Gravitational Blueshift and Redshift generated at Laboratory Scale

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In this paper we show that it is possible to produce gravitational *blueshift* and *redshift* at laboratory scale by means of a device that can strongly intensify the local gravitational potential. Thus, by using this device, it is possible to generate electromagnetic radiation of *any frequency*, from ELF radiation (f < 10*Hz*) up to *high energy gamma-rays*. In this case, several uses, such as medical imaging, radiotherapy and radioisotope production for PET (positron emission tomography) scanning, could be realized. The device is smaller and less costly than conventional sources of gamma rays.

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1. Introduction

It is known that electromagnetic radiation is *blueshifted* when propagating from a region of weaker gravitational field to a region of stronger gravitational field. In this case the radiation is blueshifted because it gains energy during propagation. In the contrary case, the radiation is *redshifted*. This effect was predicted by Einstein's Relativity Theory [1, 2] and was widely confirmed by several experiments [3, 4]. It was first confirmed in 1959 in the Pound and Rebka experiment [3].

Here we show that it is possible to produce gravitational *blueshift* and *redshift* at laboratory scale by means of a device that can strongly intensify the local gravitational potential* [5]. Thus, by using this device, it is possible to generate electromagnetic radiation of *any frequency*, from ELF radiation (f < 10*Hz*) up to *high energy gamma-rays*. In this case, several uses, such as in medical imaging, radiotherapy and radioisotope production for PET (positron emission tomography) scanning and others, could be devised. The device is smaller and less costly than conventional sources of gamma rays.

2. Theory

From the quantization of gravity it follows that the *gravitational mass* m_g and the *inertial mass* m_i are correlated by means of the following factor [5]:

$$\chi = \frac{m_g}{m_{i0}} = \left\{1 - 2\left[\sqrt{1+\left(\frac{\Delta p}{m_{i0}c}\right)^2} - 1\right]\right\} \tag{1}$$

where m_{i0} is the *rest* inertial mass of the particle and Δp is the variation in the particle's *kinetic momentum*; c is the speed of light.

When Δp is produced by the absorption of a photon with wavelength λ, it is expressed by $\Delta p = h/\lambda$. In this case, Eq. (1) becomes

$$\frac{m_g}{m_{i0}} = \left\{1 - 2\left[\sqrt{1+\left(\frac{h/m_{i0}c}{\lambda}\right)^2} - 1\right]\right\}$$
$$= \left\{1 - 2\left[\sqrt{1+\left(\frac{\lambda_0}{\lambda}\right)^2} - 1\right]\right\} \tag{2}$$

where $\lambda_0 = h/m_{i0}c$ is the *De Broglie wavelength* for the particle with *rest* inertial mass m_{i0}.

It has been shown that there is an additional effect - *Gravitational Shielding*

* De Aquino, F. (2008) *Process and Device for* Controlling the Locally the Gravitational Mass and the Gravity Acceleration, BR Patent Number: PI0805046-5, July 31, 2008.

effect - produced by a substance whose gravitational mass was reduced or made negative [6]. The effect extends beyond substance (gravitational shielding) , up to a certain distance from it (along the central axis of gravitational shielding). This effect shows that in this region the gravity acceleration, g_1, is reduced at the same proportion, i.e., $g_1 = \chi_1 g$ where $\chi_1 = m_g / m_{i0}$ and g is the gravity acceleration *before* the gravitational shielding). Consequently, *after a second gravitational shielding*, the gravity will be given by $g_2 = \chi_2 g_1 = \chi_1 \chi_2 g$, where χ_2 is the value of the ratio m_g / m_{i0} for the *second* gravitational shielding. In a generalized way, we can write that after the *nth* gravitational shielding the gravity, g_n, will be given by

$$g_n = \chi_1 \chi_2 \chi_3 \ldots \chi_n g \tag{3}$$

This possibility shows that, by means of a battery of gravitational shieldings, we can strongly intensify the gravitational acceleration.

In order to measure the extension of the shielding effect, samples were placed above a superconducting disk with radius $r_D = 0.1375m$, which was producing a gravitational shielding. The effect has been detected up to *a distance of about 3m* from the disk (along the central axis of disk) [7]. This means that *the gravitational shielding effect extends, beyond the disk by approximately 20 times* the disk *radius*.

