THEORY

Extraction of a vacuum energy conforming to Emmy Noether's theorem

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ABSTRACT

This theoretical work corresponds to the hope of extracting, without contradicting the laws of thermodynamics or Emmy Noether's theorem, an energy present throughout the universe: that of the spatial quantum vacuum!

This article shows that - theoretically - it should be possible to maintain continuous periodic vibration of a piezoelectric structure. These vibrations generate current peaks for a fraction of the period. They are obtained by controlling automatically and at appropriate instants the action of an attractive Casimir force by a repulsive and ephemeral Coulomb force applied to return electrodes**.**

The attractive Casimir force appears between the two electrodes of a reflector and deforms a piezoelectric bridge embedded in its two extremities. The internal electric field created by the deformation of the piezoelectric bridge, attracts -from the mass- opposing moving charges. The systematic homogenization of the electric charges of one of the faces of the piezoelectric bridge with a Coulomb return electrode, creates a current peak and a Coulomb force opposite, ephemeral and greater than the Casimir force.

This Coulomb force cancels at least the action of the Casimir force and contributes to the disappearance of the deformation of the piezoelectric bridge. The device then returns to its initial position without electrical charges by using the deformation energy created by the Casimir force and stored in the piezoelectric bridge. The Coulomb force then disappears and the Casimir force deforms the bridge again.

During the homogenization of the electrical charges, a current peak ΔI passing through an inductance induces a voltage peak ΔU. These power peaks ΔI. ΔU are transformed – thanks to electronics without electrical power supply - into a continuous and usable voltage.

Casimir and Coulomb forces, vibrations, current or voltage peaks appear spontaneously and without any external energy input. The system vibrates because Casimir energy due to quantum vacuum fluctuations is constantly present.

To manufacture these different structures, an original micro technology is proposed. It should make it possible to produce the electronics and to control the very weak interfaces between the Casimir electrodes or the Coulomb return electrodes!

Key Words: *Casimir; Coulomb; Vacuum Quantum energy extraction, Piezoelectric; MEMS*

INTRODUCTION

The vacuums energy is the zero-point energy of all fields (tensorial and scalar) in space. In quantum field theory, this vacuum energy energy defined as reference, is the ground state of fields. It has been observed and shown theoretically that this so-called zero-point energy, is non-zero for a simple quantum harmonic oscillator, since its minimum energy is equal to E = h v /2 with v the natural frequency of the oscillator, and h the Planck's constant.

Originally, the Casimir effect is derived from statistical fluctuations of total vacuum energy and is the attraction (in general) between two plates separated by a vacuum [1-4]. In this approach, this Casimir energy is the part

$$E_{CA} = S\left(\frac{\pi^2 \hbar c}{740\ z_4^3}\right) \tag{1}$$

of the vacuum energy which is a function of the z_S separation of the Casimir plates.

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Thus, the Casimir force associated, is

$$F_{CA} = \frac{d(E_{CA})}{dz} = S\left(\frac{\pi^2 \hbar c}{240\ z_4^4}\right) \quad (2)$$

With ħ the reduced Planck constant, c the speed of light and S the reflector's surface, z_s the distance between the plates. The presence of the reflecting plates excludes the wavelengths of the virtual particles higher than z_0. They induce a pressure difference between the internal and external space of the 2 plates which pushes the plates against each other. (Figure. 1)

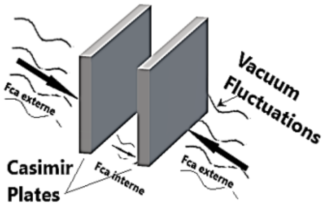


Figure 1) *Casimir effect*

Description of the principle used to "Extract" energy from the vacuum

The term vacuum energy is sometimes used by some scientists who claim that it is possible to extract energy from the vacuum, i.e., mechanical work, heat. These different hypotheses arouse great skepticism because they question a principle mathematically demonstrated by the theorem implying the conservation of energy by the mathematician Emmy Noether in 1915.

This theorem is accepted in physics and has never been challenged until now!

In fact, the problem is less to extract energy from the vacuum than to extract it without spending more energy that we cannot hope to recover! Thus, in a cyclic system on the model of a piston engine, moving from a position n°1 to n°2 and then from n°2 to n°1, the Casimir force being in $1/zs^4$, therefore greater in position (2) than in (1), necessarily seems to require more energy for a force of constant intensity to return to the position n° 1.

We know that in the case of a deformation perpendicular to the polarization of a piezoelectric layer, the fixed charges Q_F induced by the deformation of this piezoelectric layer are proportional to F_{CA} and are therefore in $1/z_s^4$.

$$Q_F = \frac{d_{31} F_{CA} l_p}{a_p} \quad (3)$$

Ref, does not depend on the common width bp = bs = bi of the structures [5, 6]. This point is important and facilitates the technological realization of these structures since it limits the difficulties to obtain a deep and straight engraving of the different structures. (Figure 2)

d_{31} = piezoelectric coefficient (CN^{-1}), l_p, a_p respectively length and thickness (m) of the piezoelectric bridge. These fixed electric charges on the two metallized faces of the piezoelectric bridge have opposite signs and attract mobile charges of opposite signs from the mass (Figure 3).

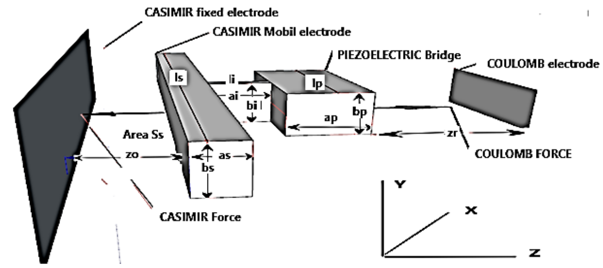


Figure 2) *General representation of the structure.*

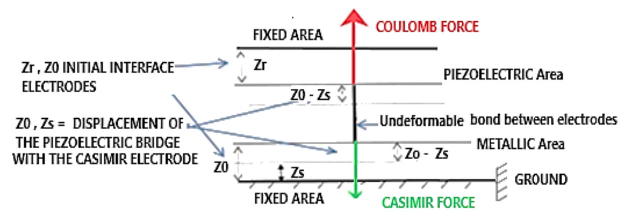


Figure 3) *Nomenclature and Notations of the positions of electrodes for the device*

$$F_{CO} = \left(\left(S_S \frac{\pi^2 \hbar c}{240}\right)\frac{d_{31} l_p}{a_p}\left(\frac{1}{z_s^4} - \frac{1}{z_0^4}\right)\right)^2 \left(\frac{1}{4\pi\varepsilon_0 \varepsilon_r}\right)\left(\frac{1}{z_r + z_0 - z_s}\right)^2 \quad (4)$$

We note that Coulomb's force F_{CO} = 0 when the bridge has no deflection ($zs = z_0$), so no electrical charges! This Coulomb Force in $1/z_s^{10}$ can therefore become greater than that of Casimir which is in $1/z_s^4$.

As a preamble, we suppose that the events which induce the attractive force of Casimir are exerted in a universal, isotropic, perpetual, and immediate way. Let's consider a Casimir reflector device made of a parallelepipedic metallic and mobile electrode, of surface $S_{s1} = S_{s2}$, separated by a distance z_0 from a fixed metallized surface S_{s3} (Figures 3-5).

This parallelepipedic metallic Casimir reflector is rigidly linked, by a metallic finger, to a piezoelectric bridge embedded in its two ends. A displacement of the mobile Casimir electrode induces a deformation of the piezoelectric bridge and thus the appearance of ionic electric charges (Figures 4, 5).

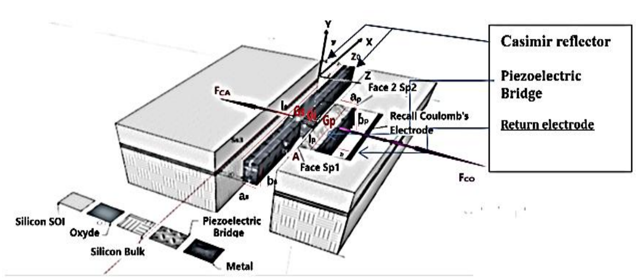


Figure 4) *Different view of the device*

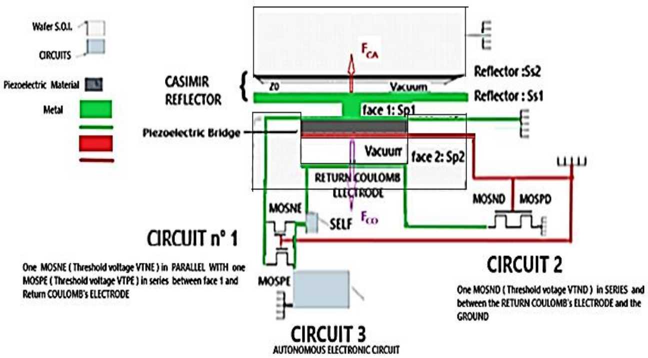


Figure 5) *General configuration of the device: MOS grid connections (Face 2 of the piezoelectric bridge: red), Source connections (Face 1 of the piezoelectric bridge: green)*

We observe, in Figure 5, that the two surfaces $Sp_1 = Sp_2 = b_p * l_p$, of the piezoelectric bridge, are connected:

1. At the mobile electrode of the Casimir reflector through the metal finger (green), for the face n°1. Thus, the metallic surfaces S_{p1} and the metallic parallelepiped $Ss_1 = S_{s2}$ are equipotential.
2. At the grids of the switch's circuits n°1 and n°2, for the face n ° 2 of area Sp_2.

The Casimir force caused deformations of the piezoelectric bridge, which produce ionic electric charges generating an electric field. These fixed charges attract from the mass respectively mobiles electrics charges Q_{mp1} and Q_{mn2} on the metallics electrodes.

We observe in Figure 5:

1. The switch circuit n°1 made with enriched transistors MOSNE, MOSPE in parallel and with the threshold voltages VT_{NE}, $V_{TPE,}$ (Figure 6),

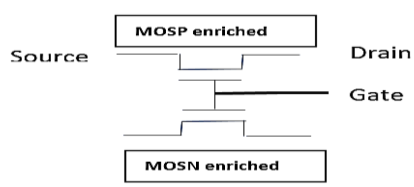


Figure 6) *Circuit n°1*

2. The switch circuit n°2 made with depletion transistors MOSND, MOSPD in series with threshold voltages $VT_{ND,}$ VT_{PD} (Figure 7)

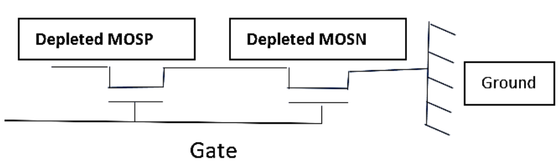


Figure 7) *Circuit n°2*

3. The Circuit n°3, is an autonomous device operating without any electrical power source. It rectifies and accumulates the AC power delivered to the terminals of the inductance and transforms them into a usable DC voltage source.

The threshold voltages are technologically positioned as: $0 < VT_{PD} < VT_{NE}$ and $VT_{PE} < VT_{ND} < 0$

The Figure 8 resumes this configuration

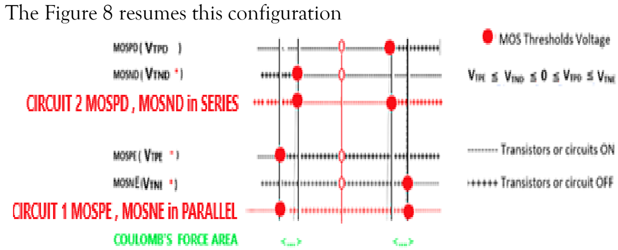


Figure 8) *Distribution of the threshold voltages of enriched and depleted N and P MOS switches*

We call V_{GRIDS} the voltage, appearing simultaneously on the gates of all the MOS transistors, created by the electric charges moving on the face 2 of the piezoelectric bridge.

Their sign on the Sp1 and Sp2 surfaces depends on the polarization of the piezoelectric bridge obtained during its realization; the V_{GRIDS} voltage on the MOS gates can be positive or negative.

The system (Casimir reflector, piezoelectric bridge, switches, return Coulomb electrode) finds the following cyclic situations (Figure 8).

1. When $0 < V_{GRIDS} < VT_{ND} < VT_{NE}$, or $VT_{PE} < VT_{ND} < V_{GRIDS} < 0$ then switch 1 is OFF, and switch 2 is ON. The Coulomb returns electrode is grounded and isolated from piezoelectric bridge. There are no electric charges on the return electrode and no Coulomb's force F_{CO} appears.
2. When $0 < VT_{ND} < V_{GRIDS} < VT_{NE}$, or $VT_{PE} < V_{GRIDS} < VT_{ND} < 0$, then switch 1 is OFF, and switch 2 is OFF. The Coulomb returns electrode is insulated from ground and the piezoelectric bridge. There are no electric charges on the return electrode

As long as the voltage on the gates of the enriched MOS of circuit 1 does not reach their threshold voltages, the state of circuit 1 and 2 do not change!

In these two situations, the only force that deforms the piezoelectric bridge is the Casimir force F_{CA}

3. When $0 < VT_{ND} < VT_{NE} \leq V_{GRIDS}$, or $V_{GRIDS} \leq VT_{PE} < VT_{ND} < 0$, then switch 1 is ON, and switch 2 is OFF, Thus, the moving electric charges passing through switch 1 become homogenized between the return Coulomb electrode and the S_{p1} face.

Let $S_{p1} = S_{p2} = l_p.\ b_p = S_r$ be the surface area of the faces of the piezoelectric bridge and of the return electrode, facing the metallized face S_{p2} of the piezoelectric bridge.

