SOLAR-GRAVITATIONAL SYSTEM FOR DEORBITING SPACE DEBRIS AND REENTRY IN EARTH'S ATMOSPHERE AND ACCELERATING ACTIVE SATELITES FOR ORBIT REESTABLISHEMENT

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ABSTRACT

This paper presents a technology for de-orbiting of space debris or accelerating of active satellites using gravitational interaction. Paper published in a physical review presented the possibility to generate a flux of gravitational radiation through multiple reflections of electromagnetic radiation between two or more parallel mirrors. When the gravitational radiation generated in this way interacts with a body, that body will be attracted in a direction which is perpendicular to the mirrors' surface. Generation of gravitational radiation in this way occurs when electromagnetic energy (as solar light) is continuously fed into the gap between mirrors. When the total energy of light reflecting continuously between the reflective surfaces is sufficiently high, the radiated gravitational power becomes significant. Deceleration and atmosphere re-entry are triggered when this radiation impacts the rear end of space debris. Acceleration and orbit re-establishment occurs when this radiation is directed to the front of operational satellites.
The paper presents only the main design principles of this concept related by collection and reflection of solar light between reflective surfaces.
Conclusions are that this new technology could be currently applied in future but much research work is necessary in the field of solid physics for increasing materials reflectivity to extremely high values.

KEYWORDS: space debris removal, gravitational radiation

NOMENCLATURE

a, acceleration, [m/s^2]
c, speed of light, [m/s]
d, distance, [m]
E*, energy, [J]
E, electric field, [dyne/SC in CGS]
G, universal constant of gravitation [Nm^2/kg^2]
h, Planck's constant, [J·s]
m, mass, [kg]
P, power, [W]
r, radius, [m]
R, reflectivity, dimensionless

Greek
λ, wave length, [m]

1. INTRODUCTION

The presence of space debris around Earth constitutes a difficult problem. Practically, 85% of orbiting objects are space debris. Space debris is distributed in all regions of near Earth space, particularly in the GEO and LEO regions, as shown in fig.1 and fig.2. [1]
The presence of space debris is already a great danger becoming the main threat to safety of space exploration and exploitation.

The space debris are composed of used boost stages of rockets, spent rocket upper stages, paint exfoliations, pieces of solid rocket motors, remnants of old scientific experiments, non-functional satellites, various fragments which are the result of collisions, materials detached from International Space Station, components of satellites destroyed by missiles etc. [2]
The number of objects in orbit will grow, even if no further objects are launched into space because the collisions cannot be kept under control. Unconstrained collisions can lead to a cascade effect with no further possibility of human intervention and leading to an increased level of hazard for space operations.

Figure 1: Space debris in GEO region [ESA]

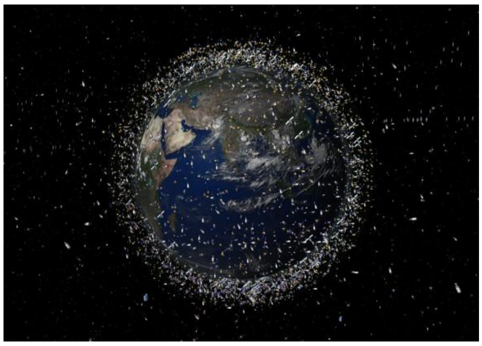

Figure 2: Space debris in LEO region [ESA]

There are three categories of space debris: [3]
Category I (<1cm) - this causes significant damage to vulnerable parts of a satellite
Category II (1-10 cm) – causes serious damages or destruction of a satellite after a collision
Category III (>10cm)-destroys a satellite in a collision and it can be tracked
This paper presents a so called solar-gravitational system for removal of space debris through a new technology: deceleration of space debris using gravitational attraction. The system can be lunched in space as any satellite on a geocentric, heliocentric or Sun-synchronous orbit.

