# Characterization Of Anomalous Nonlocal Forces Generated By Piezoelectric Devices

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***Abstract*— We performed accurate measurements on piezoelectric devices concerning to the existence of forces induced at distance by their operation under the application of electric fields or mechanical stress, according to the methodology reported in our previous works. In the experimental setup designed for checking possible sources of that interaction, we reinforced that the effects of non-local force induction by piezoelectric materials must be generated by quantum mechanisms, by excluding acoustic and electromagnetic origins. The induction of forces at distance was also reinforced by more accurate measurements without the possible explanation of the effect as a noise. In addition, we also determined the characteristics of the anomalous effect which were remarked accordingly. The control and or enhancement of the effect can provide us with high efficient sensors which can be used in inaccessible places.**

***Keywords—piezoelectricity; direct mode; reverse mode ; quantum entanglement; piezoelectric devices***

## I. Introduction

In our previous works [1,2], we reported the existence of nonlocal forces generated by applying a high electric field or mechanical stress on piezoelectric devices, the so-called reverse or direct modes of piezoelectricity [3-5]. As known, the usual properties presented by piezoelectric materials have been used in many applications involving sound detection, sensors, filters,
actuators, ultrasonic motors and others [6-10]. The effect described in [1] and later reinforced by measurements of deviations of laser beams when they are in the surroundings of a piezoelectric ceramic subjected to high voltages provided us the patent proposed in [11]. Such works indicated the possibility of new applications, proposed in order to use the non-local effect: the piezoelectric device could be applied to the metrology in space regions in which it is impossible to put a measurement instrument. As also explained in [1,11], the main physical agent for that new application is the quantum entanglement between the polarized molecules and the external particles in the environment [11]. This weak coupling of the huge set of molecules and the environment can macroscopically be uncovered when the voltage is applied to the piezoelectric material. The coupling between the polarized molecules and all external particles is performed according to the concept of Generalized Quantum Entanglement (GQE) or GQE formalism, as early described in equivalent phenomena already recently studied [12-19]. Such anomalous effects correspond to anomalous forces on capacitors under high voltage [12-14], known as Biefeld-Brown effect, anomalous forces produced by magnetic cores [15], induced forces at distance by semiconductor laser diodes [16], anomalous forces generated by superconductors [17,18], anomalous thrusts in dielectric EM-Drives [19] and in EM-Drives without a dielectric medium but provided of a magnetron [20]. From the exposed, we have as main motivation in the
present paper to confirm that forces induced at distance are really generated by the operation of piezoelectric devices, even though their magnitude is in fact weak. In order to confirm the accuracy of the measurements, it was needed to improve our experimental setup so that other possible interferences could be ruled out and the presence of the forces could be detected with no doubt. Further it is a relevant motivation of our research to verify the consistency of the GQE as possible explanation of the phenomenon. In other words, we want to verify that the quantum entanglement phenomenon [21] which occurs in many-body systems [22,23] can consistently explain the effect if we consider the idea of a connection between the micro and macroscopic world or the concept of quantum witness [24] and the real possibility of generalized interconnection among all the bodies [23], which is the conceptual basis of GQE formalism. Besides, one of our main objectives in the study based
on our present experiments is really to discard other possible sources for the field of forces, as the electromagnetic and acoustic ones, then we implemented some new configurations of setup which allowed us to avoid possible alternative classical explanations. In summary, in next section we have as main objectives to describe the experimental setup and the experiments from which one can exclude acoustic and electromagnetic mechanisms as sources for the field of forces at distance, so that the possible mechanism for the effect is in fact derived from quantum mechanics. In the following, we describe the theoretical explanation from a classical formulation to describe the magnitude of the induced forces, based on the idea of quantum witness [24]. At last, we present our main results and conclusions, reporting

that our new experiments confirm the presence of anomalous nonlocal forces generated by devices constituted of piezoelectric materials.