As there is no electric field in a conductor, the mobiles charges for example negative Q_{mn1}, initially distributed on the metallic surfaces S_{p1} are distributed on the surfaces $S_{p1} + S_r$. The return Coulomb's electrode has a charge

$$Q_{mn} = \frac{Q_{mn1}}{2} = F_{CA} \frac{d_{31}\, l_P}{2\, a_P} \qquad (5)$$

Between the faces S_{p2} and S_r, with an opposite sign electric charge, appears an attractive force of Coulomb, parallel and opposite to the attractive force of Casimir [5]. (Figure 5 and 9)

$$F_{CO} = \left(\left(S_S \frac{\pi^2 \hbar c}{240}\right) \frac{d_{31}\, l_p}{a_p}\left(\frac{1}{z_s^{\,4}} - \frac{1}{z_0^{\,4}}\right)\right)^2 \left(\frac{1}{8\,\pi\,\varepsilon_0\,\varepsilon_r}\right)\left(\frac{1}{z_r + z_0 - z_s}\right)^2 \quad (6)$$

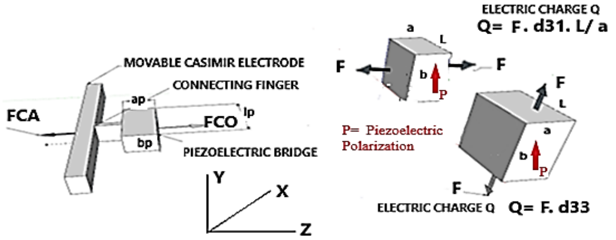


Figure 9) *Polarization and applied force and load on a piezoelectric block*

The threshold voltage of the MOSNE is adjusted so that the Coulomb force is triggered only when F_{CO} = p F_{CA}, with a chosen proportionality factor p. Then the total repulsion force Ft, variable in time, and applied to the piezoelectric bridge becomes

$$\overrightarrow{F_T} = \overrightarrow{F_{CA}} - \overrightarrow{F_{C0}} = (1-p)\ \overrightarrow{F_{CA}} \Rightarrow \overrightarrow{F_T} < 0 \quad (7)$$

Repulsive, this force Ft induces a deformation of the piezoelectric bridge in the opposite direction, and the piezoelectric bridge returns or slightly exceeds (because of inertia) its neutral position, therefore towards its position without any electrical charge.

Calculation of the homogenization current

Since there is no electric field in a metal, the variation in time of the mobile charges on the initially grounded but now insulated coulomb return electrode follows, to a first approximation, the law of charge distribution on a short-circuited capacitor.

This time variation of the charges is given by the well-known exponential form of the charge of a capacitor according to the formula

$$Q_{mn} = Q_{mn1}\left[1 - Exp\left(-\frac{t}{R_m\, C_S}\right)\right] \quad (8)$$

This variation stops when the electrical charges Q_{mn} are uniformly distributed and equal to Q_{mn1} / 2 over the two electrodes S_{p1} and Sr, so at time t_e = R_m C_s ln (2) (Eq. (5)). The time t_e is to reach this balance, with R_m the ohmic resistance of the metal track, L_{in} the coil inductance, C_s the capacitance formed by the electrodes.

$R_m \cong \rho_m . l_m / S_m$, with ρ_m the resistance of the coil between electrode, l_m its total length, S_m its section. $Cs = \varepsilon_0 . \varepsilon_{0m}\, l_p . b_p / z_r$, the capacitance between return and S_{p2} electrode. With ε_0 the permittivity of vacuum, ε_{0m} the relative permittivity of the metal oxide, l_p and b_p the geometries of the return electrode.

An approximation of the duration of the homogenization of the electric charges and therefore of the duration of the current peak, gives $t_e \cong 10^{-9}$ s. It is based on an estimate to propagate in the resistivity part of the L_{IN} inductance of about 10^{-5} Henri, plus the resistance of the MOS.

This current peak I_{IN} circulating for the duration of time t_e is I_{IN} =d(Q_{mn})/dt

$$I_{IN} = -\frac{Q_{mn1}}{R_m C_S}\, Exp\left(-\frac{t}{R_m C_S}\right) \quad (9)$$

The time t =0 is counted from the closing of one of the transistors of circuit 1. This current peak is present even if the switch transistors close some time after, because the mobile charges have already propagated.

This current peak I_{IN} crossing an inductance L_{IN} during the time t_e induces a voltage peak U_{IN} at the terminals of this inductance L_{IN} as a function of time according to the usual formula:

$$U_{IN} = L_{IN}\frac{d(I_{IN})}{dt} = -L_{IN}\frac{Q_{mn1}}{(R_m C_S)^2} Exp\left(-\frac{t}{R_m C_s}\right) = \quad (10)$$

$$= -L_{IN}\frac{Q_{mn1}\, Ln(2)}{R_m\, C_S\, t_e}\ Exp\left(-\frac{t\, Ln(2)}{t_e}\right)$$

An alternative AC voltage peak U_{IN} with a maximum voltage at time t = 0, is therefore automatically recovered at the terminals of the solenoid L_{IN}. This AC voltage peak can then be rectified to a direct DC voltage of a few volts, by suitable electronics operating without power supply.

An opposite, intense and ephemeral Coulomb's force F_{CO} = p F_{CA} appears suddenly between return electrode and face 2. The piezoelectric bride is then, submitted to the force F_{CA} (1-p) with p a factor of proportionality chosen by the value of the threshold voltages of the MOSE and MOSD.

The position ze of appearance of this Coulomb force corresponds to the following equation F_{CO} = p F_{CA} and is solve numerically, see equation 11 and Figure 10

$$F_{CO} = \left(\frac{d_{31}\, l_p}{a_p}\, l_S\, b_S\, \frac{\pi^2 \hbar c}{240}\left(\frac{1}{z_s^{\,4}} - \frac{1}{z_0^{\,4}}\right)\right)^2 \left(\frac{1}{8\,\pi\,\varepsilon_0\,\varepsilon_r}\right)\left(\frac{1}{z_r + z_0 - z_s}\right)^2 = \quad (11)$$

$$p\, F_{CA} = p\, l_s b_s \frac{\pi^2 \hbar c}{240}\frac{1}{z_s^{\,4}}$$

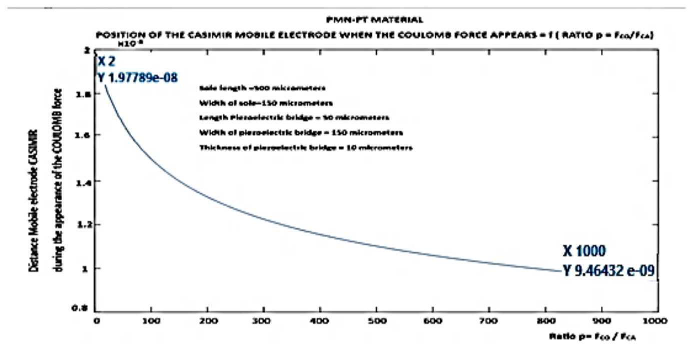


Figure 10) *Position z_e of the mobile Casimir electrode when the Coulomb force occurs for $z_r = z_0$ =200A° ls = 500 μm; bs = 150 μm; lp = 50μm; bp = 150μm ; ap = 10μm*

4. As long as $0 < V_{TND} < V_{GRIDS} \leq V_{TNE}$, or $V_{TPE} \leq V_{GRIDS} < V_{TPD} < 0$, the Coulomb force F_{CO} continues to exist. The bridge deformation and the voltage on the MOS gates continue to decrease with the same expression of the different forces (Eq. 1, 3 ,4).

As long as the voltage on the gates of the MOSD of circuit 2 does not reach their threshold voltages V_{TND} or V_{TPD}, the piezoelectric bridge continues its movement to its initial position z_0.

5. $0 < V_{GRIDS} \leq VT_{ND} < VT_{NE}$, or $VT_{PE} < VT_{PD} \leq V_{GRIDS} < 0$, the circuit 2 commute ON.

The return Coulomb electrode is again connected to ground. The Coulomb force F_{CO} disappears. But the bridge, having acquired kinetic energy, spends it by inertia to continue its ascent towards z_0 and even slightly exceeds its neutral position.
Still present, the Casimir force F_{CA} is again the only one that applies! It attracts again the metallic surface S_{S2} against S_{S3} and the events described above are repeated.

The consequence is that the structure made up of the piezoelectric bridge, the connecting finger, the metal block forming the mobile Casimir electrode starts to vibrate.

With a frequency depending:

1. Of the Casimir restoring force, and of the Coulomb return electrode force therefore so with:
   a) the starting z_0 and z_r separation interface
   b) geometric dimensions of the different electrodes,
2. Properties of the piezoelectric bridge,
3. The choice of threshold voltages of the different MOS transistors
4. The choice of conductive metal.

As we will see, this frequency is lower than the first resonance frequency of the moving structure if the initial interface $z_0 < 150$ A° .

In conclusion, it seems that all the electro-physical phenomena leading to a vibration of the structure and thus to the production of a peak of electric power, are only the consequence of a single phenomenon. The one linked to the Casimir force - resulting from the fluctuations of the vacuum energy - but controlled by a Coulomb force.

Calculation of the behaviour of the structure

Let us calculate the evolution in time of the force of Casimir which is applied between the two electrodes separated by an initial distance z_0. We use the theorem of angular momentum to this vibrating structure

$$\overrightarrow{\sigma^{S}_{Ax,y,z}(\,Structure\,)} = \overline{I^{S}_{A\,x,y,z}}\ \overrightarrow{\theta^{S}_{A\,x,y,z}} \tag{12}$$

With σ^{S}_{Axyz} the angular momentum vector of the structure I^{S}_{Axyz} the inertia matrix of the structure with respect to the reference (A, x,y,z) and Ω^{S}_{A} the rotation vector of the piezoelectric bridge with respect to the axis Ay, α the low angle of rotation along the y axis of the piezoelectric bridge (Figure 11)

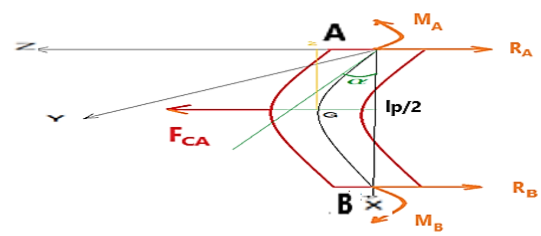


Figure 11) *Piezoelectric bridge Bending Moment, Deflection*

We have

$$\overrightarrow{\Omega^{S}_{A}} = \begin{pmatrix} 0 \\ {d\alpha}/{dt} \\ 0 \end{pmatrix} \text{ with } {d\alpha}/{dt} \approx \frac{2}{l_p}\frac{dz}{dt} \text{ because } \sin(\alpha) = \sin\left(\frac{2z_s}{l_p}\right) \approx \frac{2z_s}{l_p}$$

because $z \ll l_p$

Because $\sin(\alpha) = {2zs}/{l_p} \approx \frac{2zs}{l_p}$

Let (Gp, x, y, z), (Gi, x, y, z), (Gs, x, y, z) be the barycentric points respectively of the piezoelectric bridge, the metal connecting finger and the metal block constituting the sole mobile of the Casimir reflector.
We have (Figure 4):

$$\overrightarrow{AG_{P,x,y,z}} = \frac{1}{2}\begin{pmatrix} l_P \\ b_P \\ a_P \end{pmatrix} \quad \overrightarrow{AG_{I,x,y,z}} = \frac{1}{2}\begin{pmatrix} l_P + l_i \\ b_P + b_i \\ a_P + a_i \end{pmatrix}$$

$$\overrightarrow{AG_{S,x,y,z}} = \frac{1}{2}\begin{pmatrix} l_P + l_i + l_S \\ b_P + b_i + b_S \\ a_P + a_i + a_S \end{pmatrix}$$

The inertia matrix of the bridge, in the frame of reference (Gp, x, y, z) is:

$$I^{P}_{GP} = \frac{m_P}{12}\begin{pmatrix} a^2_P + b^2_P & 0 & 0 \\ & l^2_P + b^2_P & 0 \\ 0 & 0 & a^2_P + l^2_P \end{pmatrix}$$

Taking Huygens' theorem into account, this inertia matrix becomes Eq. (13):

$$I^{P}_{A,x,y,z} = m_P\begin{pmatrix} \frac{a^2_P + b^2_P}{3} & -\frac{l_P b_P}{4} & -\frac{l_P a_P}{4} \\ -\frac{l_P b_P}{4} & \frac{a^2_P + l^2_P}{3} & -\frac{a_P b_P}{4} \\ -\frac{l_P ba}{4} & -\frac{a_P b_P}{4} & \frac{l^2_P + b^2_P}{3} \end{pmatrix} \tag{13}$$

The inertia matrix of the finger is, in the frame of reference (Gi, x, y, z) is:

$$I^{I}_{GI} = \frac{m_i}{12}\begin{pmatrix} a^2_i + b^2_i & 0 & 0 \\ 0 & a^2_i + l^2_i & 0 \\ 0 & 0 & l^2_i + b^2_i \end{pmatrix}$$

Taking Huygens' theorem into account, this inertia matrix become Eq. (14)

$$I^{I}_{A,x,y,z} = \frac{m_i}{12}\begin{pmatrix} a^2_i + b^2_i & 0 & 0 \\ 0 & a^2_i + l^2_i & 0 \\ 0 & 0 & l^2_i + b^2_i \end{pmatrix} + m_i \quad (14)$$

$$\begin{pmatrix} \frac{(b_p+b_i)^2+(a_p+a_i)^2}{4} & -\frac{(b_p+b_i)(l_p+l_i)}{4} & -\frac{(a_p+a_i)(l_p+l_i)}{4} \\ -\frac{(b_p+b_i)(l_p+l_i)}{4} & \frac{(l_p+l_i)^2+(a_p+a_i)^2}{4} & -\frac{(b_p+b_i)(a_p+a_i)}{4} \\ -\frac{(a_p+a_i)(l_p+l_i)}{4} & -\frac{(b_p+b_i)(a_p+a_i)}{4} & \frac{(b_p+b_i)^2+(l_p+l_i)^2}{4} \end{pmatrix}$$

The inertia matrix of the reflector in the frame of reference (GS, x,y,z) is

$$I^{C}_{GS} = \frac{m_s}{12}\begin{pmatrix} a^2_s + b^2_s & 0 & 0 \\ 0 & a^2_s + l^2_s & 0 \\ 0 & 0 & l^2_s + b^2_S \end{pmatrix}$$

Taking Huygens' theorem into account, this inertia matrix becomes: Eq. (15)

$$I^{C}_{A,x,y,z} = \frac{m_s}{12}\begin{pmatrix} a^2_s + b^2_s & 0 & 0 \\ 0 & a^2_s + l^2_s & 0 \\ 0 & 0 & l^2_s + b^2_S \end{pmatrix} + m_s \quad (15)$$

$$\begin{pmatrix} \frac{(b_p+b_i+b_s)^2+(a_p+a_i+a_s)^2}{4} & -\frac{(l_p+l_i+l_s)(b_p+b_i+b_s)}{4} & -\frac{(l_p+l_i+l_s)(a_p+a_i+as)}{4} \\ -\frac{(l_p+l_i+l_s)(b_p+b_i+b_s)}{4} & \frac{(l_p+l_i+l_s)^2+(a_p+a_i+a_s)^2}{4} & -\frac{(b_P+b_i+b_s)(a_p+a_i+as)}{4} \\ -\frac{(l_p+l_i+l_s)(a_p+a_i+as)}{4} & -\frac{(b_P+b_i+b_s)(a_p+a_i+as)}{4} & \frac{(b_p+b_i+b_s)^2+(l_p+l_i+l_s)^2}{4} \end{pmatrix}$$

The total inertia of the structure becomes in the reference (A, x,y,z), $I^{s}_{A,x,y\,z} = I^{P}_{A,x,y,z} + I^{I}_{A,x,y,z} + I^{c}_{A,x,y,z}$ with A at the edge of the recessed piezoelectric bridge .The angular momentum theorem applied to the whole structure gives

$$\frac{\overrightarrow{d(\sigma^S_{A,x,y,z})}}{dt} = \overline{I^S_{A,x,y,z}}\ \frac{\overrightarrow{d\theta^s_A}}{dt} \Rightarrow \overline{I^S_{A,x,y,z}}\ \frac{2}{l_P}\begin{pmatrix} 0 \\ \frac{d^2z}{dt^2} \\ 0 \end{pmatrix} = \sum_A \overrightarrow{Moments\ of\ the\ structure} = \quad (16)$$

$$= \overrightarrow{M_A} + \overrightarrow{M_B} + \overrightarrow{F_{CA}} \wedge \begin{pmatrix} l_P/2 \\ 0 \\ 0 \end{pmatrix} \ with\ \overrightarrow{F_{CA}} = \begin{pmatrix} 0 \\ 0 \\ F_{CA} \end{pmatrix}$$

The structure rotates around the Ay axis. We know (see X), that the moments are $M_{AY} = M_{BY} = - F_{CA}\, lp\,/8$.