2. GENERATING OF ARTIFICIAL GRAVITATIONAL FIELD

Generating of artificial gravitation is a new challenge for our civilization in the field of propulsion. An article published in the Journal of Advances in Physics demonstrates the 'Theorem of Conversion of Electromagnetic Radiation (Waves) into Gravitational Radiation (Waves)' [4, 5]. This theorem shows that electromagnetic energy in the form of electromagnetic radiation (waves) can be converted into gravitational energy, i.e., gravitational radiation (waves). Generation of gravitational radiation in this way is a direct consequence of Einstein's General Theory of Relativity.
According to the mentioned theorem, a flux of gravitational radiation must be produced through multiple reflections of electromagnetic waves between two or more parallel mirrors (reflective layers). When the gravitational radiation generated in this way interacts with a body, that body will be attracted in a direction which is perpendicular to the mirrors' surface.
If a large amount of electromagnetic radiation (solar light) is injected into the gap existing between two mirrors and begins to reflect between them, the radiated gravitational power becomes significant. Maximum radiated power is emitted when the light direction is normal to the mirrors surfaces and when the distance between mirrors is equal to a half of wave length of the continuously reflecting light. The gravitational radiation generated in this way can be called 'artificial' because it is generated by equipment which normally does not exist in nature.
It must be mentioned that the radiation of a gravitational wave during reflection of a light ray by a reflective surface is a natural effect which must occur frequently in nature. However, the gravitational wave generated by a single reflection of a light ray is too weak. An extreme large number of reflections is necessary for generating gravitational radiation with a significant power which is usable for interaction with space debris.
The next sub-sections discuss the production of this radiation as a result of multiple reflections of concentrated solar light and how to direct this radiation to the rear of space debris for inducing deceleration or to the front side of satellites that need to be accelerated and boosted back onto desired orbits.

2.1 The physical basis of gravitational emissions

For understanding this important phenomenon, the main steps of the demonstration of 'Theorem of Conversion of Electromagnetic Radiation (Waves) into Gravitational Radiation (Waves)' are presented below:[4]
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 this normal reflection has a huge value due to the high speed of light:

$$a = \frac{\Delta V}{\Delta t} = \frac{-c-(+c)}{T} = \frac{-2c}{T} = -2c\nu \qquad (1)$$

where,
- ΔV is speed variation,
- Δt is the duration of photon-surface interaction
- c is the speed of light in vacuum
- T is the oscillation period of light
- ν is the frequency of light

During reflection, the matter of photon oscillates as a quadrupole (fig. 1) and for this reason it must generate gravitational waves. The direction of the electric field E and magnetic field, H, are perpendicular to the photon's travel direction. During reflection, the matter of photon oscillates in radial direction simultaneously with electric field, E, and magnetic field, H. When the associated photonic wave is reflected the sense of the electric field, E, and magnetic field, H, are reversed. On the other hand, during reflection the photon's matter oscillates longitudinally due to direction reversal.
Note: It was demonstrated in advanced physics that only a quadrupole and not a dipole can generate gravitational waves.

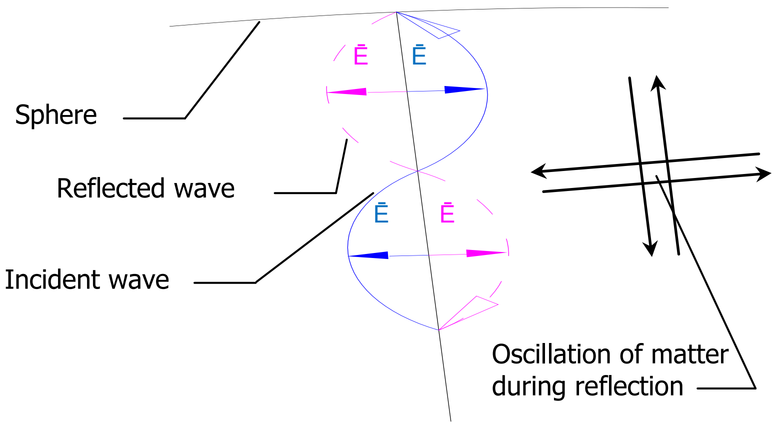

Figure 1: During reflection, the matter of a photon oscillates like a

Unexpectedly, the direction of graviton emitted during normal reflection of a photon is opposite to the direction of the incident photon. While intuition indicates that the graviton is emitted in the direction of the incident wave, actually the momentum conservation law shows that the opposite is true (fig.2).