From Electrodynamics we know that when an electromagnetic wave with frequency f and velocity c incides on a material with relative permittivity ε_r, relative magnetic permeability μ_r and electrical conductivity σ, its *velocity is reduced* to $v = c/n_r$ where n_r is the index of refraction of the material, given by [8]

$$n_r = \frac{c}{v} = \sqrt{\frac{\varepsilon_r \mu_r}{2}\left(\sqrt{1+(\sigma/\omega\varepsilon)^2}+1\right)} \tag{4}$$

If $\sigma >> \omega\varepsilon$, $\omega = 2\pi f$, Eq. (4) reduces to

$$n_r = \sqrt{\frac{\mu_r \sigma}{4\pi\varepsilon_0 f}} \tag{5}$$

Thus, the wavelength of the incident radiation (See Fig. 1) becomes

$$\lambda_{\text{mod}} = \frac{v}{f} = \frac{c/f}{n_r} = \frac{\lambda}{n_r} = \sqrt{\frac{4\pi}{\mu f \sigma}} \tag{6}$$

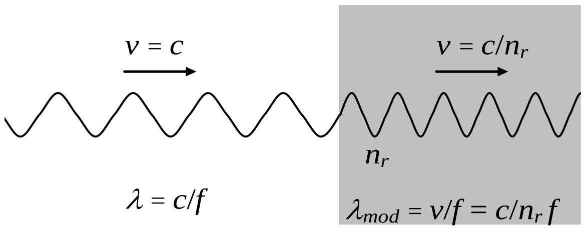

Fig. 1 – *Modified Electromagnetic Wave*. The wavelength of the electromagnetic wave can be strongly reduced, but its frequency remains the same.

If a lamina with thickness equal to ξ contains n atoms/m^3, then the number of atoms per area unit is $n\xi$. Thus, if the electromagnetic radiation with frequency f incides on an area S of the lamina it reaches $nS\xi$ atoms. If it incides on the *total area of the lamina*, S_f, then the total number of atoms reached by the radiation is $N = nS_f\xi$. The number of atoms per unit of volume, n, is given by

$$n = \frac{N_0 \rho}{A} \tag{7}$$

where $N_0 = 6.02\times10^{26}\, atoms/kmole$ is the Avogadro's number; ρ is the matter density of the lamina (in *kg/m*^{3}) and A is the molar mass(*kg/kmole*).

When an electromagnetic wave incides on the lamina, it strikes N_f front atoms, where $N_f \cong (n S_f)\phi_m$, ϕ_m is the "diameter" of the atom. Thus, the electromagnetic wave incides effectively on an area $S = N_f S_m$, where $S_m = \frac{1}{4}\pi\phi_m^2$ is the cross section area of one atom. After these collisions, it carries out $n_{collisions}$ with the other atoms (See Fig.2).

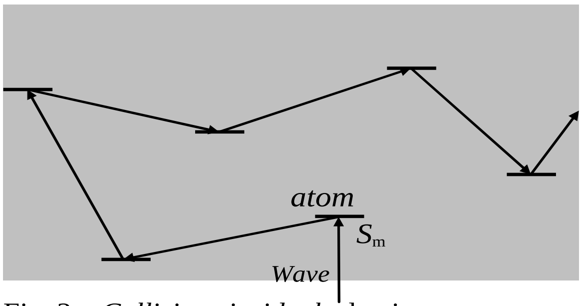

Fig. 2 – *Collisions inside the* lamina.

Thus, the total number of collisions in the volume $S\xi$ is

$$N_{collisions} = N_f + n_{collisions} = n_l S\phi_m + (n_l S\xi - n_m S\phi_m) = \\ = n_m S\xi \qquad (8)$$

The power density, D, of the radiation on the lamina can be expressed by

$$D = \frac{P}{S} = \frac{P}{N_f S_m} \qquad (9)$$

We can express the *total mean number of collisions in each atom*, n_1, by means of the following equation

$$n_1 = \frac{n_{total\ \ photons} N_{collisions}}{N} \qquad (10)$$

Since in each collision a *momentum* h/λ is transferred to the atom, then the *total momentum* transferred to the lamina will be $\Delta p = (n_1 N)h/\lambda$. Therefore, in accordance with Eq. (1), we can write that

$$\frac{m_{g(l)}}{m_{i0(l)}} = \left\{1 - 2\left[\sqrt{1 + \left[(n_1 N)\frac{\lambda_0}{\lambda}\right]^2} - 1\right]\right\} = \\ = \left\{1 - 2\left[\sqrt{1 + \left[n_{total\ photons} N_{collisions}\frac{\lambda_0}{\lambda}\right]^2} - 1\right]\right\} \qquad (11)$$