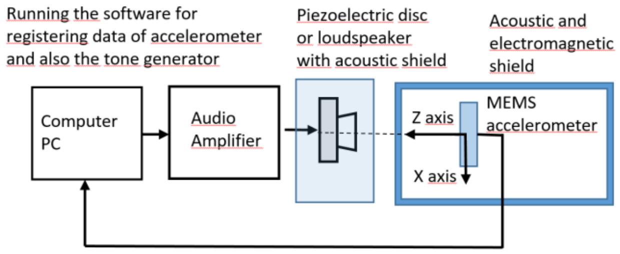


FIG. 1. *Scheme of the basic experimental setup of the experiments performed in order to detect forces at distance by the piezoelectric device or the loudspeaker. In the right side, it is indicated the accelerometer used in the measurements which is connected to the computer for collecting all the acceleration data.*

## II. Experimental Work

The experimental setup for our new objectives includes an emitter of induction of force at distance such as a piezoelectric disc (PZT5) plugged in the output of an amplifier. The amplifier receives a signal from the computer PC running a tone generator software (200 Hz frequency, squared wave, 50% duty cycle). The piezoelectric disc with 2cm diameter and 2mm thickness is used in the usual piezoelectric load speakers. The Figure 1 shows the scheme of the basic setup established for our experimental proposal.

The experimental setup also included a MEMS accelerometer model Vectornav VN-100S rugged used such as a sensor or detector of force inducted at distance by the piezoelectric disc. The accelerometer is connected in the USB interface of the computer PC running the software for registering the data and plotting the graphic curves of the acceleration variations. During the measurements, the symmetry axis of the piezoelectric disc was aligned to the z axis sensor (vertical) of the accelerometer. Both the emitter and the detector were acoustically shielded by glass enclosures. One or two glass barriers were placed between them and the detector was enclosed by thin aluminum foil connected in the electric ground of the building to avoid any possible electromagnetic influence, although the detector is insensitive to the electromagnetic fields generated by the emitter. It was desirable to apply the maximum power in the emitter - that is, the piezoelectric disc- so that the contraction of its thickness when directly polarized or the distension thereof when reversely polarized was maximal. In order to avoid that such a mechanical movement induces some acoustic disturbance in the detector, glass enclosures were included as barriers. Only the glass enclosure in the emitter has been enough to reduce the acoustic noise generated up to the room level (between

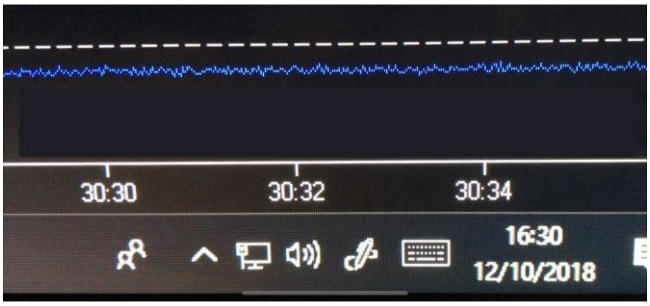


FIG. 2. *Frame of the z-axis acceleration variation (vertical axis in m/s$^2$) in 4s periods (horizontal axis in seconds) for the loudspeaker polarized in opposite mode in "on" period. The quantity of peaks is 56.*

60dB and 65dB) since only 10% of the original noise intensity passes through the barrier. As known, the common glass can reduce up to 29dB in the local noise [25] and, due to the logarithmic scale, each 10dB corresponds to a 50% reduction [26]. Besides, we performed some experimental tests in order to check that intensity without and with the glass barrier and, as improvement of the setup, more barriers were included in order to practically guarantee the complete elimination of any acoustic influence between emitter and detector. In our first setup, the sensor (accelerometer) was placed in the bottom covered by aluminum foil, such as the Faraday trap connected to the electric ground of the building. The emitter is also enclosed by the glass box (2mm thickness) where it is supported by a rigid table and closed at the bottom by an EVA material. In the piezoelectric loudspeaker used in the experiment, the piezoelectric disc (emitter) was taken out to be used in the measurements.