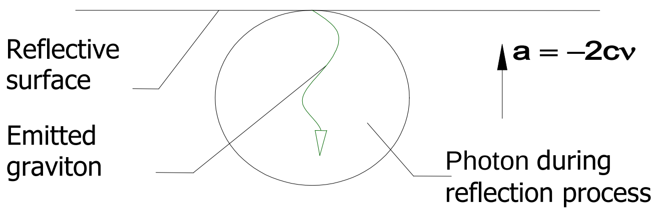

Figure 2: Inertia determines the direction of graviton emission along the path of reflected wave

The physical explanation is as follows:
Reflection of photon by a mirror is equivalent to a strong braking. Because the photon is not electrically charged, the single force which opposing this braking is gravitation. Thus, 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.
The laws of energy and momentum conservation support this conclusion. Assume the mass of the emitted graviton is m_g., E^*_{if}- the energy of incident photon, E^*_{rf} - the energy of reflected photon and E^*_g= the energy of graviton, then the energy balance during the reflection process is given by:

$$E^*_{if} = E^*_{rf} + E^*_g \tag{2}$$

Based on Eq. (2), 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:

$$h \cdot \nu_{if} / c + h \cdot \nu_{rf} /(-c) + m_g \cdot (-c) = 0 \tag{3}$$

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 (3) shows that the direction of radiated gravitational wave is opposite to the incident electromagnetic wave i.e. the same as the reflected wave in the case of normal reflection and that the propagation speed of gravitational wave is c (this fact, was already demonstrated for weak gravitational fields.
The energy of a graviton emitted during reflection 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:

$$E^*_g = \frac{\chi^* \cdot G \cdot h^2}{c^5} \cdot \nu_g{}^3 \tag{4}$$

where χ^* is a constant composed of universal constants, i.e. it itself is a universal constant.
The constant χ^* shows that during normal reflection of photons, the gravitons are emitted as energy quanta. The energy of emitted graviton is proportional to the cube of light frequency.
The equation (4) can be written in a new form (5),

$$E^*_g = \frac{\chi^* \cdot G}{c^5 \cdot h} \cdot h^3 \cdot \nu^3 = \frac{\chi^* \cdot G}{c^5 \cdot h} \cdot E^{*3}_e = h_{ge} \cdot E^{*3}_e \tag{5}$$

Eq. (5) reveals a connection between radiated gravitational energy, E^*_g, and reflecting electromagnetic energy, E^*_e: 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 is composed of gravitational constants and can also be considered a universal constant.

2.2 Theorem of Conversion of Electromagnetic Radiation (Waves) into Gravitational Radiation (Waves)

This theorem states: [4]

'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'.

If two packs of electromagnetic waves 1, 2 each having energy E*, frequency, ν, and implicitly the same number of photons n, reflect continuously between two mirrors A, B separated by a gap $d = \lambda$ (fig.3), the radiated gravitational power according to equation (6):

$$P_g = 2 \cdot n \cdot \frac{1}{T} \cdot \frac{\chi * \cdot G \cdot h^2}{c^5} \cdot \nu^3 = \frac{2n\chi * Gh^2\nu^2}{c^5} \cdot \nu^2 = \frac{\chi * G}{c^5} \cdot E *^2 \cdot \nu^2 \tag{6}$$

Eq. (6) 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 energy E* of each incident pack of electromagnetic waves, and their frequency, ν .
In the above equation, the incidence angle was taken equally to zero.
The equipment presented in fig. 3 can continuously generate a uniform flux of 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.
Each gravitational flux (created by mirrors A and B), penetrate mirrors B and A respectively, leaving the space between mirrors. This vectored flux of gravitational radiation can be obviously used to create gravitation forces exerted on bodies (particularly braking space debris for de-orbiting and accelerating satellites for re-establishing orbit).

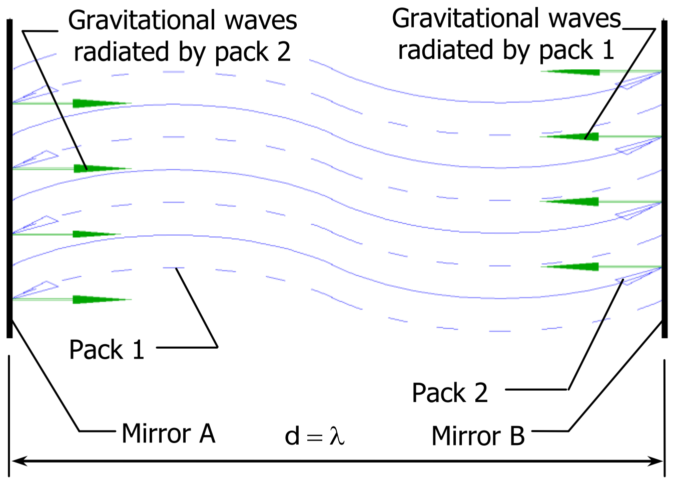

Figure 3: Two packs of electromagnetic energy which continuously radiate gravitational waves through multiple reflections