Since Eq. (8) gives $N_{collisions} = n_l S\xi$, we get

$$n_{total\ \ photons} N_{collisions} = \left(\frac{P}{hf^2}\right)(n_l S\xi) \qquad (12)$$

Substitution of Eq. (12) into Eq. (11) yields

$$\frac{m_{g(l)}}{m_{i0(l)}} = \left\{1 - 2\left[\sqrt{1 + \left[\left(\frac{P}{hf^2}\right)(n_l S\xi)\frac{\lambda_0}{\lambda}\right]^2} - 1\right]\right\} \qquad (13)$$

Substitution of P given by Eq. (9) into Eq. (13) gives

$$\frac{m_{g(l)}}{m_{i0(l)}} = \left\{1 - 2\left[\sqrt{1 + \left[\left(\frac{N_f S_m D}{f^2}\right)\left(\frac{n_l S\xi}{m_{i0(l)}c}\right)\frac{1}{\lambda}\right]^2} - 1\right]\right\} \qquad (14)$$

Substitution of $N_f \cong (n_l S_f)\phi_m$ and $S = N_f S_m$ into Eq. (14) results

$$\frac{m_{g(l)}}{m_{i0(l)}} = \left\{1 - 2\left[\sqrt{1 + \left[\left(\frac{n_l^3 S_f^2 S_m^2 \phi_m^2 \xi D}{m_{i0(l)} c f^2}\right)\frac{1}{\lambda}\right]^2} - 1\right]\right\} \qquad (15)$$

where $m_{i0(l)} = \rho_{(l)} V_{(l)}$.

Now, considering that the lamina is inside an ELF electromagnetic field with E and B, then we can write that [9]

$$D = \frac{n_{r(l)} E^2}{2\mu_0 c} \qquad (16)$$

Substitution of Eq. (16) into Eq. (15) gives

$$\frac{m_{g(l)}}{m_{i0(l)}} = \left\{1 - 2\left[\sqrt{1 + \left[\left(\frac{n_{r(l)} n_l^3 S_f^2 S_m^2 \phi_m^2 \xi E^2}{2\mu_0 m_{i0(l)} c^2 f^2}\right)\frac{1}{\lambda}\right]^2} - 1\right]\right\} \qquad (17)$$

In the case in which the area S_f is just the *area of the cross-section of the lamina* (S_α), we obtain from Eq. (17), considering that $m_{i0(l)} = \rho_{(l)} S_\alpha \xi$, the following expression

$$\frac{m_{g(l)}}{m_{i0(l)}}=\left\{1-2\left[\sqrt{1+\left[\left(\frac{n_{r(l)}n_l^3 S_\alpha S_m^2\phi_m^2 E^2}{2\mu_0\rho_{(l)}c^2 f^2}\right)\frac{1}{\lambda}\right]^2}-1\right]\right\} \quad (18)$$

According to Eq. (6) we have

$$\lambda=\lambda_{mod}=\frac{v}{f}=\frac{c}{n_{r(l)}f} \quad (19)$$

Substitution of Eq. (19) into Eq. (18) gives

$$\frac{m_{g(l)}}{m_{i0(l)}}=\left\{1-2\left[\sqrt{1+\frac{n_{r(l)}^4 n_l^6 S_\alpha^2 S_m^4\phi_m^4 E^4}{4\mu_0^2\rho_{(l)}^2 c^6 f^2}}-1\right]\right\} \quad (20)$$

Note that $E=E_m\sin\omega t$ .The average value for E^2 is equal to $\frac{1}{2}E_m^2$ because E varies sinusoidaly (E_m is the maximum value for E). On the other hand, $E_{rms}=E_m/\sqrt{2}$. Consequently we can change E^4 by E_{rms}^4, and the equation above can be rewritten as follows

$$\chi=\frac{m_{g(l)}}{m_{i0(l)}}=$$

$$=\left\{1-2\left[\sqrt{1+\frac{n_{r(l)}^4 n_l^6 S_\alpha^2 S_m^4\phi_m^4 E_{rms}^4}{4\mu_0^2\rho_{(l)}^2 c^6 f^2}}-1\right]\right\} \quad (21)$$

Now consider the *Gravitational Shift Device* shown in Fig.3.