Another setup was taken in place using part of the earlier mentioned setup (amplifier and PC computer running the software generating a signal with squared wave of 200Hz frequency) and the piezoelectric disc was replaced by the usual electromagnetic loudspeaker of 4 ohm impedance. In this setup, the detector (accelerometer) was not shielded with electromagnetic
and acoustic shields. This setup was assembled to check if some acoustic noise generated by other kind of acoustic emitter than the piezoelectric disc could be detected by the accelerometer. The setup was also conceived in order to check if an usual loudspeaker can acoustically affect the readings of the detector via sound waves when it is applied an squared wave signal
with 200Hz frequency. The symmetry axis of the loudspeaker was aligned with the geometric center of the accelerometer (z axis sensor - vertical) and positioned 2cm above it. The audio intensity in the detector position was adjusted to 70dB, that is, a little bit above the noise level of the room and the noise generated by the piezoelectric disc enclosed with the glass shield, that is, between 60dB and 65dB. The audio was turned on and turned off during some period of seconds.

Multiple video frames were captured regarding the variation of the acceleration signal of the z axis sensor of the accelerometer using its related software running in the PC computer. It was made a comparison between the standard deviation of the frames when the audio was turned on and when it was turned off analyzing the quantity of the characteristic amplitude peaks with more than two dots over the mean oscillations of the signal. According to the majority of readings, the quantity of peaks seems to be the same between the "on" period and the "off" period. It means that the acoustic signal (70 dB) generated by the loudspeaker did not affect the readings of the accelerometer for both the speaker directly polarized (as the cone is pushed out) and in the opposite case (as the cone is pushed in). The Figure 2 shows a frame (5013 register) of the acceleration variation between the period 30:30s and 30:34s when the loudspeaker is polarized in reverse mode in the "on" period, where the quantity of counted peaks is 56.

The Figure 3 shows as frame (5014 register) of the acceleration variation between the period 30:38s and 30:42s when the "off" period of the loudspeaker is polarized in opposite mode, where the quantity of counted peaks is 56, that is, the same of the "on" period. Therefore, it seems that the audio noise of the loudspeaker at 70dB cannot affect the readings of the accelerometer.


FIG. 3. *Frame of the z-axis acceleration variation (vertical axis in m/s$^2$) in 4s periods (horizontal axis in seconds) for the loudspeaker polarized in opposite mode in "off" period. The quantity of peaks is also 56.*

FIG. 4. *Photo of the experimental setup established to detect the forces at distance. The piezoelectric disc was enclosed in the partial camera of the syringe. The distance between the z-sensor of the accelerometer and the disc was 10cm and the former was electromagnetically shielded with an aluminum foil and from external noises due* to the two glass containers.

After the measurements with the loudspeaker, the piezoelectric disc was used such as the emitter for inducting force at distance to the detector (accelerometer).

The piezoelectric disc was enclosed inside the compressible tube of the syringe and the position of the plunger was adjusted accordingly to generate the internal partial vacuum when the noise level was reduced to the minimum, that is, the room's noise between 60dB and 65dB. In this condition, the symmetry axis of the piezoelectric disc was aligned with the geometric center and z sensor (vertical) of the accelerometer and the distance between them was adjusted to 10 cm. Two glass containers enclosed the accelerometer also electromagnetically shielded by the aluminum foil connected to the electric ground of the building, as shown in Figure 4.