[Note: The maximum radiated gravitational power can be four times higher than that given in equation (6). This phenomenon can take place because stationary waves can exist between the two mirrors even when the distance d is equal to a half of the wavelength $\lambda/2$ ($d = \lambda / 2$)].
In fig. 4 a system composed of If (q+1) mirror is able to multiply by q the radiated gravitational power. Two adjacent mirrors are separated by distances $d = \lambda$ (fig.4). Between any pair of adjacent mirrors, two packs of electromagnetic waves with energy E are injected. The total gravitational power radiated by system, P_{gq} is given by equation 7.

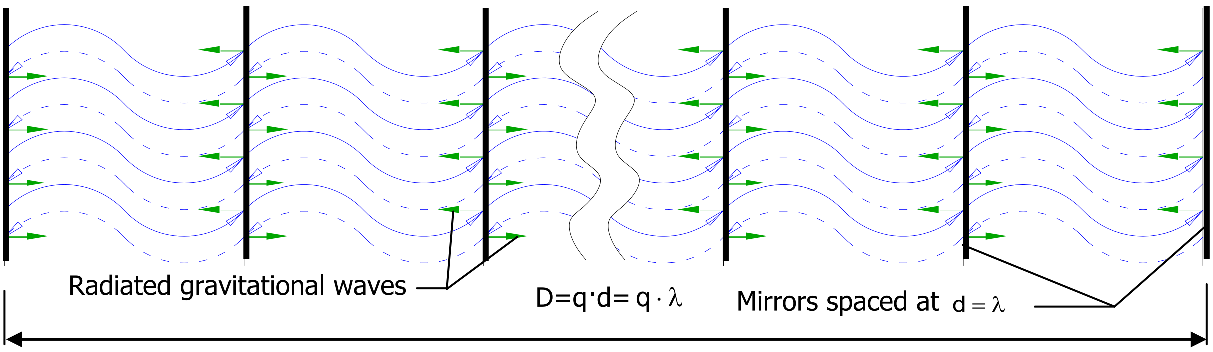

Figure 4: Equipment with multiple reflecting surfaces for increasing the power of gravitational radiation

To greatly boost the power of gravitational radiation a large number of pairs of mirrors must be used. When (q+1) mirrors (thin reflective layers) are used, the radiated power becomes:

$$P_{gq} = q \cdot P_g = \frac{q \cdot \chi * \cdot G}{c^5} E *^2 \cdot \nu^2 \tag{7}$$

The constant χ^* must be finally determined by experiments. Initial evaluations, based on another consequence of Einstein's General relativity yielded the value:

$$\chi^* \approx 512 / 5 = 102.4 \quad (8)$$

Equation (7) is useful for calculation of gravitational action on bodies (space debris, satellites etc.).

2.3 Design of solar-gravitational system for de-orbiting of space debris

The operating principle of a gravitational system for de-orbiting of space debris is presented in fig.5, 6. The large parabolic mirror is permanently oriented towards the Sun, collects light rays and directs them to the focal point, F. The small parabolic mirror has the same focal point, F, and is positioned face to face with the large parabolic mirror. The light rays focused into focal point F by the large parabolic mirror are reflected then by the small parabolic mirror in parallel light rays (concentrated light beam) which enters the central light guide when the light shutter is opened. After that, the concentrated light beam enters the cellular wave guide which directs it to the multiple parallel mirrors. The mirrors are placed at an angle $\alpha=90°+\delta$, were δ is a very small angle. When the light rays reflect between mirrors, gravitational waves are generated while the frequency of light decreases (all the components of the white light coming from Sun are red-shifted). [4]
At the end of this process, light is evacuated in space as brilliant red light. The gravitational radiation (I) is convergent (fig.5) and it is used for decelerating space debris forcing re-entry and burning in atmosphere. The gravitational radiation (II) is divergent and it is lost into space. The shutter is a thin disc plated with gold on both faces. If the front light shutter is closed, the light is sent back to the small parabolic mirror, to the large parabolic mirror and then to the Sun. In this situation gravitational radiation is not generated.