Therefore: Σ Moments on the structure relative to the axe Ay = ¼.lp .F_{CA} .

$$\overline{I^s_y}\ \frac{2}{l_P}\ \frac{d^2z}{dt^2} = \frac{l_P}{4}\, F_{CA} = \frac{l_P}{4}\ S_S\, \frac{\pi^2 \hbar c}{240\ z^4} \quad (17)$$

Any calculation done we obtain: (17) with I_y^S the inertia of the structure relatively to the axe Ay.

$$I^S_Y = \rho_P a_P b_P l_P \left(\frac{(l_P{}^2 + a_P{}^2)}{12} + \frac{(l_P{}^2 + a_P{}^2)}{4}\right) + \rho_i a_i b_i l_i \left(\frac{(l_i{}^2 + a_i{}^2)}{12} + \frac{(l_P + l_i)^2 + (a_P + a_i)^2}{4}\right)$$

$$+ \rho_s a_s b_s l_s \left(\frac{(l_s{}^2 + a_s{}^2)}{12} + \frac{(l_P + l_i + l_s)^2 + (a_P + a_i + a_S)^2}{4}\right) \quad (18)$$

With ρ_P, ρ_i, ρ_S, respectively the densities of the piezoelectric bridge, the intermediate finger and the mobile electrode of the Casimir reflector.

As long as $0 < VT_{ND} < V_{GRIDS} < VT_{NE}$ or $VT_{PE} < V_{GRIDS} < VT_{ND} < 0$
By equation 12, we obtain the differential equation which makes it possible to calculate the interval between the two electrodes of the Casimir reflector as a function of time during the "descent" phase when the Coulomb forces are not present

$$\frac{d^2z}{dt^2} = \frac{l_P{}^2}{8\ I_Y{}^S}\, S_S\, \frac{\pi^2 \hbar c}{240}\, \frac{1}{z^4} = \frac{B}{z^4} \quad with\ B = \frac{l_P{}^2}{8\, I_Y{}^S}\, S_S\, \frac{\pi^2 \hbar c}{240} \quad (19)$$

This differential equation (19) unfortunately does not have a literal solution and we programmed it on MATLAB to calculate the duration of this "descent" of free Casimir electrode. This duration depending on the desired value of the coefficient of proportionality p.

Just at the moment of closing circuit n°1, we have $F_{CO} = - p\, F_{CA}$ with p a coefficient of proportionality ≥ 2 defined by the threshold voltages of the MOS interrupters. The total force FT exerted in the middle of the piezoelectric bridge just at the start of the charge transfer becomes: $F_T = F_{CA} - F_{CO} = F_{CA}\,(1-p)$

The "descent" time of the free Casimir electrode will therefore stop when $F_{CO} = -pF_{CA}$. This moment, we know that: $V_{GRIDS} = VT_NE$ or $V_{GRID}S = VT_{PE}$

1. The Casimir force is variable in time and its equation is (Eq. (2)): $F_{CA} = \frac{d(E_{CA})}{dz} = S(\frac{\pi^2 \hbar c}{240\ z^4_4})$
2. The mobile charges transiting from side 1 to the Coulomb electrode through circuit 1 variable in time are: $Q_{mn} \approx \frac{Q_{mn1}}{2} = \frac{d_{31}\ F_{CA}\ l_P}{2\ a_P}$ (20)
3. The Coulomb force, variable over time, acting in opposition to the Casimir force (Eq. (4)):

$$F_{CO} = \left(\frac{d_{31} l_p}{a_p}\, l_S b_S\, \frac{\pi^2 \hbar c}{240}\left(\frac{1}{z_s{}^4} - \frac{1}{z_0{}^4}\right)\right)^2 \left(\frac{1}{8\,\pi\,\varepsilon_0\,\varepsilon_r}\right)\left(\frac{1}{z_r + z_0 - z_s}\right)^2 =$$

$$p\, F_{CA} = p\, l_s b_s\, \frac{\pi^2 \hbar c}{240}\, \frac{1}{z_s{}^4}$$

The "descent" of the free Casimir electrode stops when the inter electrode interface zs reach the position ze such that Eq 11:

$$z_S{}^4 \left(\left(\frac{1}{z_R + z_0 - z_S}\right)^2 \left(\frac{1}{z_S{}^4} - \frac{1}{z_0{}^4}\right)^2\right) = \frac{1920\ p\,\varepsilon_0\,\varepsilon_r}{\pi \hbar c\, S_S}\left(\frac{a_P}{d_{31}\, l_P}\right)^2 \quad (21)$$

Figure 10 therefore gives the time td of the "descent" of the structure submitted to the Casimir force: This programmable equation depending on the coefficient of proportionality p, is calculable and will stop when the interelectrode interface z_s has a value z_e satisfying equation (21). At this instant the total force is

$$F_T = (1-p)\, F_{CA} \Rightarrow (1-p)\, S_S \frac{\pi^2 \hbar c}{240\, z_{sm}^4} < 0 \;\; if \;\; p > 1$$

and the displacement of the mobile system reaches is maximum position z_{sm} and changes direction, but as switch 2 is still open the Coulomb force persists.

During all the phase where $0 < VT_{ND} < V_{GRIDS} \leq VT_{NE}$, or $VT_{PE} \leq V_{GRIDS} < VT_{ND} < 0$, the total force, variable over time and exerted at the center of the piezoelectric bridge, becomes:

$$F_T = F_{CA} - F_{CO} = \left(S_S \frac{\pi^2 \hbar c}{240\, z_S^4} - \frac{1}{2} \left[\frac{S_S\, \pi^2 \hbar c}{240} \left(\frac{1}{z_S^4} - \frac{1}{z_0^4} \right) \left(\frac{d_{31} l_P}{a_P} \right) \right]^2 \right) \left(\frac{1}{4 \pi \varepsilon_0 \varepsilon_r} \right) \left(\frac{1}{z_r + z_0 - z_s} \right)^2 \quad (22)$$

The piezoelectric bridge subjected to this force then rises towards its neutral position. The Casimir inter electrode interval increases causing the Casimir force to decrease. As the deformations on the piezoelectric faces decrease, so do the electrical charge, resulting in a decrease in the Coulomb force? During the "ascent", the FT force therefore rapidly approaches the starting FCA force. Let us calculate an approximation of the duration of this "rise». It is a maximization of this time because in fact the Coulomb force FCO stop when the circuit 2 close to ground another time.

As we don't know the threshold voltage VT_ND or VT_{PD}, we made this calculation as there are null.

In these conditions, to know the time taken by the structure to "go back" to its neutral position, we must solve the following differential equation: (Eq. (22))

$$\frac{d^2 z}{dt^2} = \frac{l_P^2}{8 I_S^Y} \left(F_{CA} - F_{CO} \right) = \frac{l_P^2}{8 I_S^Y} \left\{ \left(l_S b_S \frac{\pi^2 \hbar c}{240\, z_S^4} \right) - \frac{1}{2} \left[l_S b_S \frac{\pi^2 \hbar c}{240} \left(\frac{1}{z_S^4} - \frac{1}{z_0^4} \right) \left(\frac{d_{31} l_P}{a_P} \right) \right]^2 \right\} \left(\frac{1}{4 \pi \varepsilon_0 \varepsilon_r} \right) \left(\frac{1}{z_r + z_0 - z_S} \right)^2$$

By posing $A_1 = \left\{ \left(l_S b_S \frac{\pi^2 \hbar c}{240} \right) \right\}$ this differential equation concerning the "ascent" of the bridge is written

$$\frac{d^2 z}{dt^2} = \frac{l_P^2}{8 I_S^Y} \left(F_{CA} - F_{CO} \right) = \frac{l_P^2}{8 I_S^Y} A_1 \left\{ \frac{1}{z_S^4} - A_1 \left(\frac{d_{31} l_P}{a_P} \right)^2 \right\} \left(\frac{1}{8 \pi \varepsilon_0 \varepsilon_r} \right) \left(\frac{1}{z_S^4} - \frac{1}{z_0^4} \right)^2 \left(\frac{1}{z_r + z_0 - z_S} \right)^2 \quad (23)$$

This differential equation (23) has no analytical solution and can only be solved numerically.
We programmed it on MATLAB. The properties and dimensions of the different materials used in this simulation are as follows (Table 1).

TABLE 1
Table of characteristics used for MATLAB and ANSYS simulations

	PZT	**AlN**	**LiNbO3**	**PMN-PT :**
Young Modulus ($kg*m*s^{-2}$) / m²)	$Ep=8.9*10^{10}$	$Ep=32*10^{10}$	$Ep=2.45*10^{9}$	Ep=150*10^9
Volumic mass (kg m^{-3})	dp =7600	dp=3255	dp=4700	dp=7920
Piezoelectric coefficient d31 of the beam (C / ($kg* m* s^{-2}$)	$d31=200*10^{-12}$	$d31=2.400*10^{-12}$	$d31=6*10^{-12}$	$d31= 1450*10^{-12}$
Length piezoelectric beam: lp (m)	$50\ 10^{-6}$	$50\ 10^{-6}$	$50\ 10^{-6}$	$50\ 10^{-6}$
Width piezoelectric beam: bp (m)	$150\ 10^{-6}$	$150\ 10^{-6}$	$150\ 10^{-6}$	$150\ 10^{-6}$
Thickness piezoelectric: ap (m)	$10\ 10^{-6}$	$10\ 10^{-6}$	$10\ 10^{-6}$	$10\ 10^{-6}$
Connecting finger length: li (m)	$10\ 10^{-6}$	$10\ 10^{-6}$	$10\ 10^{-6}$	$10\ 10^{-6}$
Width finger connection: bi (m)	$150\ 10^{-6}$	$150\ 10^{-6}$	$150\ 10^{-6}$	$150\ 10^{-6}$
Thickness finger connection: ai (m)	$10\ 10^{-6}$	$10\ 10^{-6}$	$10\ 10^{-6}$	$10\ 10^{-6}$
Mobile Casimir electrode block length: ls (m)	$500\ 10^{-6}$	$500\ 10^{-6}$	$500\ 10^{-6}$	$500\ 10^{-6}$
Mobile Casimir electrode block width: bs (m)	$150\ 10^{-6}$	$150\ 10^{-6}$	$150\ 10^{-6}$	$150\ 10^{-6}$
Casimir mobile electrode block thickness: as (m)	$10\ 10^{-6}$	$10\ 10^{-6}$	$10\ 10^{-6}$	$10\ 10^{-6}$

In these MATLAB simulations we consider that the metal electrodes and the metal block are oxidized to a thickness allowing an interface between the Casimir electrodes of 200 A°. This modifies the mass and inertia of the vibrating structure.

It turns out that the choice of aluminum as the metal deposited on these electrodes is preferable given:

1. It's easy oxidation in Al2O3
2. Its low density increases and optimizes the vibration frequency of the structure by minimizing the inertia of the Casimir reflector and the parallelepipedic block that transfers the Casimir force.

The mass $M_{structure}$ of the vibrating structure is then:

$$M_{STRUCTURE} = d_{pm} \left(a_s b_S l_S + a_i b_i l_i \right) + 2 d_{om} z_{of} \left(a_{s0} b_{S0} + b_{s0} l_{s0} + a_{s0} l_{S0} \right) + d_p \left(a_p b_p l_p \right)$$

With d_{pm} the density of the metal, a_s, b_s, l_s the geometries of the mobile metal part of the Casimir electrode sole, d_{om} the density of the metal oxide, a_{so}, b_{so}, l_{so} the geometries of the oxidized parts around the 6 faces of the metal block, d_p the density of the piezoelectric parallelepiped:

Simulation of devices with different piezoelectric bridge

We present below the results of the MATLAB simulations carried out by numerically calculating of the differential equations (19) and (23). These numerical calculations give the vibration frequency of the structure which vibrates at a frequency lower than its first resonant frequency. This vibration frequency depends on the characteristics of the structure (Nature of material, geometric dimensions, coefficient of proportionality p = F_{CO} / F_{CA}...)). Annex X.

The metal used for the Casimir reflector block is Aluminum with a density of 2.7 g cm^{-3} and the Piezoelectric material = PMN-PT With these simulations, for an interval between Casimir electrode z_0= 200 Angstroms, we obtain the evolution over time of the Casimir and Coulomb forces as well as the F_{CO}/F_{CA} ratio of Figures 12 to 27 below.