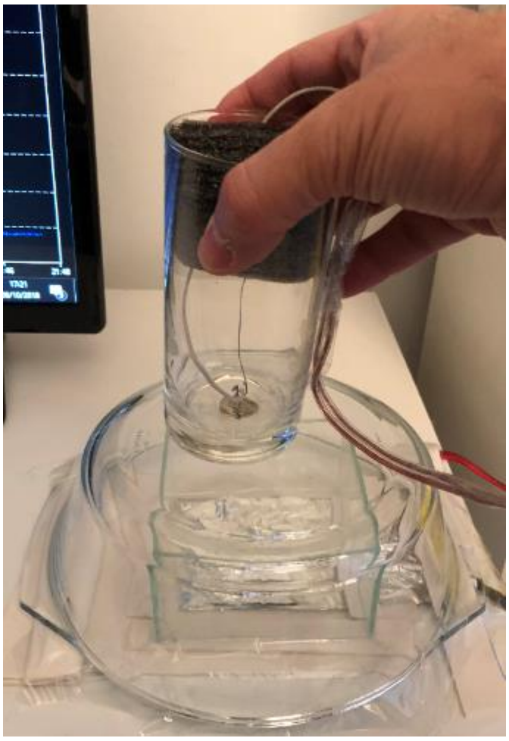

FIG. 5. *Setup of other experiment configured with the same conditions before, but in which the syringe was substituted by the cup of glass.*

The piezoelectric disc was polarized directly (++ - -) in order to suffer a variable contraction in this thickness (z direction) when the squared signal with 200Hz frequency was supplied by the amplifier. In this condition, the visual readings of the accelerometer show a small reduction of the standard deviation of the gravity acceleration with the reduction of the quantity of the peaks counted. This effect disappeared when the piezoelectric disc was misaligned with the sensor z of accelerometer, that is, when the detector was not totally encompassed or beamed by the emitter. The standard deviation variation and collimated induction can be considered the exclusive characteristic of the effect and it cannot be

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reproduced acoustically by the usual electromagnetic loudspeaker even considering

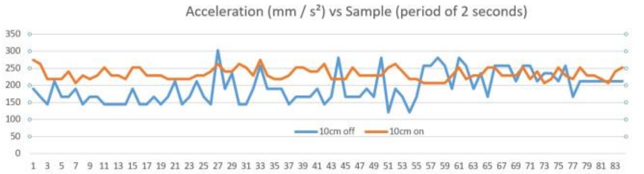


*FIG. 6. Plot of the z-axis gravity acceleration variation (in mm/s$^2$) of the setup with 10cm distance between emitter and accelerometer versus samples of measurement of 2s periods. The two curves represent the period "on" and period "off" in order to make comparison.*

its application without acoustic or electromagnetic shields in the short distance (2cm) using a higher noise level (70dB). This characteristic effect was also remarkably detected by the accelerometer even considering the partial vacuum around the piezoelectric disc, the glass barriers of two containers, the electromagnetic shield enclosing the accelerometer and the distance between emitter and detector.

The next experiment was taken in place with the same conditions mentioned before but replacing the syringe by the cup of glass. The noise generated by the piezoelectric disc remained low, that is, the same than room noise around 60dB and 65dB. The piezoelectric disc was polarized directly (++- -), so that the contraction of its thickness was taking in place when the signal was applied on it. The Figure 5 shows this new setup. Note that manual alignment between the emitter and the detector is made easy because all containers are made of glass.

FIG. 7. *Scheme of other setup in which it is added one more glass container in the experiment.*

Through the graph plotted by the software of the accelerometer were recorded some frames both of the periods "on" (when the square signal was applied to the piezoelectric disc) as in the periods "off" (when the signal was turned off). It is remarkable the difference between the variation of acceleration registered between the period "on" and the period "off".

The standard deviation of the gravity acceleration was reduced from the period off (register 4940 - between 03:22s and 03:24s) to the period on (register 4939 - between 03:14s and 03:16s) when the quantity of peaks was reduced respectively from 49 to 31. The Figure 6 shows the graphics of gravity acceleration measured in period "on" and it also shows the graphics of gravity acceleration measured in the period "off". The characteristic effect was remarkably detected again by the accelerometer even considering three glass barriers between emitter and detector.

In order to make a test with higher distance between the emitter and the detector it was built a new setup adding one more glass container, as shown in the Figure 7. In this setup, 4 glass acoustic barriers with 7mm, 5mm, 5mm and 2mm between emitter and detector besides gaps filled by air were taken in place, considering a total distance equal to 24cm. When we consider the same squared wave signal with 200Hz frequency applied in the piezoelectric disc polarized directly (++--), we observed that the accelerometer detected the reduction of the standard deviation of gravity acceleration again when it was compared the period "on" (4945 register - period between 37:40s and 37:42s) with the period "off" (4947 register - period 37:50s and 37:52s). The quantity of peaks decreased from 32 to 18.