Inside the device there is a *dielectric tube* ($\varepsilon_r \cong 1$) with the following characteristics: $\alpha=60mm$, $S_\alpha=\pi\alpha^2/4=2.83\times10^{-3}m^2$. Inside the tube there is an *Aluminum sphere* with 30mm radius and mass $M_{gs}=0.30536kg$. The tube is filled with *air* at ambient temperature and 1atm. Thus, inside the tube, the air density is

$$\rho_{air}=1.2\ kg.m^{-3} \quad (22)$$

The number of atoms of air (Nitrogen) per unit of volume, n_{air}, according to Eq.(7), is given by

$$n_{air}=\frac{N_0\rho_{air}}{A_N}=5.16\times10^{25}\,atoms/m^3 \quad (23)$$

The *parallel metallic plates* (p), shown in Fig.3 are subjected to different drop voltages. The two sets of plates (*D*), placed on the extremes of the tube, are subjected to $V_{(D)rms}=16.22V$ at $f=1Hz$, while the central set of plates (*A*) is subjected to $V_{(A)rms}=191.98V$ at $f=1Hz$. Since $d=98mm$, then the intensity of the electric field, which passes through the 36 *cylindrical air laminas* (each one with 5mm thickness) of the *two* sets (*D*), is

$$E_{(D)rms}=V_{(D)rms}/d=165.53V/m$$

and the intensity of the electric field, which passes through the 7 *cylindrical air laminas* of the central set (*A*), is given by

$$E_{(A)rms}=V_{(A)rms}/d=1.959\times10^3 V/m$$

Note that the *metallic rings* (5*mm* thickness) are positioned in such way to block the electric field out of the cylindrical air laminas. The objective is to turn each one of these laminas into a *Gravity Control Cells* (GCC) [10]. Thus, the system shown in Fig. 3 has 3 sets of GCC. Two with 18 GCC each, and one with 19 GCC. The two sets with 18 GCC each are positioned at the extremes of the tube (*D*). They work as gravitational *decelerator* while the other set with 19 GCC (*A*) works as a gravitational *accelerator*, intensifying the gravity acceleration and the *gravitational potential* produced by the mass M_{gs} of the Aluminum sphere. According to Eq. (3) the gravity, after the 19^{th} GCC becomes $g_{19}=\chi^{19}GM_{gs}/r_1^2$, and the gravitational potential $\varphi=\chi^{19}GM_{gs}/r_1$ where $\chi=m_{g(l)}/m_{i(l)}$ is given by Eq. (21) and $r_1=35mm$ is the distance between the center of the Aluminum sphere and the surface of the first GCC of the set (A).

The objective of the sets (*D*), with 18 GCC each, is to reduce strongly the value of the external gravity along the axis of the tube. In this case, the value of the external gravity, g_{ext}, is reduced by the factor $\chi_d^{18}g_{ext}$, where $\chi_d = 10^{-2}$. For example, if the base BS of the system is positioned on the Earth surface, then $g_{ext} = 9.81 m/s^2$ is reduced to $\chi_d^{18} g_{ext}$ and, after the set A, it is increased by χ^{19}. Since the system is designed for $\chi = -308.5$, then the gravity acceleration on the sphere becomes $\chi^{19}\chi_d^{18} g_{ext} = 2.4\times10^{-12} m/s^2$, this value is much smaller than $g_{sphere} = GM_{gs}/r_s^2 = 2.26\times10^{-8} m/s^2$.

The values of χ and χ_d, according to Eq. (21) are given by

$$\chi = \left\{1 - 2\left[\sqrt{1 + \frac{n_{r(l)}^4 n_l^6 S_\alpha^2 S_m^4 \phi_m^4 E_{(A)rms}^4}{4\mu_0^2 \rho_{(l)}^2 c^6 f^2}} - 1\right]\right\} = \\ = \left\{1 - 2\left[\sqrt{1 + 1.645\times10^{-9} E_{(A)rms}^4} - 1\right]\right\} \tag{24}$$

$$\chi_d = \left\{1 - 2\left[\sqrt{1 + \frac{n_{r(l)}^4 n_l^6 S_\alpha^2 S_m^4 \phi_m^4 E_{(D)rms}^4}{4\mu_0^2 \rho_{(l)}^2 c^6 f^2}} - 1\right]\right\} = \\ = \left\{1 - 2\left[\sqrt{1 + 1.645\times10^{-9} E_{(D)rms}^4} - 1\right]\right\} \tag{25}$$

