 100% transmission, (c) 50 % transmission, (d) 10% transmission, all conducted in the dark.

$$G = 6.912 \times 10^{-11} Nm^2 kg^{-2}$$
$$\mathrm{T} = 220.836\mathrm{s}$$



(a)

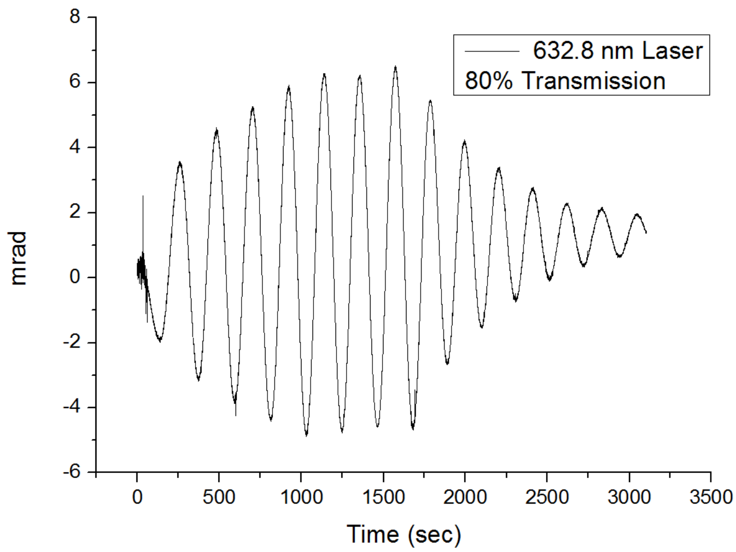
$$G = 9.675 \times 10^{-11} Nm^2 kg^{-2}$$
$$\mathrm{T} = 217.909\mathrm{s}$$



(b)

$$G = 9.131 \times 10^{-11} Nm^2 kg^{-2}$$

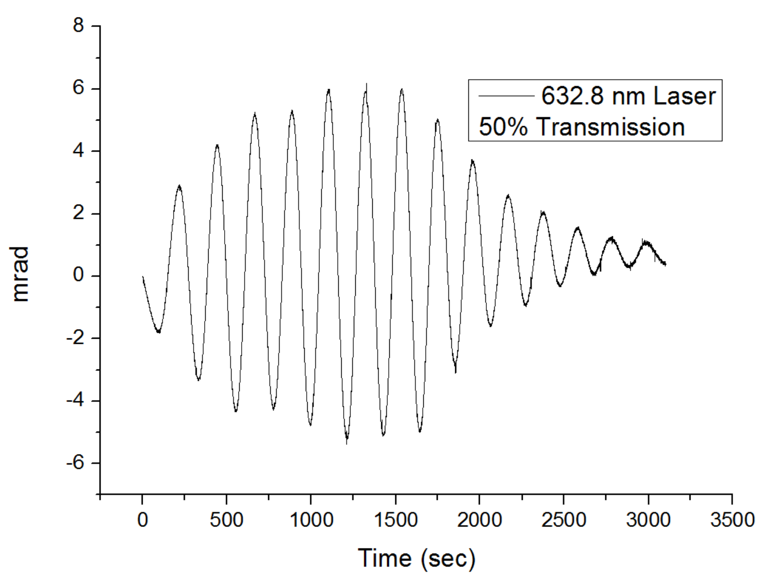
$$\mathrm{T} = 218.927\mathrm{s}$$



(c)

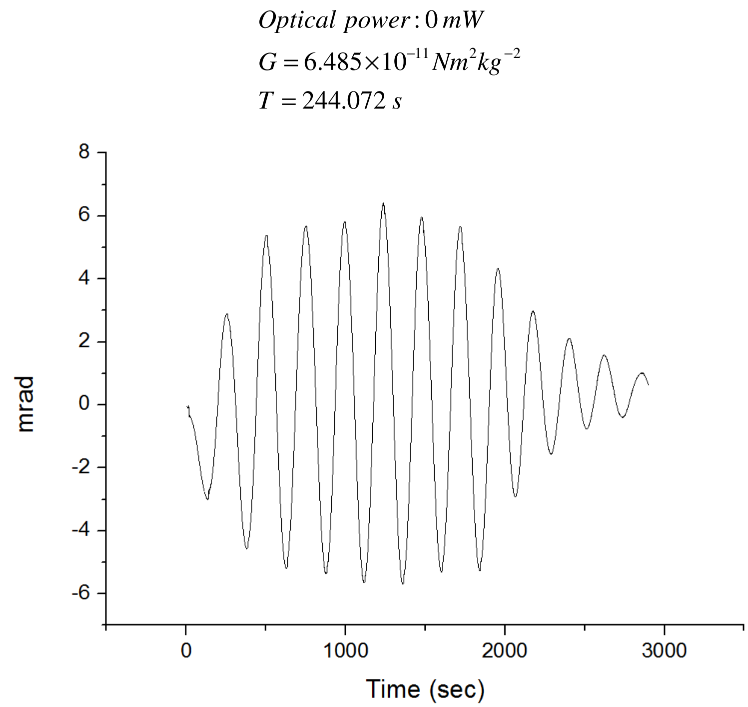
$$G = 8.838 \times 10^{-11} Nm^2 kg^{-2}$$