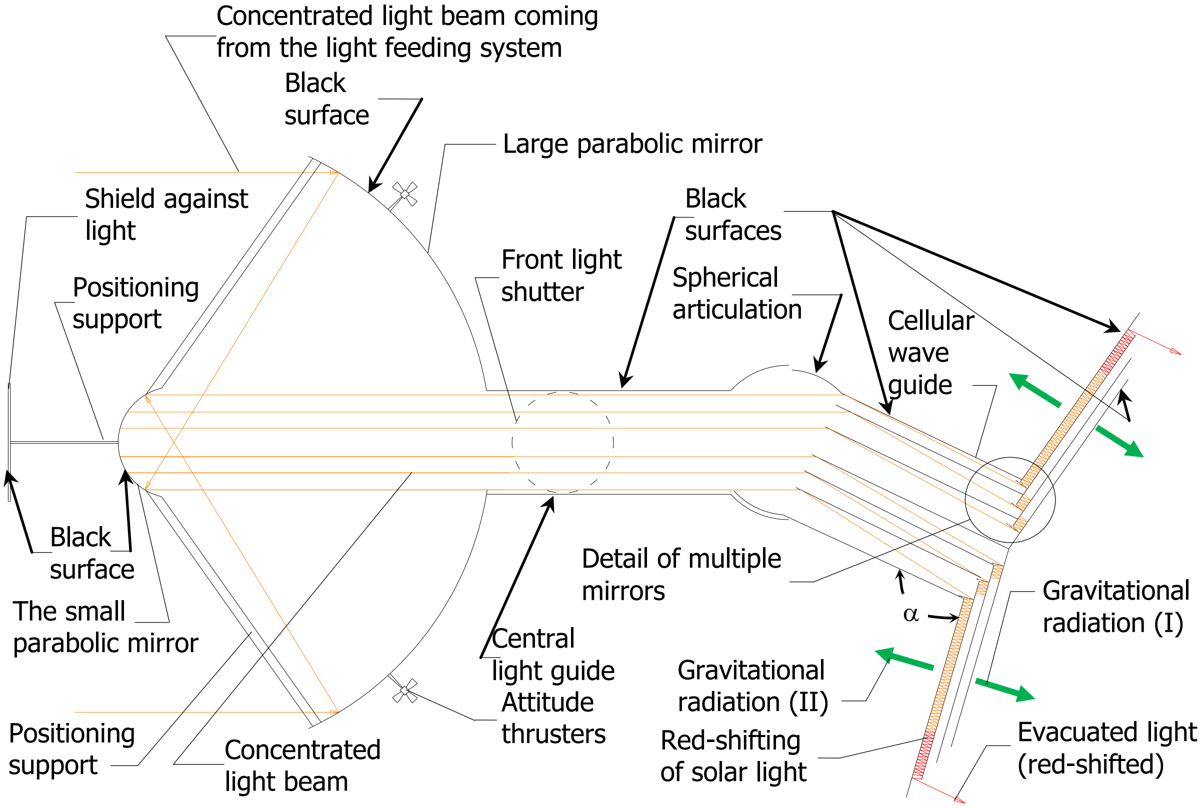

Figure 5: The scheme of a solar-gravitational de-orbiting for space debris

The large and small parabolic mirrors, plane mirrors and light guides are made of composite materials (graphite fibre or grapheme base) and are gold plated on the reflective surfaces. The heat is radiated in space through radiation of black surfaces of the above mentioned components.