where $n_{r(air)} = \sqrt{\varepsilon_r \mu_r} \cong 1$, since $(\sigma << \omega\varepsilon)$[†]; $n_{air} = 5.16\times10^{25} atoms/m^3$, $\phi_m = 1.55\times10^{-10} m$, $S_m = \pi\phi_m^2/4 = 1.88\times10^{-20} m^2$ and $f = 1Hz$. Since $E_{(A)rms} = 1.959\times10^3 V/m$ and $E_{(D)rms} = 165.53 V/m$, we get

$$\chi = -308.5 \tag{26}$$

and

$$\chi_d \cong 10^{-2} \tag{27}$$

[†] The electrical conductivity of air, *inside the dielectric tube*, is equal to the electrical conductivity of Earth's atmosphere near the land, whose average value is $\sigma_{air} \cong 1\times10^{-14} S/m$ [11].

Then the gravitational acceleration *after the 19th gravitational shielding* of the set A (See Fig.3) [‡] is

$$g_{19} = \chi^{19} g_1 = \chi^{19} GM_{gs}/r_1^2 \tag{28}$$

and the *gravitational potential* is

$$\varphi = \chi^{19}\varphi_1 = \chi^{19} GM_{gs}/r_1 \tag{29}$$

Thus, if photons with frequency f_0 are emitted from a point 0 near the Earth's surface, where the gravitational potential is $\varphi_0 \cong -GM_\oplus/r_\oplus$ (See photons source in Fig.3), and these photons pass through the region in front of the 19th gravitational shielding, where the gravitational potential is increased to the value expressed by Eq. (29) then the frequency of the photons in this region, according to Einstein's relativity theory, becomes $f = f_0 + \Delta f$, where Δf is given by

$$\Delta f = \frac{\varphi - \varphi_0}{c^2} f_0 = \frac{-\chi^{19} GM_{gs}/r_1 + GM_\oplus/r_\oplus}{c^2} \tag{30}$$

If $\chi < 0$, then $\chi^{19} < 0$ and $\Delta f > 0$ (*blueshift*). Note that, if the number n of Gravitational Shieldings in the set **A** is *odd* ($n = 1,3,5,7,...$) then the result is $\Delta f > 0$ (*blueshift*). But, if n is *even* ($n = 2,4,6,8,...$) and $\left|\chi^n M_{gs}/r_1\right| > \left|M_\oplus/r_\oplus\right|$ then the result is $\Delta f < 0$ (*redshift*). Note that to reduce $f_0 = 10^{14} Hz$ down to $f \cong 10^{11} Hz$ it is necessary that $\Delta f = -0.999\times10^{14} Hz$. This precision is not easy to be obtained in practice. On the other hand, if for example,

[‡] *The gravitational shielding effect extends beyond the gravitational shielding by approximately 20 times* its *radius* (along the central axis of *the gravitational shielding*). [7] Here, this means that, *in absence of the set D* (*bottom of the device*), *the gravitational shielding effect extends, beyond the 19th gravitational shielding, by approximately 20* ($\alpha/2$) ≈ 600mm.

$f_0 = 10^{14} Hz$ and $\Delta f = -10^{10} Hz$ then $f = f_0 + \Delta f \cong 10^{14} Hz$ i.e., the redshift is negligible. However, the device can be useful to generate *ELF radiation* by redshift. For example, if $f_0 = 1GHz$, $n = 18$ and $\chi = 95.15278521$, then we obtain ELF radiation with frequency $f \cong 1Hz$. Radiation of any frequency can be generated by gravitational blueshift. For example, if $f_0 = 10^{14} Hz$ and $\Delta f = +10^{18} Hz$ then $f = f_0 + \Delta f \cong 10^{18} Hz$. What means that a light beam with frequency $10^{14} Hz$ was converted into a gamma-ray beam with frequency $10^{18} Hz$. Similarly, if $f_0 = 1MHz$ and $\Delta f = +9MHz$, then $f = f_0 + \Delta f \cong 10MHz$, and so on.

Now, consider the device shown in Fig. 3, where $\chi = -308.5$, $M_{gs} = 0.30536kg$, $r_1 = 35mm$. According to Eq. (30), it can produce a Δf given by

$$\Delta f \cong \frac{-\chi^{19} GM_{gs}/r_1}{c^2} \cong 3.6 \times 10^{22} Hz \qquad (31)$$

Thus, we get

$$f = f_0 + \Delta f \cong 3.6 \times 10^{22} Hz \qquad (32)$$

What means that the device is able to convert any type of electromagnetic radiation (frequency f_0) into a gamma-ray beam with frequency $3.6 \times 10^{22} Hz$. Thus, by controlling the value of χ and f_0, it is possible to generate radiation of any frequency.