For a ratio of 1000, we have respectively: the maximum current delivered by the vibrating structure, the threshold voltage of the MOSE and the vibration frequency of the structure are respectively: 1.2 10^4 A, Vt = 3.2 V and 957000 Hertz

1. Evolution of the Casimir interface as a function of time during two periods: PMN-PT

   For the F_{CO} / F_{CA} ratio = 10000 induces a period of 3.85 10^{-6} s and a rise time of 21.3 10^{-9} s with a deflection of the bridge of 105 A °. The structure vibrates at 259.7 kHz. (Figure 12).

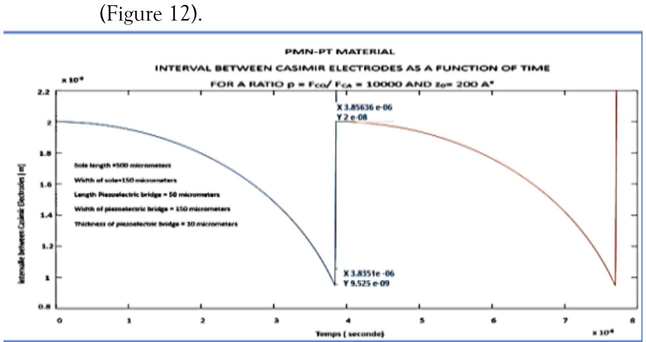


Figure 12) *Plot of the evolution of the Casimir inter-electrode interval as a function of time over two periods and an Fco/Fca Ratio = 10000: Casimir inter-electrode interface = 200 A°*

Due to inertia, at the rise sequence, the structure exceeds by 20 A° the initial 200 A° A ratio F_{CO}/F_{CA} = 1000 induces a period of 2.96 10^{-6} s and a rise time of 44.5 10^{-9} s with a deflection of the bridge of 50 A°. Due to inertia, the structure exceeds the initial 200 A° with 0.05 A°. The structure vibrates at 337.8 kHz: (Figure 13),

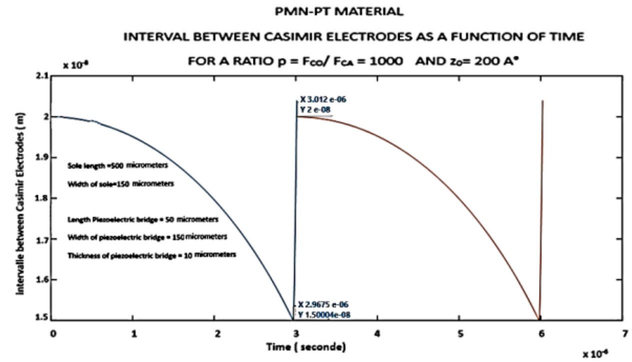


Figure 13) *Plot of the evolution of the Casimir inter-electrode interval as a function of time over two periods and an Fco/Fca Ratio = 1000: Casimir inter-electrode interface = 200 A°*

For the ratio F_{CO} /F_{CA} = 2 (Figure 12) a vibration amplitude of just 0.27 A° and a period of 1.86 10^{-7} s is obtained (Figure 14).

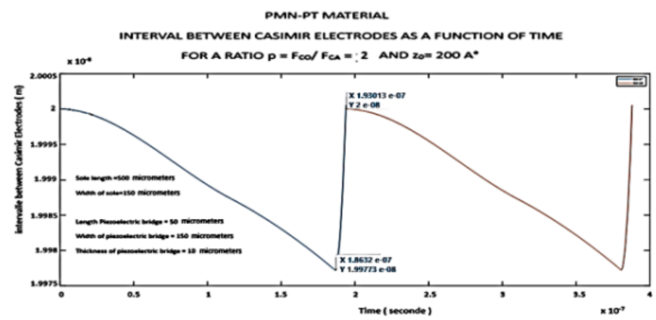


Figure 14) *Plot of the evolution of the Casimir inter-electrode interval as a function of time over two periods and a Ratio Fco /Fca =2. Casimir interelectrode interface = 200 A*

This low deformation of the PMN-PT piezoelectric bridge is mainly due to the extremely high piezoelectric coefficient d31 of 1450 (pC/N) of PMN-PT compared to 120 (pC/N) for PZT (Table 1). We observe the weak overshoot of the initial interface.

2. Evolution of the forces of Casimir and Coulomb: PMN-PT

   We obtain:

   The evolution of the Casimir and Coulomb forces as a function: a) of the inter-electrode interface (Figure 15) and b)over time (Figure 16)

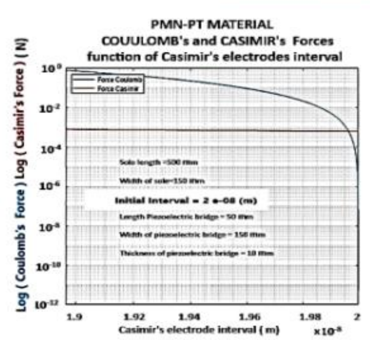


Figure 15) *Materials = PMNPT: Coulomb and Casimir force as a function of the inter-electrode interface*

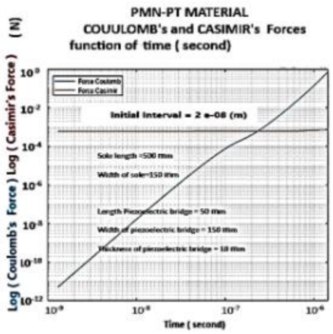


Figure 16) *Materials = PMNPT: Coulomb and Casimir force as a function of time. Start interface = 200A °*

The FCO / FCA ratio as a function of time for an entire period (Figure 17).

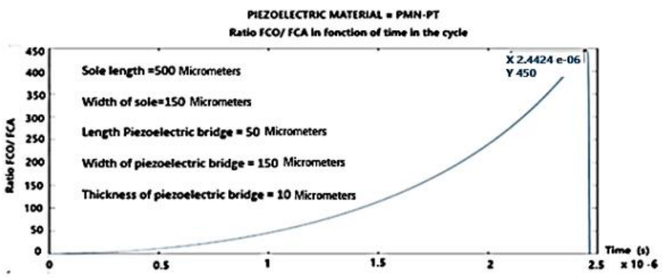


Figure 17) *Materials = PMNPT: Ratio p =* F_{CO} */* F_{CA} *as a function of time, during a period of vibration. Start interface = 200A°, Maximum ratio chosen = 450*

The break circuits n°1 triggering at time t =2.44 10^{-6}, suddenly induce a rise of the mobile electrode, therefore a sudden decrease in electric charges and grids voltages. We observe the gradual evolution towards the chosen ratio of 450 and then the sudden drop in this ratio as the electrodes regain their initial position (Figure 17).

3. Ratio F_{CO}/F_{CA} as a function of Casimir interval and current peak as a function of the ratio: PMN-PT

We observe (Figure 18) that for PMN-PT, a length of the piezoelectric bridge of 150 µm and a deformation of 10 A° of piezoelectric bridge, is sufficient to have a ratio = 1000.

On Figure 19, we see that a ratio of 2 gives a peak current of 7 10^{-7} A, while a ratio of 1000 produces a peak current of about 3.25 10^{-4} A, for the same time of homogenization of the charges of about 10^{-9} s.

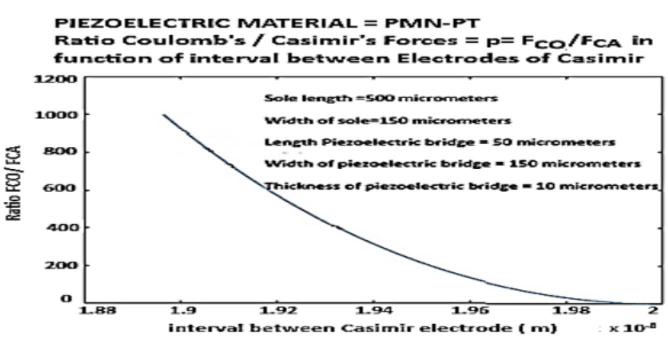


Figure 18) *Materials = PMN-PT: Coulomb Force / Casimir Force ratio as a function of the Casimir inter-electrode interface. Start interface = 200A°*

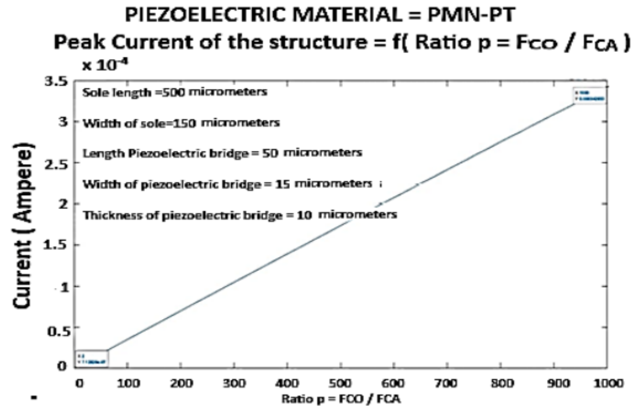


Figure 19) *Materials = PMN-PT: Peak Current delivered by the structure as a function of the Fco / Fca Ratio. Start interface = 200A°*

We see (Figure 20) that the Coulomb return force is less important for an initial interelectrode gap z_r = 400A° than for z_r = 200A°

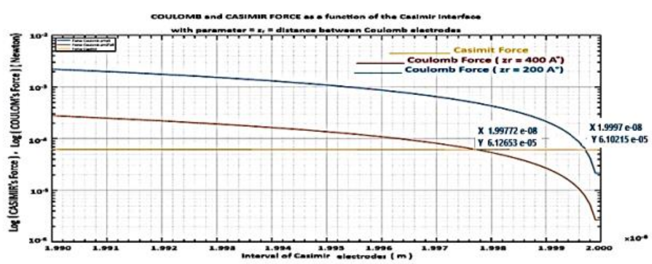


Figure 20) *Materials = PMN-PT: Coulomb force for* z_r *= 200 A° (Blue) and* z_r *= 400 A° (Red) and Casimir force (Yellow,* z_0 *=200 A°) as a function of the inter-electrode interface Starting interface = 200 A*

4. peak current as a function of time and peak voltage across the inductance for 2 periods: PMN-PT

The following figures illustrate the peak current generated by the automatic vibrating structure with an inserted magnification showing the shape of this peak as a function of time (Figure 21) and its exponentially decrease during about 10^{-9}s. This current of about 1.2 10^{-4} A flowing through an inductor LIN of 3 10^{-5} Henri naturally generates a voltage of 4 Volts (Figure 22)

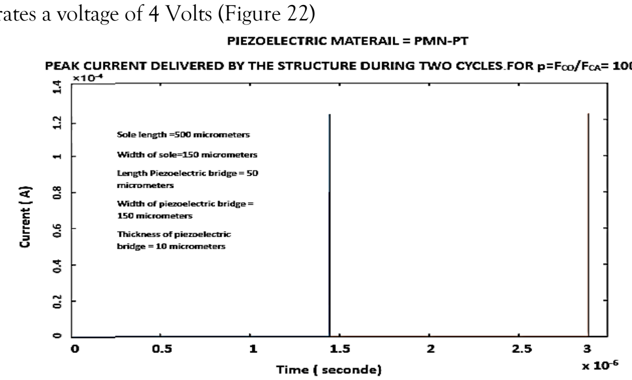


Figure 21) *Materials = PMN-PT: Current peak as a function of time obtained over 2 cycles. Starting interface = 200A ° Ratio p=Fco /Fca=1000*

Note the exponential form of the current peak in each period. As the current peak cross an inductor, it induces by itself a voltage peak

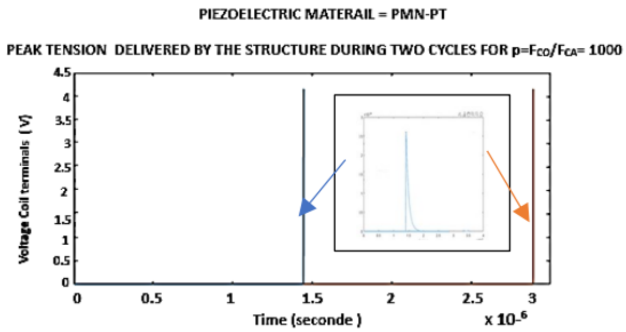


Figure 22) *Materials = PMN-PT: Voltage peak across the 4. 10^5 H solenoid as a function of the time obtained over 2 cycles. Starting interface = 200A °, Ratio p=Fco /Fca=1000*

5. peak voltage across the inductance and threshold voltage according to the desired.

It can be seen (Figure 23) that the automatic peak voltage obtained without any energy expenditure increases by a factor of 16 from 0.25 V to 4 V, when the ratio p = FCA / FCO changes from 2 to 1000. Similarly, the MOSE threshold voltage allowing these ratios increases from 0.2 V to 3.2 V (Figure 24).

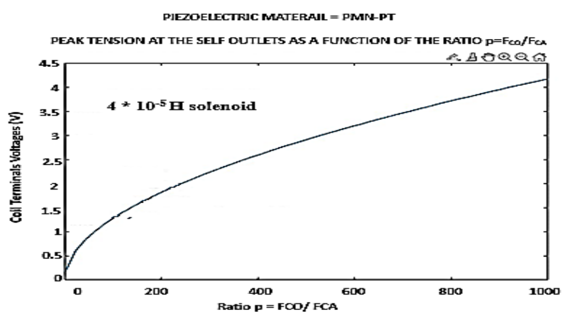


Figure 23) *Materials = PMN-PT: Voltage peak across the 4*10^5 H solenoid as a function of the F_{CO} /F_{CA} Ratio. Start interface = 200A °*

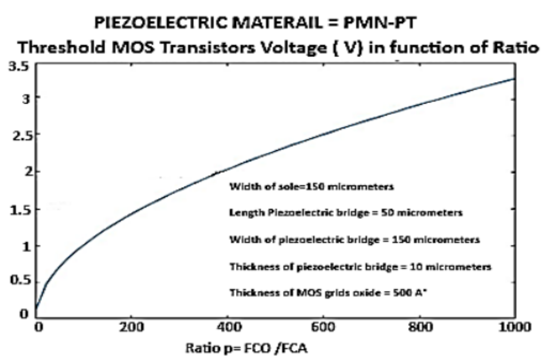


Figure 24) *Materials = PMN-PT: Threshold voltage of the Enriched or Depleted MOTS according to the F_{CO} / F_{CA} Ratio. Start interface = 200A°*

6. Vibration frequency as a function of the F_{CO} / F_{CA} ratio and peak current as a function of the initial Casimir interval chosen: PMN-PT

Note (Figure 25), that for an initial interface z_0 = 200 A°, and for a ratio F_{CO} / F_{CA} = 2, the vibration frequency of the structure is 3.50 MHz. It falls to 750 kHz for a ratio of 1000. These frequencies are still lower than the calculated first resonance of the structure, which is of the order of 7.94 Megahertz.