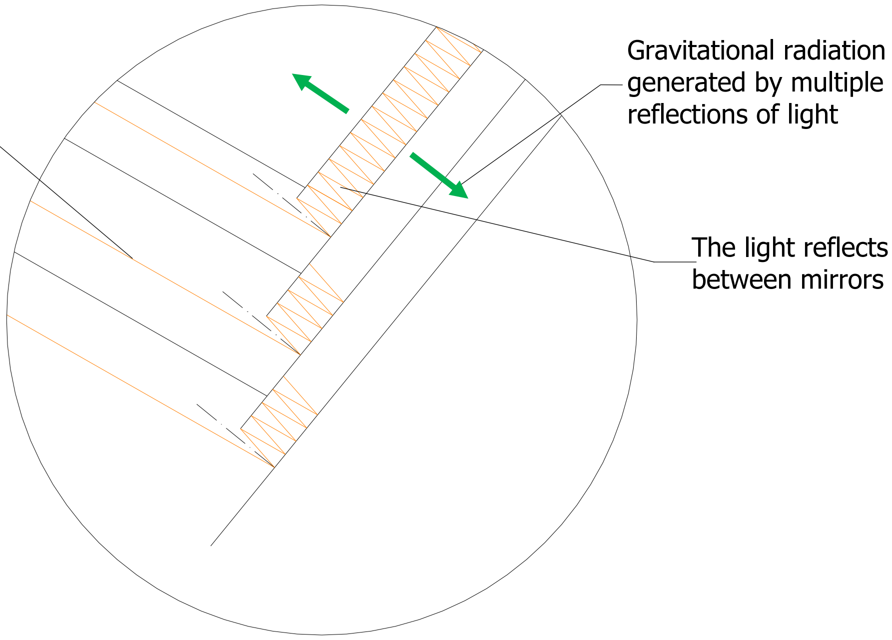

Figure 6: Detail of multiple reflection of light between mirrors

3. CALCULATION OF RADIATED GRAVITATIONAL POWER

In ideal conditions (reflectivity coefficient of surfaces R=1), the gravitational power radiated by two parallel mirrors due to multiple reflection of two packets of light (i.e., q=1) having energy E* each, for infrared, visible and ultraviolet light is given in the Table 1.

Table 1: Power of gravitational radiation produced through reflection of infrared to ultraviolet light

E*, kJ ⇨ **ν, Hz** ⇩	**1** $\frac{dE^*}{dt}, kW$	**10^3** $\frac{dE^*}{dt}, kW$	**10^5** $\frac{dE^*}{dt}, kW$	**10^7** $\frac{dE^*}{dt}, kW$	**10^9** $\frac{dE^*}{dt}, kW$	**10^{11}** $\frac{dE^*}{dt}, kW$	**10^{13}** $\frac{dE^*}{dt}, kW$
$3x10^{11}$ (infrared)	$2.5x10^{-25}$	$2.5x10^{-19}$	$2.5x10^{-15}$	$2.5x10^{-11}$	$2.5x10^{-7}$	$2.5x10^{-3}$	$2.5x10^{1}$
$3x10^{14}$ (infra red)	$2.5x10^{-19}$	$2.5x10^{-13}$	$2.5x10^{-9}$	$2.5x10^{-5}$	$2.5x10^{-1}$	$2.5x10^{3}$	$2.5x10^{7}$
$3.75x10^{14}$ (red)	$4x10^{-19}$	$4x10^{-13}$	$4x10^{-9}$	$2x10^{-5}$	$4x10^{-1}$	$4x10^{3}$	$4x10^{7}$
$5x10^{14}$ (yellow)	$0.7x10^{-18}$	$0.7x10^{-12}$	$0.7x10^{-8}$	$0.7x10^{-4}$	$0.7x10^{0}$	$0.7x10^{4}$	$0.7x10^{8}$
$5.75x10^{14}$ (light green)	$0.9x10^{-18}$	$0.9x10^{-12}$	$0.9x10^{-8}$	$0.9x10^{-4}$	$0.9x10^{0}$	$0.9x10^{4}$	$0.9x10^{8}$
$6x10^{14}$ (dark green)	$1x10^{-18}$	$1x10^{-12}$	$1x10^{-8}$	$1x10^{-4}$	$1x10^{0}$	$1x10^{4}$	$1x10^{8}$
$6.25x10^{14}$ (light blue)	$1.1x10^{-18}$	$1.1x10^{-12}$	$1.1x10^{-8}$	$1.1x10^{-4}$	$1.1x10^{0}$	$1.1x10^{4}$	$1.1x10^{8}$
$6.5x10^{14}$ (dark blue)	$1.2x10^{-18}$	$1.2x10^{-12}$	$1.2x10^{-8}$	$1.2x10^{-4}$	$1.2x10^{0}$	$1.2x10^{4}$	$1.2 x10^{8}$
$7x10^{14}$ (light violet)	$1.4x10^{-18}$	$1.4x10^{-12}$	$1.4x10^{-8}$	$1.4x10^{-4}$	$1.4x10^{0}$	$1.4x10^{4}$	$1.4x10^{8}$
$7.5x10^{14}$ (dark violet)	$1.6x10^{-18}$	$1.6x10^{-12}$	$1.6x10^{-8}$	$1.6x10^{-4}$	$1.6x10^{0}$	$1.6x10^{4}$	$1.6x10^{8}$
$3x10^{15}$ (ultra violet)	$1.6x10^{-17}$	$1.6x10^{-11}$	$1.6x10^{-7}$	$1.6x10^{-3}$	$1.6x10^{1}$	$1.6x10^{5}$	$1.6x10^{9}$