$$\mathrm{T} = 219.836\mathrm{s}$$

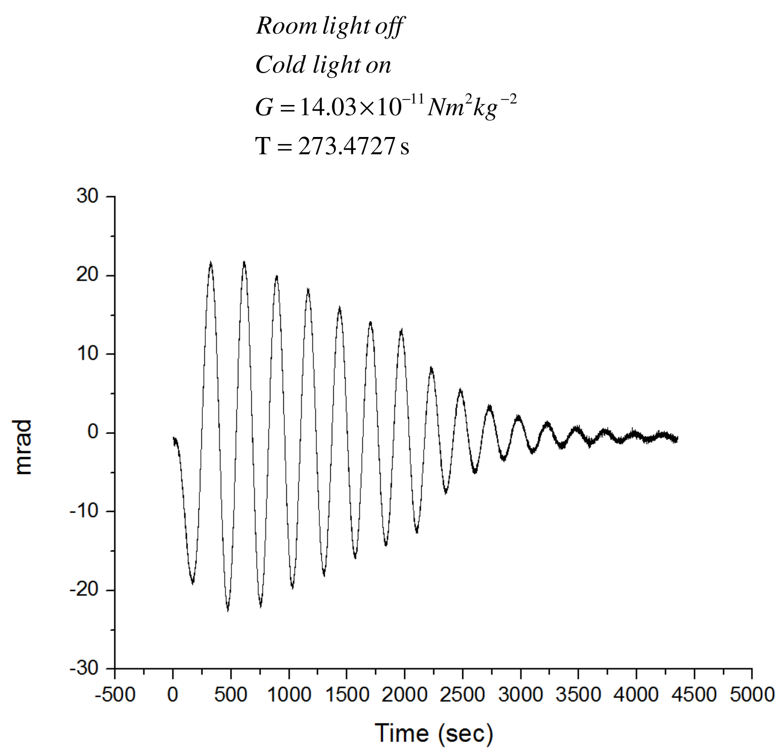


(d)

Fig. 4. Results of the He-Ne laser grazing experiment, with (a) laser beam on but blocked; (b) laser beam 100% transmission, (c) 80 % transmission, (d) 50% transmission, all in the dark.

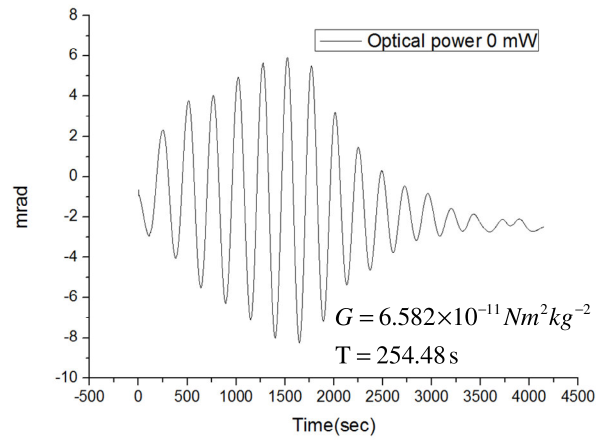


(a)

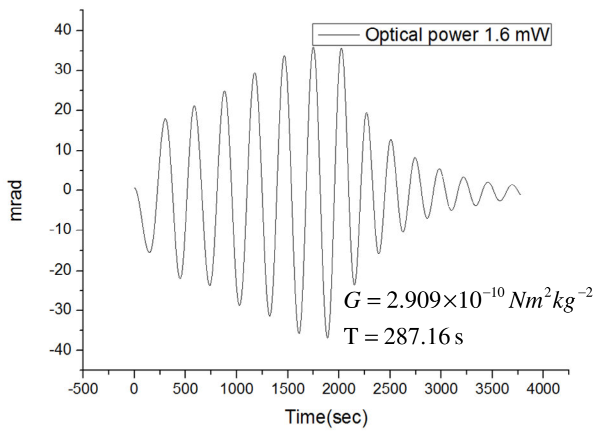


(b)

Fig. 5. Cold fluorescent light ring experiment results, with (a) light ring fully depleted in power, (b) light ring power decayed to a flat level of 0.63 μW.



(a)



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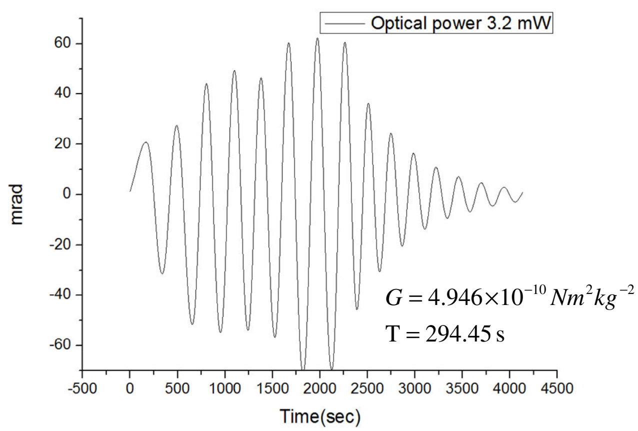

(c)

Fig. 6. Results of surface-mounted white LED experiment, with (a) LED turned off, (b) LED powered at 1.6 mW, (c) LED powered at 3.2 mW.