This vibration frequency of the Casimir structure approaches that of the first resonance for weaker interfaces below 200 A°. But we are then confronted with the technological possibility of controlling such a weak interface. For a ratio F_{CO}/F_{CA} = 500, the maximum current delivered by the structure falls as a function of an increase in the initial Casimir interval (Figure 26).

It seems that the piezoelectric material PMN-PT coupled with a conductor like aluminum is an interesting couple for our vacuum energy extraction structure.

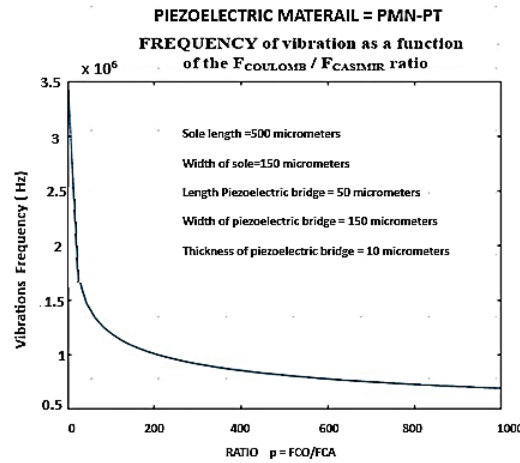


Figure 25) *Materials = PMN-PT: Vibration frequency as a function of the F_{CO} / F_{CA} Ratio. Start interface = 200A°*

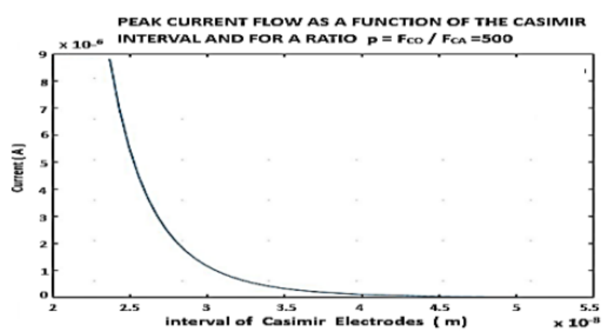


Figure 26) *Materials = PMN-PT: Current peak across the 2.10^4 H inductance as a function of the starting interval between Casimir electrodes*

ENERGY BALANCE

In this chapter we make an assessment of the energies that pass through this system. In particular we show that the CASIMIR force is blocked in its evolution towards a collapse of its two electrodes, by a COULOMB force. It is much more intense but lasts an extremely short time because it is cancelled very quickly. Let us recall that the voltage thresholds of the MOS are by technological design as:

$0 < VT_{ND} < VT_{NE}$, and $VT_{PE} < VT_{ND} < 0$

1. Note that the mobile parallelepipedic metal electrode remains parallel to the fixed metal electrode when it moves! It simply transmits its movement to a piezoelectric bridge which deforms by bending.
2. The expulsion of entropy ΔS from the vibrating electrode

of Casimir is transmitted to the piezoelectric bridge but causes an extremely small increase in its temperature ΔT. This one expels this heat to the outside.

Let's calculate an order of this calculated magnitude ΔT: Let's call ΔQ_{vib} the heat transmitted by the vibrations of the piezoelectric bridge. In first approximation, we can use the well-known formula $\Delta Q_{vib} = \Delta S.\Delta T$, with ΔS entropy variation (J °K^{-1}) and ΔT= temperature variation (° K)

However, we also know that [7]:

$$\Delta Q_{vib} = \frac{M_{Structure} \left(2 \pi f_{vib} \right)^2 z_e^{\,2}}{2} \tag{24}$$

With: f_{vib}= Vibration frequencies of the piezoelectric bridge, m = mass of this bridge, z_e = maximum deflection of the bridge.

This heat, expended at the level of the piezoelectric bridge, causes its temperature increase.

As a first approximation we can say: $\Delta Q_{vib} = m_{STRUCTURE}. C_{piezo}\ \Delta T$, with: C_{piezo} = Specific heat capacity of the piezoelectric bridge (J Kg^{-1} °K^{-1}), ΔT = Temperature variation (°K).

Consequently,

$$\Delta T = \frac{2 \left(\pi f_{vib} \right)^2 z_e^{\,2}}{C_{piezo}} \text{ = Temperature variation of the bridge} \tag{25}$$

For example, for a PMN-PT piezoelectric film: $C_{piezo} = C_{PMN\text{-}PT}$ = 310 (J Kg^{-1} °K^{-1}), $f_{vib} \cong 10^6$ Hz, $z_e = x_{max} \cong 100*10^{-10}$ m, we then obtain: $\Delta T \cong 10^{-3}$ °K which is negligible.

The expulsion of entropy from the vibrating Casimir Electrode is negligible.

So, the energy associated with the FCA force, is only used to deform the piezoelectric bridge with a WDEFCA energy and also create QF fixed charges in this structure. This energy is stored in the deformed bridge as a potential energy.

The fixed charges Q_F attract moving charges from the mass. When circuit 1 closed, the circuit 2 of switches MOSD is already opened (see Figure 6). The free charges Q_{mn}, stored on the metal electrodes of face 1, passing through one of the MOSE transistors, are uniformly distributed on the Coulomb metal electrode of the same surface S_{P1}.This metallic Coulomb's electrode therefore has approximately a mobile charge $\frac{Q_{mn}}{2}$.

The free charges Q_{mp}, which are stored on the other grids electrode (face 2), don't move. (Figure 5). So, grids electrode and return electrode have opposite free charge. A Coulomb's force then appears between these two electrodes during a very short time of the order of a few tens of nanoseconds (Figure 5, 12,13,14). The position ze of appearance of this force is such that F_{CO} =p F_{CA}, and is numerically calculated by MATLAB (Figure 10). So, this position ze depends of the values of the interface's z_o of Casimir's electrodes and of Coulomb's electrodes z_r We describe below the energy the cycle of the moving positions of the piezoelectric bridge.

From z_0 to z_e (going phase)

$0 < V_{GRIDS} < VT_{MOSD} < VT_{MOSE}$ or $VT_{MOS}E < VT_{MOSD} < V_{GRIDS} < 0$ and $F_{CO} / F_{CA} < p$

No moving electric charge appears on the return side of the Coulomb electrode which is connected to ground by switch 2, which is ON, and isolated from the piezoelectric bridge by switch 1, which is OFF. Therefore, there is any electricals charges on this return electrode and the Coulomb force does not exist! In a cycle from z_0 to z_e, thus, during the displacement " going " the energy $W_{CASIMIR}$ is used for 3 points:

1. the deformation of the piezoelectric bridge WDEFCA,
2. the apparition of electrics charges W_{bridge} in the of the piezoelectric bridge
3. for the energy E_{CA} of displacement of the force F_{CA}
4. for the creation of heat $\Delta Q_{vib/2}$:

<u>The deformation of the piezoelectric bridge is</u>

We know that the deformation energy of an elastic system is the energy that accumulates in the solid body during its elastic deformation. Yet, the deformation energy of the piezoelectric bridge is more important than the simple displacement energy of the F_{CA} force.

$$\int_{z_0}^{z_e} F_{CA}\, dz = E_{CA} = S \left(\frac{\pi^2 \hbar c}{740\, z_s^{\,3}} \right)$$

If we neglect the quantities of energy lost during the deformation ΔQ_{vib}, then a part of this work $W_{CASIMIR}$ is transformed partly into the elastic deformation energy of the body W_{DEFCA}.

Let us carry out a simplified calculation to obtain an order of magnitude of this deformation energy which is spent by the Casimir force in its path from z_o to z_e. Consider an intermediate state during a deformation and consider that the stress σz (N.m^{-2}) along the z-axis is constant during an elementary deformation d_z. The total elongation in the z-direction is: ε_z. dz, with ε_z the strain along the z axis.

If dV =dx.dy.dz is the elementary volume element then the elementary work dW_Z performed is:

$dW_Z = \sigma z.\ d\varepsilon_z$.(dx.dy.dz). Knowing that the material obeys Hooke's law with $\sigma z = E_p.\ \varepsilon z$, the total work W_{DEFCA} of the external forces becomes, with ε_{zm} the maximum deformation at the center of the bridge, E_p Young Modulus of bridge.

$$W_{DEFCA} = \int_0^{\varepsilon_{zm}} \left(\sigma_x d\varepsilon_x + \sigma_y d\varepsilon_y + \sigma_z d\varepsilon_z \right) dV \approx$$

$$V \int_0^{\varepsilon_{zm}} \left(\sigma_z d\varepsilon_z \right) dV \approx \int_0^{\varepsilon_{zm}} E_P\, \varepsilon_z\, d\varepsilon_z \approx V \frac{E_P\, \varepsilon_z^{\,2}}{2}$$

$$\text{with } V = l_P b_P a_P$$

with $V = l_p b_p a_p$

This is the approximate expression of the strain energy caused by the external force acting on this element of volume V. We have neglected the deformations and stresses along the x, and y axes.

We know that the maximum deflection of the piezoelectric bridge is Eq. (35).

$$z_e = \frac{F_{CA}\ l_P^{\,3}}{192\, E_P\, I_P} \text{ in } x = l_P/2$$

With I_p = bending moment of inertia along the z-axis of the section of this parallelepiped bridge which is:

$$I_P = \frac{b_P\ a_P^{\ 3}}{12} = \text{Cte}$$

Considering this arrow of the bridge subjected to a force F_{CA}, the deformation ε_z can be written in first approximation by:

$$\varepsilon_x = \frac{\Delta z}{a_P} = \frac{z_e}{a_P} \ \text{so in } x = \frac{l_P}{2} \Rightarrow \quad \varepsilon_x = \frac{F_{CA}\ \ l_p^{\ 3}}{192\ E_P\ I_P\ \ a_P}$$

So, the deformation energy can be written as:

$$W_{DEFCA} \approx l_P\ b_P\ a_P \frac{E_P}{2}\left[\frac{F_{CA}\ \ l_P^3}{192\ E_P\ \ I_P\ \ a_P}\right]^2 = \frac{F_{CA}^{\ 2}\ b_P\ l_P^{\ 7}}{73728\ a_P\ \ E_P\ I_P^{\ 2}} =$$

$$= \frac{l_s b_S b_p l_P^7}{73728\ a_P\ \ E_P\ I_P^{\ 2}}\left(\frac{\pi^2 \hbar\, c}{240\left(z_0 - z_e\right)^4}\right)^2 \qquad (26)$$

During the displacement " going " the energy $W_{CASIMIR}$ is used also to generates a potential energy W_{Bridge} accumulated in the capacity of this piezoelectric bridge which follows the equation: Eq. (27)

$$d\left(W_{BRIDGE}\right) = Q_F\, d\left(V_{PIEZO}\right) \Rightarrow W_{BRIDGE} = \int_0^{Q_e} \frac{Q_F}{C_{PIEZO}} \mathrm{d}Q_F = \left[\frac{Q_F^{\ 2}}{2\,C_{PIEZO}}\right]_0^{Q_e} =$$

$$= \frac{a_P}{2\, l_P\, b_p\, \varepsilon_0\, \varepsilon_{PIEZO}}\left(\frac{d_{31} l_p}{2\, a_P}\right)^2 F_{CA}^{\ 2} = \frac{a_P}{2\, l_P\, b_p\, \varepsilon_0\, \varepsilon_{PIEZO}}\left(\frac{d_{31}\ l_p\ l_s b_S\ \pi^2 \hbar\, c}{480\, a_P}\right)^2 \left(\frac{1}{z_e}\right)^2$$

In this equation, we have $d(QF) = C_{pi}\ d(V_{pi})$, where C_{pi} = electrical capacity, $C_{PIEZO} = \varepsilon_0\, \varepsilon_{PIEZO} \dfrac{l_P\, b_P}{a_P}$ and V_{pi} the voltage across the piezoelectric bridge , z_e the position of the very brief appearance of the Coulomb force, ε_{pi} the piezoelectric relative permittivity, l_p ,b_p, a_p the length, width, and thickness of the bridge. With QF the naturally creating fixed charges on this piezoelectric structure.

$Q_F = \dfrac{d_{31}\ F_{CA}\, l_P}{a_P}$ Eq. (3), and $Q_e = -Q_F$ = the accumulated mobile charges, coming from the mass, on the surface of the "return" electrode when coulomb's force is triggered.

So, during the phase "going" from z_0 to z_e the total energy E_{going} = $W_{CASIMIR}$ is use to deform the piezoelectric bridge and to produce the electrical charges as potential energy use during the return phase.

This part W_{bridge} of $W_{CASIMIR}$ is stored in the piezoelectric bridge and is the usable energy $W_{electric}$ appearing during a cycle.

$W_{electric}$ is not due to any electrical energy applied, but produced by the potential energy W_{bridge} accumulated in the piezoelectric bridge.

We have: $E_{going} = W_{CASIMIR} = W_{DEFCA} + \Delta Q_{vib}/2 + W_{bridge}$

Since the elasticity conditions of the deformed piezoelectric bridge obviously apply, and we are not entering the plasticity domain, W and B are potential energies that will be used when the bridge returns to its equilibrium position, i.e., without deformation.

From z_e to z_0 (returning phase)

Two phases: from 1: z_e to z_0 and from 2: z_e to z_0.

We note z_c the bridge position where switch 2 switches back to ON and therefore to ground, thus cancelling the Coulomb force.

First return phase From z_e to z_C

As F_{CO}/F_{CA} £ p then $0 < VT_{PD} < V_{GRIDS}$ £ VT_{NE} or $< VT_{PE}$ £ V_{GRIDS} < $VT_{ND} < 0$

The sudden and ephemeral appearance of this Coulomb force is due to the fact that circuit 1, returning very quickly to the OFF state, disconnects the Coulomb electrode from the piezoelectric bridge. Shortly afterwards, circuit 2 switches back to the ON state, bringing the Coulomb electrode to ground! (See Figure 6). This cancels the F_{CO} force.