$3x10^{16}$ (ultra violet)	$2.5x10^{-15}$	$2.5x10^{-9}$	$2.5x10^{-5}$	$2.5x10^{-1}$	$2.5x10^{3}$	$2.5x10^{8}$	$2.5x10^{11}$

Table 1 shows that the radiated gravitational power can have high values if the energy E of the reflecting light packets is sufficiently high. The distance between reflective layers is of the order of wave length of light. For increasing radiated gravitational power, a high number q of reflective layers can be used. Only half of this power is used for actuating space debris because the rest is lost in space (fig.8).

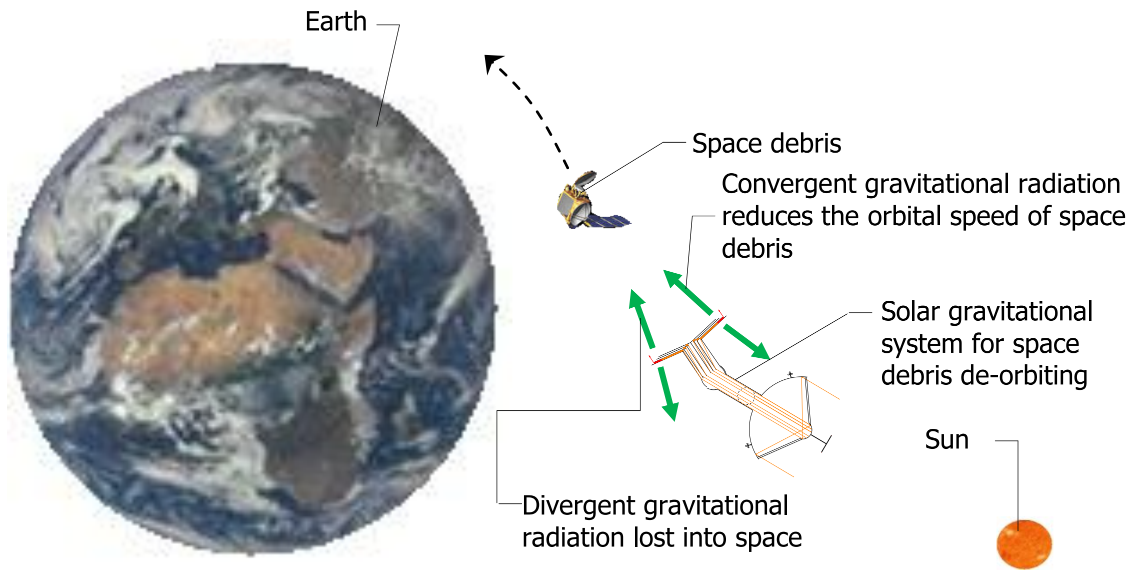

Figure 8: Action of solar-gravitational system for space removal

4. THE PROBLEM OF MIRRORS' REFLECTIVITY

There is plenty of light in space to be collected for generation gravitational radiation through multiple reflections. However, the low reflectivity of present materials is a great problem which must be solved. Until this problem will be solved, the solar-gravitational system for space debris de-orbiting cannot be built. , In reality, packets of light having energy E cannot be maintained a long period of time in a continuous reflecting process due to absorption of light during reflection. The best reflective materials (gold, silver, aluminum) can reach a reflectivity of only R=0.98…0.99 while for creating large packets of energy E, reflectivity must be very close by 1.
New artificial materials or charging of reflective layers with electrons at a very high potential could offer the necessary reflectivity. This is a very difficult problem of solid physics and much research work is necessary for solving it.

5. CONCLUSIONS

▪The solar-gravitational system for space debris de-orbiting uses gravitational attraction for reduction of orbital speed of space debris. In this way the space debris enters the dense atmosphere and burns. This system could be currenly used in future both for space debris de-orbiting and orbit reestablishing of satellites.

▪The gravitational radiation is produced through multiple reflections of concentrated sun-light between two or more parallel mirrors. This possibility is recognized today by advanced physics.

▪The main problem which must be solved for building of a gravitational system for space debris de-orbiting is increasing mirrors' reflectivity. This must be very high, close to 1. Much research work is necessary in the field of solid physics for obtaining mirrors with very high reflectivity. This can be achieved if new materials are developed or by charging the mirror metal with electrons at very high electric potentials.

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