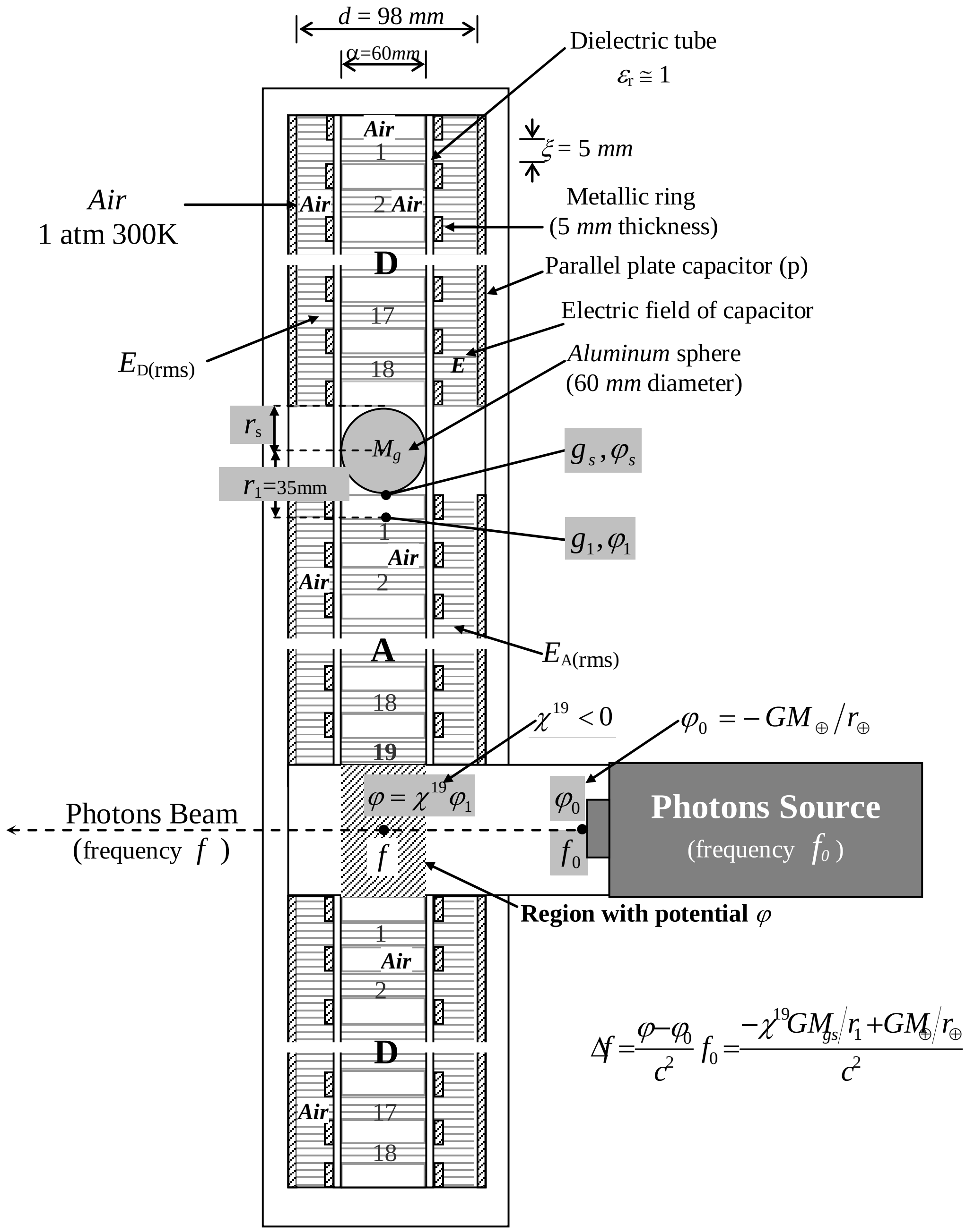

Fig. 3 – *Schematic diagram of the Gravitational Shift Device* (*Blueshift and Redshift*) – The device can generate electromagnetic radiation of *any frequency*, since ELF radiation (f < 10*Hz*) up to *high energy gamma-rays*.

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