The have already predetermined the position ze of appearance of this force such that F_{CO}= p F_{CA}. Note that it's extremely small value, since it goes from 1 A° for an F_{CO}/F_{CA} ratio = 2 to 10 A° for a ratio of 1000. (Eq 11 Figure 10).

When the equilibrium position z_e is reached, the mobile's electrical charges are:

1. on the isolated Coulomb's electrode, the charge is constant (circuit 1 is closed and circuit 2 is opened).

$$Q_{mn} = \frac{1}{2}\left(\frac{S_S\ \pi^2 \hbar\ c\ \ d_{31}\ l_P}{240\ a_P\ \ z_e^{\ 4}}\right)$$ (28) because the area of Coulomb's electrode ≅ area of bridge

2. on the moving piezoelectric electrode connected to the transistor gates, the charge Q_{mp} is time-dependent, as it depends on the bridge position over time.

$$Q_{mp} == \frac{d_{31}\ l_P}{a_P}\left(F_{CO} - F_{CA}\right)$$

$$Q_{mp} = \frac{d_{31}\, l_P}{a_P}\left\{Q_{mp}\ Q_{mn}\left(\frac{1}{4\,\pi\,\varepsilon_0\,\varepsilon_r}\right)\left(\frac{1}{z_r + z_0 - z_s}\right)^2 - S_S \frac{\pi^2 \hbar\, c}{240}\left(\frac{1}{z_S^{\ 4}} - \frac{1}{z_0^{\ 4}}\right)\right\}$$

So the Eq. (29):

$$Q_{mp} = \left\{\frac{d_{31}\, l_P}{a_P}\, Q_{mn}\left(\frac{1}{4\,\pi\,\varepsilon_0\,\varepsilon_r}\right)\left(\frac{1}{z_r + z_0 - z_s}\right)^2 - 1\right\} = S_S \frac{\pi^2 \hbar\, c}{240}\frac{d_{31}\, l_P}{a_P}\left(\frac{1}{z_S^{\ 4}} - \frac{1}{z_0^{\ 4}}\right)$$

⇒

$$Q_{mp} = \frac{S_S \dfrac{\pi^2 \hbar\, c}{240} \dfrac{d_{31}\, l_P}{a_P}\left(\dfrac{1}{z_S^{\ 4}} - \dfrac{1}{z_0^{\ 4}}\right)}{\left\{\dfrac{d_{31}\, l_P}{a_P}\, Q_{mn}\left(\dfrac{1}{4\,\pi\,\varepsilon_0\,\varepsilon_r}\right)\left(\dfrac{1}{z_r + z_0 - z_s}\right)^2 - 1\right\}}$$

Now the Coulomb force becomes

$$F_{CO} = Q_{mp}\, Q_{mn}\left(\frac{1}{4\pi\,\varepsilon_0\ \ \varepsilon_r}\right)\left(\frac{1}{z_r + z_0 - z_s}\right)^2$$

We observe that Q_{mp} therefore F_{CO} disappear when $z_s = z_0$, but remember that this force only exists and follows this law for the short time during which switch 2 is not closed to ground. After this time, i.e., when zs = zc, the charge on the Coulomb electrode is zero, so the Coulomb force disappears.

The energy associated with the displacements of these forces therefore takes into account that relating to the movement of the Coulomb force F_{CO} from ze to zc (where it cancels out) and that of the displacement of the Casimir force F_{CA} from z_e to z_0.

During the return phase, therefore, we have the energy induced by F_{CA}

$$\int_{z_e}^{z_0} F_{CA}\ \mathrm{d}z = E_{CA} = S_S\left(\frac{\pi^2 \hbar\ c}{740\ z_s^{\ 3}}\right)$$ and the Coulomb's energy

$$W_{Coulomb} = \int_{Z_e}^{Z_c} F_{CO}\, dz_S$$

As we have seen above, during this homogenization of the mobile charges, a current and voltage peak appears for a short time. The expression of this current peak related to the homogenization of charges is Eq 9. $I_{IN} = -\frac{Q_{mn1}}{R_m C_S} Exp\left(-\frac{t}{R_m C_S}\right)$ with Q_{mn} the preceding expression (Eq 28) of the electric charges

These cyclic current peaks induce at the terminals of the inductance L_{IN} a voltage peaks whose expression is:

$$U_{IN} = L_{IN}\frac{d(I_{IN})}{dt} = -L_{IN}\frac{Q_{mn1}}{(R_m C_S)^2}Exp\left(-\frac{t}{R_m C_s}\right) =$$

$$= -L_{IN}\frac{Q_{mn1}\, Ln(2)^2}{t_e^{\,2}}\; Exp\left(-\frac{t\, Ln(2)}{t_e}\right) \qquad (30)$$

During one cycle, the only energy which is effectively used outside is associated with these power U_{IN} I_{IN} peaks and becomes:

$$W_{ELECTRIC} = ABS\left(\int_0^{t_e} I_{IN} U_{IN}\, dt\right) = \frac{L_{IN}}{2}\left(\frac{d_{31} F_{CA}\, l_P\, Ln(2)}{a_P\, t_e}\right)^2 \{1 - exp(-2Ln(2))\} \quad (31)$$

From z_c to z_0 $0 < V_{GRIDS} \leq VT_{PD} < VT_{NE}$ or $VT_{PE} < VT_{ND} \leq V_{GRIDS} < 0$

When the piezoelectric bridge reaches the z_c position, circuit 2 switches ON, which connects the Coulomb electrodes to ground, so $F_{CO} = 0$. Only the Casimir force F_{CA} remains.

But during the previous phase, the whole mass structure $M_{structure}$, has acquired a speed $V_{structure}$.

This speed gives to it a kinetic energy $W_{CIN} = ½\, M_{structure}\, V^2_{structure}$, so an inertia which must be spent until the stop of the structure only submit to the force F_{CA}. This kinetic inertia induces, for the bridge, a position which can slightly exceed the starting position z_0 because of the inertia.

We have $W_{COULOMB} + W_{CIN} + E_{CA} = W_{DEFCA}$ and:
$W_{Returning} = W_{coulomb} + W_{CIN} + E_{CA} + W_{electric} + DQ_{vib}/2 = W_{DEFCA} + W_{electric} + DQ_{vib}/2$

Recall that: $W_{bridge} = W_{electric}$ and $E_{going} = W_{CASIMIR} = W_{DEFCA} + W_{bridge} + DQ_{vib}/2$

Thus, we see that in the balance $E_{going} - W_{Returning} = W_{CASIMIR} - W_{CASIMIR} = 0$

The energy expended by the Coulomb force F_{CO} remains weaker than the Casimir energy. This Casimir energy consumed by the deformation of the piezoelectric bridge and the creation of the electrics charges is partly restored in the form of usable electrical energy.

So, the energy $W_{CASIMIR}$ is conservated over a complete cycle. We do not create a new energy because the Casimir force is conservative!

Simply, the energy of Casimir is used in a different way. The ubiquitous Casimir force not only moves in a translation but more importantly deforms a piezoelectric bridge. It induces naturally a large opposing Coulomb force but of very short duration which remains of low ENERGY but of high POWER. The energy balance of a cycle therefore seems to satisfy Emmy NOTHER's theorem but it seems that we can recuperate and use a small electrical energy $W_{electric}$.

Some important remarks

In fact, energy expended by the Coulomb force is lower than that calculated by the previous expression (Eq 29). Indeed, this $W_{Coulomb}$ energy is maximized for at least three reasons because:

1. The previous formula 29 presupposes that all the points along the length of the piezoelectric bridge move on a distance z_0-z_e, so from a position of $z = z_r + z_0 - z_e$ to $z = z_r$. This consideration is wrong because the bridge is recessed at both ends.

The ends of this bridge do not move at all, only the points in $x=l_p/2$ move on a distance z_0-z_e and those between the ends of bridge and the middle move on a distance shorter than z_0-z_e!

In fact (Appendix and Figure 27), for a bridge recessed in its two extremities and subjected to a force F_{CA} in its middle, we know that the form z(x) of this bridge follows the law for $0 \leq x \leq lp/2$ (Appendix X Eq 36 and Figure 27)

$$z = \frac{F_{CA}\, x^2 \left(l_P - \frac{4x}{3}\right)}{16\, E_P\, I_P}$$

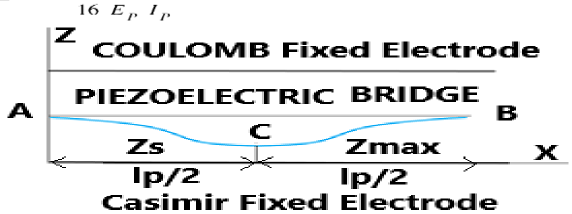


Figure 27) *Bridge follows the law*

The maximum $z_{max} = z_e$ is in $x= l_P/2$ and is $z_{max} = \frac{F_{CA}\, l_P^{\,3}}{192\, E_P I_P}$ Eq 35

So, the calculation in equation 23 assuming that the piezoelectric bridge is completely free to move parallel to the Coulomb electrode is wrong and maximize the energy $E_{COULOMB}$.

2. Piezoelectric grid electrode and Coulomb electrode are not parallel. So, the Coulomb forces which appears at each point depend on the longitudinal position considered along the bridge and is of the form $F_{CO}(x,z)$ and $F_{CA}(x,z)$!

3. We did not take into account these first two reasons because the fact that the Coulomb force was of greater intensity than the Casimir force but especially of a very short duration, was preponderant.

This duration depends on the stiffness and speed of the switching of the MOS transistors in depletion and enriched! An estimate of this duration is not simple because it depends on the technology used to produce these electronic components but this time should be on the order of some nanoseconds.

As the Coulombs force FCO only exists for a very short time, its power can be significant, but its energy remains low and does not exceed that of Casimir (following Figure 28).

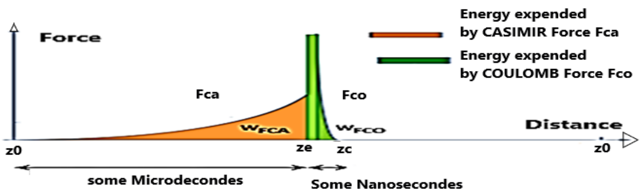


Figure 28) *Energy remains low*

For these 3 reasons, the energy expended by the Coulomb force is lower than the simple equation 25 suggests and lower than the Casimir energy which induced it! There is of course conservation of energy

Note that the $W_{Coulomb}$ approximative expression of equation 25 depends on the term z_r and decreases according to an increase in z_r with a power of z_r^{-5}! We can therefore adapt the interval z_r to minimize the energy $E_{Coulomb}$!

For example, we obtain at each vibration, for an interface z_0 = 200 A, z_r= z_o =200 A°, dimensions of the Casimir electrodes (length = 500 µm, width = 15 µm, thickness = 10 µm), dimensions of the piezoelectric bridge in PMN -PT (length = 50 µm, width = 15 µm, thickness = 10 µm), a proportionality factor p = F_{CO} / F_{CA} = 1000, an inductance L_{IN} = 1.10^{-6} H:

1. ze = 9.46 10^{-09} (m) i.e., a displacement of the mobile Casimir electrode of about 105A° (Figure 10)
2. $E_{CASIMIR} = \int_{z_0}^{z_e} F_{CA}\, dz$ = 3.4 10^{-11} (Joule) = Energy of vacuum = Energy dispensed by the force of Casimir just free *to move* from z_0 to z_e
3. W_{DEFCA}= 5.25 10^{-11}(Joule) = deformation energy of the piezoelectric bridge, embedded at both ends, to obtain a deflection of z_e at its center = energy produced by the Casimir force to deform the bridge and to give it this deflection z_e. This energy is greater than $E_{CASIMIR}$: $W_{DEFCA} > E_{CASIMIR}$
4. Peak current = 120 10^{-6} A (figure 21)
5. Voltage peak across the inductance = 0.1V (Fig 22).
6. Structure vibration frequency = 750 kHz
7. Threshold Voltage of enriched MOSE = 3.25 V (Fig 24)
8. W_{bridge} = 2.7 10^{-11} the potential energy accumulated in the piezoelectric bridge
9. $W_{electric}$ = 2.7 10^{-11} (Joule) = Usable energy associated with current and voltage peaks.
10. $W_{CASIMIR} \cong W_{bridge} + W_{DEFCA}$ = 7.95 10^{-11} (Joule)
11. Approximative duration of one peak, $t_{peak} \cong 10^{-9}$ s
12. Power of one peak = $W_{electric} / t_{peak} \cong 2.7\ 10^{-2}$ (Watt). We notice that this $W_{electric}$ usable energy and the W_{bridge} energy are lower than the Casimir energy. This usable energy is not brought by an external source but is caused by the deformation of the piezoelectric bridge caused by the omnipresent and perpetual Casimir force, itself controlled by a Coulomb force of opposite direction.
13. ΔQvib = heat transmitted by the vibrations of the piezoelectric bridge =7.8 10^{-14}J is very small and negligible.
14. We notice that $\Delta Q_{vib} + W_{electric} < W_{Casimir}$ which is consistent with Noether's theorem!
15. $W_{coulomb} + W_{CIN} = W_{CASIMIR} - (\Delta Q_{vib} + W_{electric})$= 7.95 10^{-11}- (7.8 10^{-14}+ 2.7 10^{-11}) =5.24$10^{-11}$ J

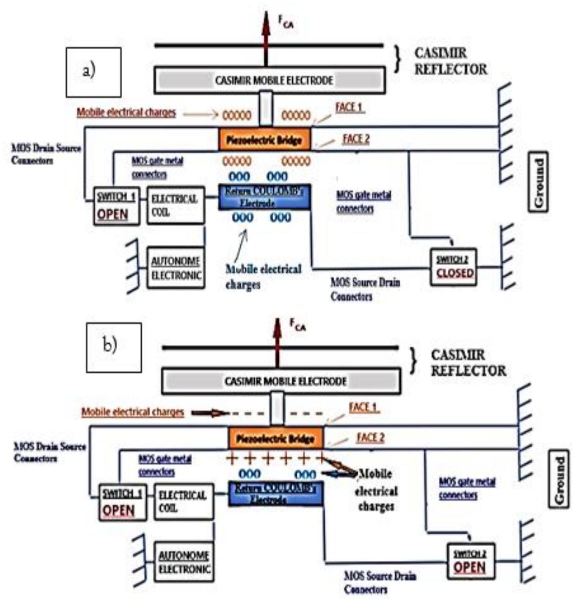
Simple remark and resume

Remember that energy is defined as the "physical quantity that is conserved during any transformation of an isolated system".