The Figure 7 shows the comparison between the curves of z-axis gravity acceleration measurements in the period "on" and "off" for the setup with 10 cm distance between emitter (piezoelectric disc) and accelerometer.

The Figure 8 also shows the comparison between the curves of z-axis acceleration measurements in the period "on" and "off" for the setup with 24 cm distance between emitter (piezoelectric disc) and accelerometer.

Finally, we increase more the distance up to 25 cm and in Fig. 9 we show the comparison between the two curves (period "on" and period "off") of the acceleration variation (in mm/s$^2$) of the setup versus samples of measurements (in seconds) for 4s periods.

More tests were taken in place using the same previous setup with the same conditions (squared wave with 200Hz applied) but reversing the polarization of the piezoelectric disc (+- +-), where the thickness of the disc was expanded instead of being contracted. The distance between the emitter and detector changed from 24cm to 25cm hanging up the emitter a little bit higher. The test was performed aligning and misalignment the emitter (when the signal is applied on it) in comparison to the detector. The result was the variation of the standard deviation of the gravity acceleration measured by the accelerometer when it is aligned with the piezoelectric disc (4967 register - period between 53:30s and

52:34s), as shown in Figure 10, in comparison than it is not aligned (4968 register - period between 52:38s and 52:42s), as shown in Figure 11. The quantity of peaks increases from 56 to 67.

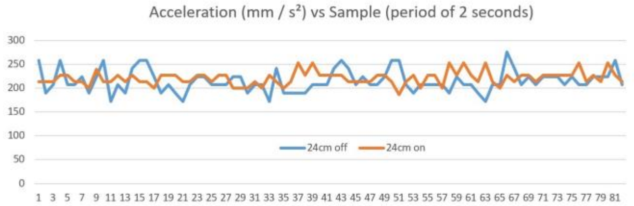


FIG. 8. *Plot of the acceleration variation (in mm/s2) of the setup with distance 24 cm versus samples of measurements (in s) for two curves (period "on" and period "off"), in order to make comparison.*

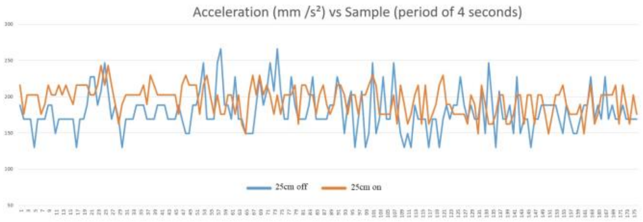


FIG. 9. *Plot of the acceleration variation (in mm/s2) of the setup with distance 25 cm versus samples of measurements for 4s periods. Two curves (period "on" and period "off") are shown for comparison.*

All of the experiments were performed by using the instruments and equipment of measurements described in Table 1.

TABLE I. *List of devices used in the experiments.*

| Device | Technical Features |
|---|---|
| Digital Oscilloscope | 100 MHz, 2 channel, Tektronicx model TBS1102B |
| Digital Capacitance meter | Minipa model MC-153 |
| Accelerometer | Vectornav model VN-100S Rugged |
| Loudspeaker | 4 Ohms |
| Piezoelectric disc | 20mm diameter - 70 nF |
| PC computer | - |
| Audio Amplifier | 8W for PC computer |
| Online tone generator software | - |
| Video camera | GoPro model White 7 Hero |

The new experiments with piezoelectric disc were improved in order to render the acoustic and electromagnetic effects negligible between the emitter and the detector. The peculiar characteristics did not change according to the quantity of acoustic barriers increasing. These characteristics could not be also reproduced using the usual acoustic generator such as the loudspeaker. There is a lot of graphics related to the measurements performed with aligning and misaligning of the emitter in comparison to the detector and also with the emitter on and off, but just some of them were included in this material in order to be used like a reference.