However, the system constituted by simply the MEMS device in space is not an isolated system while the system constituted by the MEMS device plus the space plus the energy vacuum seems an isolated system.

The part of the MEMS energy sensor vibrates continuously at frequencies depending of the size of the structure and operating conditions, but with an amplitude of just a few tens of Angstroms.

These vibrations should not be confused with an impossible perpetual motion, as the system can be continuously powered by the vacuum energy responsible for the Casimir force (Figure 29).



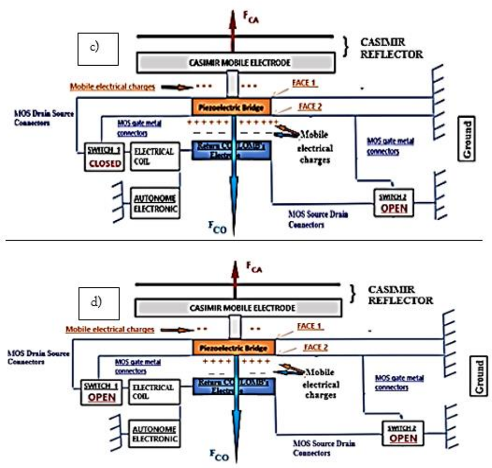


Figure 29) *Initial Intermediate Situation a) "going positions": initial Position Circuit 1 OFF, Circuit 2 ON b) "going positions": Intermediate position Circuit 1 OFF, Circuit 2 OFF c) switching_position Circuit 1 ON Circuit 2 OFF d) Returning positions": Before the moving structure reaches the position z_c: Circuit 1 OFF, Circuit 2*

Electronic transformation and amplification without external power supply of a periodic signal of a few millivolts into a dc voltage of a few volts

U_{IN} . I_{IN} power peaks lasting a few nanoseconds are present at the input of an electronic circuit without any power supply. This electronic gave encouraging simulations with a simulator SPICE. It delivers at its output an exploitable direct voltage even if it has in its input an alternating and signal of some millivolts!

The principle used to amplify and transform a weak signal without power supply derives from that of the diode bridge rectifier of Graetz or the doubler of Schenkel and Marius Latour.

The problem is that the diodes of these rectifiers are conductive only with a minimum voltage of around 0.6 V at their terminals. As the alternating signal from the vacuum energy extraction device can be weaker, it is necessary to have switches that are triggered with a lower control voltage. The principal diagram of this electronics is presented in Figure 30.

In SPICE simulations, the transformer of vacuum energy describe above was assimilated to a micro transformer delivering a power U_{IN} . I_{IN} limited to a few nW

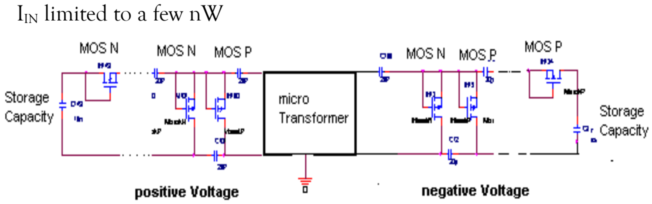


Figure 30) *Principle of the one stage of the doubler without any power supply electrical diagram*

The MOSE N and P transistors of this rectifier circuit must have a technologically defined threshold voltage as close as possible to zero. The precision of nullity of these threshold voltages will depend on the values of alternating voltages at the terminals of the inductor L_{IN}.

In the circuit of Figure 30, a micro transformer replaced the inductance L_{IN}. But this inductance plays the same role as this micro transformer since it delivers a limited power U_{IN}. I_{IN}.

The circuit is composed of several stages, without any power supply, which rectify and amplify, on the one hand the negative parts of the weak input signal and on the other hand the positive parts.

The number of elementary stages depends on the desired DC voltage, but this DC voltage saturates with the number of stages in series (Figure 31, 32). The results obtained from SPICE simulation are shown in Figure 31.

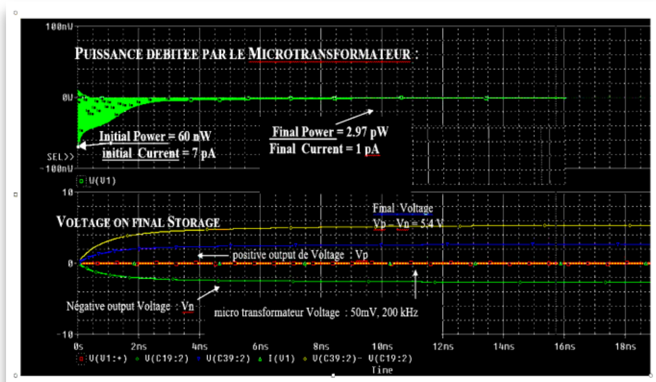


Figure 31) *SPICE simulations of voltages, current, power of the transformation electronics into a direct voltage (5.4 V) of an alternating input signal of 50 mV, frequency= 150kHz, Number of stages=14, Coupling capacities = 20 pF, stocking capacity = 10 nF*

Important points are the very low power and current consumption on the source since:

In figure 30 the power delivered by the source begin at the start with 60 nW and ends at 2.97 pW for an input current starting at 7 pA and finishing at 1pA. The component of the alternating signal 50 mv and 200 kHz is transformed in 10 ns into a negative direct voltage of V_n = -2.7 V. Likewise the component the positive alternating part is transformed into a positive direct voltage of V_p = + 2.7 V. We obtain therefore a direct voltage Vp -Vn = Vt = 5.4 V.

We need to have a high circuit output impedance of several Mega-ohms, so typically the input impedance of an operational amplifier.

The DC voltage obtained depends on the number of stages constituting these electronics without electrical power for transforming an AC signal of a few millivolts into a DC signal of a few volts. However, this transformation saturates with the number of floors, as shown in figure 32.

Note in Figures 32 and 33 that the DC output voltage saturates with the number of elementary stages. The optimal number of stages is of the order of 40 for an input signal of 100 mV and 20 mV. We note that this amplification saturates with a coupling capacity of 20 pF for an input signal of 10 mV and a storage capacity of 10 nF.

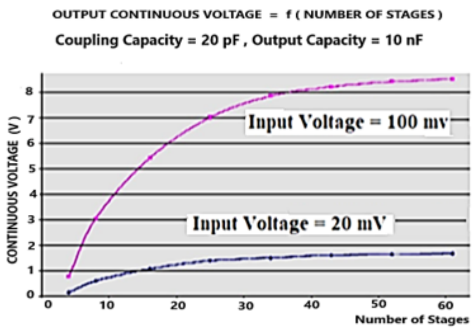


Figure 32) *DC output voltages as a function of the number of elementary stages for AC input voltages of 20 mV and the other of 100 mV, Start interface = 200A °*

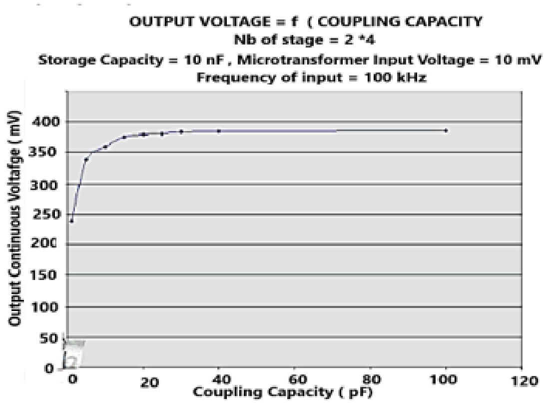


Figure 33) *Influence of the coupling capacitance on the amplification of the input signal. Start interface = 200A °*

A summary of the performance of this low "voltage doubler" device is shown in Figure 34 below

CHARACTERISTICS OF OUTPUT VOLTAGES (V), POWERS (nW) CURRENTS (nA)
AS A FUNCTION OF THE NUMBER OF STAGES
INPUT SIGNAL FREQUENCY = 150 kHz OUTPUT VOLTAGE MEASUREMENT FOR t = 50 ms

	Vg=50mV					Vg=100mV				
number of stages	Output Voltage	Current (nA) start	Current (nA) end	Power (nW) start	Power (nW) end	Output Voltage	Current (nA) start	Current (nA) end	Power (nW) start	Power (nW) end
2*3	550mV	300nA	26nA	15nW	1.3nW	1.1v	800nA	46nA	75nW	5nW
2*6	1	300nA	29nA	13nW	13nW	2V	700nA	67nA	60nW	6.5nW
2*14	2.2v	300nA	40nA	14nW	2.6nW	4,5v	700nA	50nA	65nW	4.8nW
2*21	2.8v	250nA	38nA	13nW	860pw	6v	600nA	80nA	60nW	2.7nW
2*30	3.3	250nA	43nA	12nW	12nW	6.5V	750nA	85nA	61nW	4nW
2*39	3.5v	250nA	45nA	12nW	900pW	7.5V	750nA	95nA	64nW	3.5nW
2*48	3.6v	250nA	46nA	12nW	1nW	7.6V	750nA	100nA	60nW	4.2nW
2*60	3.8	270nA	47nA	12nW	1.1nW	7.9V	700nA	90nA	65nW	4.2nW
2*61	3.8	270nA	48nA	12.1nW	1.3nW	8V	700nA	90nA	65nW	42nW

Figure 34) *Summary of transformations from low alternating voltages to direct voltage frequency of 150 kHz. Start interface = 200A °*

The interesting points for the presented electronics' device are:

1. the low alternative input voltages required to obtain a continuous voltage of several volts at the output
2. the low power and current consumed by this conversion and amplification circuit on the source which in this case is only an inductor supplied by the current peaks generated by the autonomous vibrations.
3. the rapid time to reach the DC voltage (a few tens of milliseconds)

The technology used to fabricate the MOSNE and MOSPE transistors with the lowest possible threshold voltages, is CMOS on intrinsic S.O.I. The elements are isolated from each other on independent islands. This technology, represented in the following Figure 35, strongly limits the leakage currents.

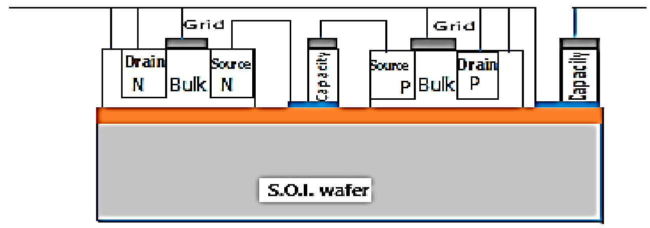


Figure 35) *S.O.I technology for making the elements of the "doubler"*

In order to minimize the size of the coupling capacitor we propose the use of titanium dioxide as insulator. His relative permittivity of the order of 100, then the size of the capacity is about 25 µm for a thickness of TiO2 = 500 A °.

Technology of realization of the current extractor device using the forces of casimir in a vacuum

For the structures presented above, the space between the two surfaces of the reflectors must be of the order of 200 A °, ... which is not technologically feasible by engraving [8,9].

Yet it seems possible, to be able to obtain this parallel space of the order of 200 A ° between Casimir reflectors, not by etching layers but by making them thermally grow!

Indeed, the SS3 and SS2 surfaces of the Casimir reflector must;

1. be metallic to conduct the mobile charges
2. insulating as stipulated by the expression of Casimir's law who established for surfaces without charges!
3. This should be possible if we grow an insulator, for example Al2O3 on Alluvium film which is previously deposited. According to S.M. Sze ref, the fraction of oxide thickness "below" the initial surface is in the ratio between the molar masses of the oyde thermally formed from the oxidizable (Figure 36) [10].

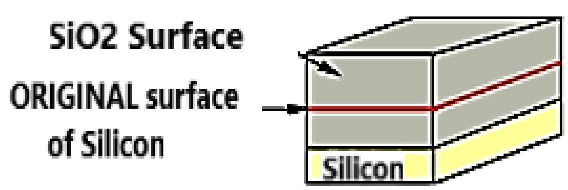


Figure 36) *Growth of SiO2 oxide on silicon*

The molecular masses of Alumina and aluminium are MAl2O3 = 102 g/mole and MAl = 27 g/mole. We obtain an aluminium attack ratio of 27/102 = 26%, which implies that the original surface of this metal has shifted by 26% so that 74% of the alumina has grown out of the initial surface of the aluminium

Regarding the technological manufacture of electronics and structure, it therefore seems preferable:

1. For electronics to choose Titanium Oxide because of its high relative permittivity εr =114 allowing to minimize the geometries required for the different capacities
2. For the Casimir structure, the choice of aluminium, because its low density increases the resonant frequency of the structure and that 74% of the Alumina Al2O3 is outside the metal, allowing to reduce the interface between Casimir electrodes.

A simple calculation shows for example that for aluminium gives: Figure 37

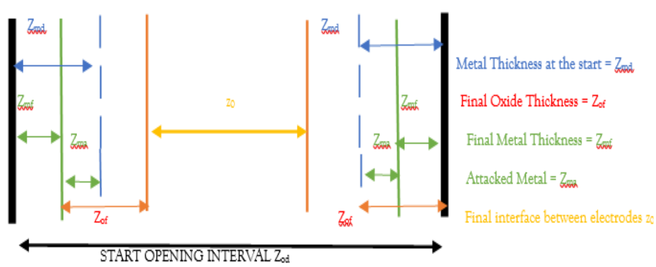


Figure 37) *Distribution of thicknesses*

$$z_{od} = 2\left(z_{md} + z_{of} - z_{ma}\right) + z_0 = 2\left(z_{md} + z_{of} \cdot (1-0.26)\right) + z_0$$

$$\Rightarrow z = z_{od} - 2\left(z_{md} + 0.74\, z_{of}\right)$$

For example, we start from an opening z_{od} = 3 µm. We deposit a metal layer of aluminium that is etched leaving a width z_{md} = 1 µm on each side of the reflector. It is then possible to grow an Al2O3 alumina whose thickness is precisely adjusted, simply by considerations of time, temperature and pressure, in order to adjust the thickness necessary to obtain the desired interface z_0!

For example, if z_0 = 200A °, z_{od} = 3 µm, z_{md} = 1 µm, then z_{of} = 0.662 µm. So, we obtain a Casimir interface of 200 A°. The final remaining metal thickness will be z_{mf} = 0.338 µm and will act as a conductor under the aluminium oxide.

Obviously, the growth of this metal oxide between the electrodes of the Casimir reflector modifies the composition of the dielectric present between these electrodes, therefore of the mean relative permittivity of the dielectric.

The average permittivity e_{0m} of the dielectric is:

$$\varepsilon_{om} = \frac{z_{qf}\ \varepsilon_0\ \varepsilon_r + z_0 \varepsilon_0 + z_{qf}\ \varepsilon_0\ \varepsilon r}{\left(2 z_{qf} + z_0\right)} = \varepsilon_0 \frac{2 z_{qf}\ \varepsilon_r + z_0 \varepsilon_0 + z_0}{\left(2 z_{qf} + z_0\right)} \approx \varepsilon_0\ \varepsilon_r\ if\ z_0 << z_r\ (\varepsilon_r = \text{relative permittivity})$$

z_0 is << z_{of} (ε_r = relative permittivity)

Steps for the realization of the structure and its electronics

We use an SOI wafer with an intrinsic silicon layer: The realisation start with voltage "doubler" is obtained by using CMOS technology with 8 ion implantations on an SOI wafer to make:

1. The sources, drains_of the MOSNE, MOSND of the "doubler" and of the Coulomb force trigger circuits and of the grounding.
2. The source, drains of the MOSPE, MOSPD of the "doubler" and of the Coulomb force trigger circuits.
3. The best adjusts the zero-threshold voltage of the MOSNE of the "doubler" circuit.
4. The best adjusts the zero-threshold voltage of the MOSPE of the "doubler" circuit.
5. To define the threshold voltage of the MOSNE of the circuit n°1.
6. To define the threshold voltage of the MOSPE of the circuit n°1
7. To define the threshold voltage of the MOSND of the circuit n°2
8. to define the MOSPD threshold voltage of the circuit n°2.

This electronic done, we take care of the vibrating structure of CASIMIR

9. engrave the S.O.I. silicon to the oxide to define the location of the Casimir structures (Figure 38)

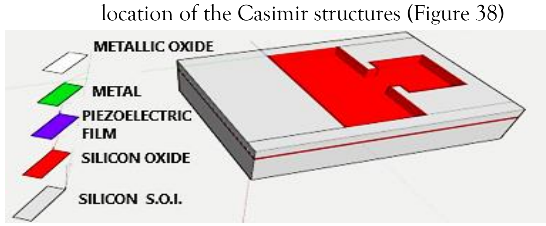


Figure 38) *Etching of S.O.I silicon*

10. Place and engrave a protective metal film on the rear faces of the S.O.I wafer (Figure 39)

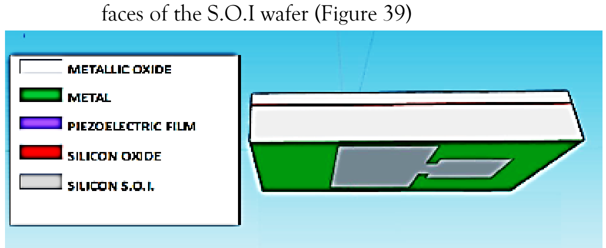


Figure 39) *Engraving of the protective metal rear face of the S.O.I. silicon*

11. Deposit and engrave the piezoelectric layer (Figure 40)

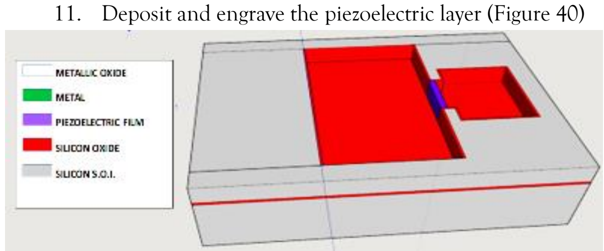


Figure 40) *Deposition and etching of the piezoelectric layer e 61 deposition and etching of the piezoelectric layer.*

12. Depose and etch the metal layer of aluminium (Figure 41).

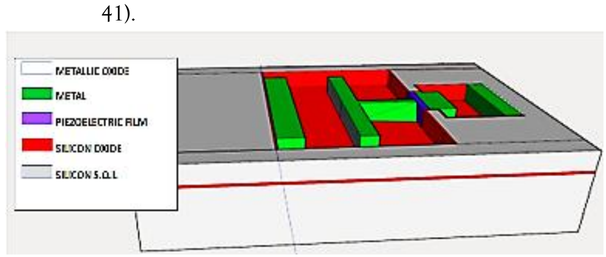


Figure 41) *Metal deposit, Metal engraving etching of the piezoelectric layer.*

13. Plasma etching on the rear side the silicon of the Bulk and the oxide of the S.O.I wafer protected by the metal film to free the Casimir structure then very finely clean both sides (Figure 42)

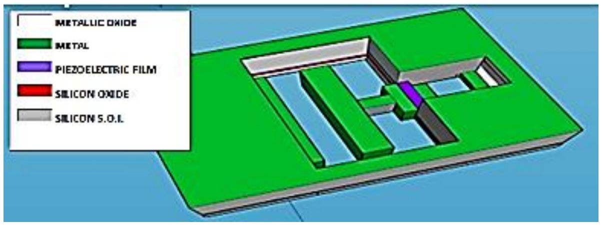


Figure 42) *View of the Casimir device on the rear face, engraving on the rear face of the structures.*

14. Place the structure in a hermetic integrated circuit support box and carry out all the bonding necessary for the structure to function.

15. Carry out the thermal growth of aluminium oxide Al_2O_3 with a measurement and control of the circuit under a box. The electronic circuit should generate a signal when the interface between the Casimir electrodes becomes weak enough for the device to vibrate and then stop the oxidation. (Figure 43)

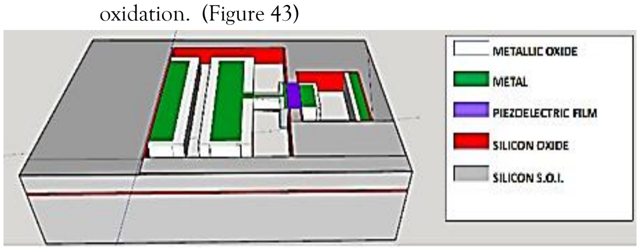


Figure 43) *Adjusted growth of metal oxide under the electronic control, front view of the Casimir device.*

16. Create a vacuum in the hermetic box. In the case where the 2 metal electrodes of Casimir, adhere to one another, they can be separated by the application of an electrical voltage on the Coulomb's electrodes.

CONCLUSIONS

According to this study, it would seem we can extract energy from the vacuum by the use of the Casimir force thwarted at the appropriate time by a temporary Coulomb force which makes the system enter into vibrations the structure.

I am fully aware that this concept may sound like incredible, but it does not seem to contradict thermodynamics' law nor Emmy Noether's theorem and, mathematical calculations and simulations give encouraging results. This vibration seems to be of the same type as a stupid and illusory perpetual motion but the difference is that an energy is constantly brought to the vibrating system: that of the quantum vacuum.

This preliminary work seems to merit further study of this concept and the fabrication of a prototype would be the last judge!

The dreamer would be happy to participate in this dream of a new source of energy.

APPENDIX

A Few Reminders from RDM

<u>Calculation of the deflection of a bridge recessed at its 2 ends</u>

Note: We take the case of pure bending, the shear force T is such that With M the bending moment applied to the piezoelectric bridge. The Casimir force in the z axis is applied in lp /2 at the centre of the bridge. (Figure 44)

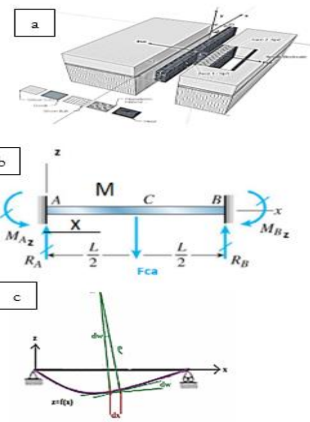


Figure 44) *general appearance a) b) of the device studied, forces and applied moments, c) of the deformed bridge*

As stated in all RDM books, the equation of the distorted mean line is:

$$\frac{d^2(f(x))}{dx^2} = -\frac{M_z(x)}{E_P I_P(x)} \quad (32)$$

We know that the radius of curvature ρ is

$$\frac{1}{\rho} = \frac{\frac{d^2 f(x)}{dx^2}}{\left(1 + \frac{df(x)}{dx}\right)^{\frac{3}{2}}} \approx \frac{d^2 f(x)}{dx^2} \approx \frac{d\varpi}{dx} = -\frac{M_z(x)}{E_P I_P(x)} \quad (33)$$

Since the bridge is parallelepiped in shape, the bending moment of inertia along the z axis of the section of this bridge is:

$$I_{GSZ} = \frac{b_P\ a_P^3}{12} = \mathrm{Cte} \quad (34)$$

$$\frac{d^2(f(x))}{d(x^2)} = \frac{d\varpi}{dx} = \frac{M_z(x)}{E_P\ I_P(x)} \Rightarrow f(x)$$

So,

$$= -\iint \frac{M_z(x)}{E_P\ I_P(x)}\, d(x) = -12 \iint \frac{M_z(x)}{E_P\ b_P\ a_P^3}\, d(x)$$

In the case of a beam recessed at both ends, we have a hyperstatic system.

However, we know (See works on Resistance of Materials) that at equilibrium, the sum at all points of the forces and bending moments is zero. Because of the symmetry of the system, we therefore have $R_{AZ} = R_{BZ}$ and $M_{BZ} = M_{Az}$ and the computational reasoning for the deformation equation is identical for $0 \le x \le lp / 2$ or $lp2 \le x \le lp$ so.

For the forces and reactions:

$$\overrightarrow{R_A} + \overrightarrow{R_A} + \overrightarrow{F_{CA}} = \overrightarrow{0} \Rightarrow +F_{CA} = 0 \Rightarrow R_{AZ} = R_{BZ} = \frac{F_{CA}}{2}$$

And for bending Moments:

M_x = the bending moment at a point $x < lp / 2$

M_{AZ} = the bending moment in A

F_{CA} = the force of Casimir applied in lp / 2 see (9)
Mz (x) = Bending moment depending on the position x on the bridge
I_P (x) the bending moment of inertia of the bridge section

$$M_z(x) = -E_P I_P \frac{d^2z}{dx^2} = \frac{F_{CA}}{2} x - M_{AZ} \Rightarrow E_P I_P \; z(x) = -\left(\frac{F_{CA}}{12} x^3 - M_{AZ} \frac{x^2}{2} + C_1 x\right.$$

$$So\ FOR\ 0 \leq x \leq \frac{l_P}{2} \Rightarrow z(x) = -\frac{\left(\frac{F_{CA}}{12} x^3 - M_{AZ} \frac{x^2}{2} + C_1 x + C_2\right)}{E_P I_P}$$

However, we have the boundary conditions which impose:

$$In\ x = 0 \Rightarrow z(0)\ and \left(dz/dx\right)_{x=0} = 0 \Rightarrow C_{(M)1} = C_2 = 0$$

$$In\ x = \frac{l_P}{2} \Rightarrow \left(\frac{dz}{dx}\right)_{x=\frac{l_P}{2}} = 0 \Rightarrow \left(M_{AZ}\right)_{x=\frac{l_P}{2}} = -\frac{F_{CA} l_P}{8}$$

$$\Rightarrow \left(M_{AZ}\right)_{x=0} = -\frac{F_{CA}\, l_P}{8}$$

$$\Rightarrow z(x) = -\frac{\frac{F_{CA}\, l_P}{12} x^3 - \frac{F_{CA}\, l_P}{16} x^2}{E_P I_P} = \frac{F_{CA}\, l_P\, x^2}{16\, E_P\, I_P}\left(l_P - \frac{4x}{3}\right) for\ 0 \leq x$$

The maximum deflection in x = lp / 2 gives an arrow:

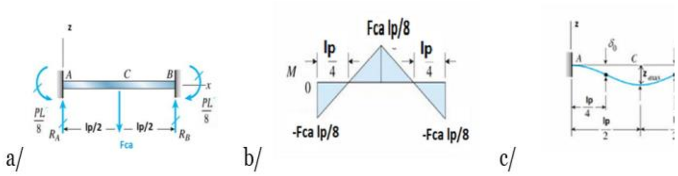


Figure 45) *a / Forces, shear forces and Moments applied on the bridge. b / Variation of bending moment. c / Shape and arrow of the bridge recessed at both ends. With: δ0 = inflection points, z_{max} = arrow of the bridge*

<u>Calculation of the resonant frequency of the piezoelectric bridge</u>

It is demonstrated (see for example: Vibrations of continuous media Jean-Louis Guyader (Hermes)) that the amplitude z (x, t) of the transverse displacement of a cross section of the beam is given by the partial differential equation, if one neglects the internal damping [7].

$$\frac{\delta^4 z}{\delta x^4} + \frac{\rho S}{E_P I_P} \frac{\delta^2 z}{\delta t^2} = 0$$

With $k = (\rho S \omega^2 / E_p\, I_p)^{1/4}$, the solution of this differential equation is written in the general form:

Z (x) = A1 exp (k x) + A2 exp (-k x) + A3 exp (i k x) + A4 exp (i k x)

and in the more convenient form:

$$z(x) = a \sin(kx) + b \cos(kx) + c\, sh(kx) + d\, ch(kx)$$

Keeping into account the boundaries conditions (Figure 45):

$$\left[sh\left(k\, l_P\right)^2 - \sin\left(k\, l_P\right)^2\right] - \left[ch\left(k\, l_P\right) - \cos\left(k\, l_P\right)\right]^2 \Rightarrow \cos\left(k\, l_P\right) = \frac{1}{ch\left(k\, l_P\right)}$$

The numerical resolution (for example by the dichotomy method in this equation gives for the first 5 solutions: a1 = 4.7300; a2 = 7.8532; a3 = 10.9956; a4 = 14.1317; a5 = 17.2787

So, the first resonant frequency of the piezoelectric bridge is Eq 36

$$\varpi_{P1} = (4.73)^2 \sqrt{\frac{E_P I_P}{M_S\, l_P^{\,3}}} \Rightarrow f_{P1} = \frac{1}{2\pi} (4.73)^2 \sqrt{\frac{E_P I_P}{M_S\, l_P^{\,3}}}$$

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