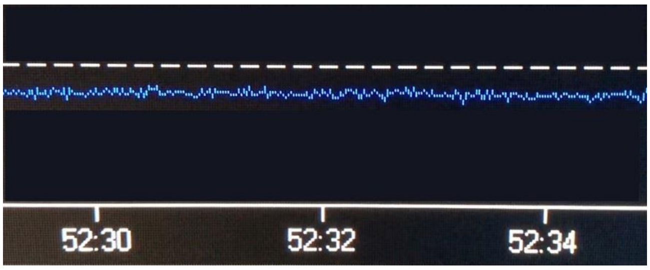


Fig. 10: *Graphic of the z-axis gravity acceleration measured by the accelerometer when it is aligned with the piezoelectric disc and the disc is reversely polarized, in the case of 4 glass acoustic barriers.*

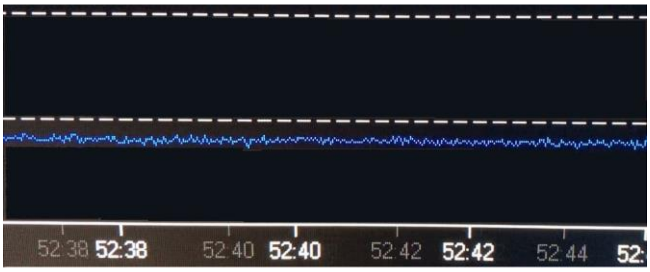


Fig. 11: *Graphic of the z-axis gravity acceleration measured by the accelerometer when it is not aligned with the piezoelectric disc and it is reversely polarized, in the case of 4 glass acoustic barriers.*

## III. EXPERIMENTAL RESULTS

In the Table 2, we show our main experimental results obtained from the setup earlier described. For the different setups are basically shown the values of the acceleration measured. By considering two different emitters (piezoelectric disc or loudspeaker) of different sizes, we performed some measurements force at distance in some samples. In column 3, we show the average of the measurements of force (on - off) and in columns 4 to 6 we present the standard deviations of the phases on, off and their differences, respectively. The measurements were performed in the periods of time given in last column. Table 2 indicates the experimental measurements performed in the setups using both the piezoelectric disc and loudspeaker, according the details and procedures shown in the last section.

The experimental setups explained indicate distances between the emitter (piezoelectric disc) and the sensor (accelerometer) of 10cm, 24cm e 25 cm, with different intermediate acoustic shielding. It was also shown the quantity of samples of measurements that the accelerometer collected in certain periods of time. The column SD on indicated the standard deviation in the period in which the emitter devices were activated while the column SD off indicated the standard deviation in the period in which the devices were deactivated (or misaligned with relation to the accelerometer). The column "SD on - SD off" shows the differences between the standard deviations of the periods of activation or deactivation. The most notable is the very lower (by orders of magnitude) magnitude of the acoustic perturbation of the loudspeaker than in the case of the non-local induction by means of the piezoelectric device. In other words, the acoustic perturbation does not alter significantly the standard deviation measured by the accelerometer, as done with the piezoelectric disc via GQE.

The perturbation of the accelerometer represented by the variation of the standard deviation is one order of magnitude or more higher in case of piezoelectric disc via GQE than the case of loudspeaker via acoustic even considering the higher distance (one order of magnitude or more) from the emitter to the detector and also the quantity of barriers between them in case of the first in comparison than the second. As mentioned before, it is also remarkable that the accelerometer readings showed that the quantity of peaks did not change between the period "on" in comparison than the period "off" for the loudspeaker. This situation was totally different in case of piezoelectric disc where the quantity of peaks clearly changed between the periods "on" and "off". The variation of the standard deviation shows better the signature of the phenomenon.

## IV. THEORETICAL MODEL

The device used as emitter of induction is called a bimorph piezoelectric actuator27–30. It is constituted by two round polarized piezoelectric parallel layers, so that when it is applied an electric tension in it one layer contracts while the second one expands.

The ratio between the contraction of one layer and the expansion of the other is not the same, that is, there is an asymmetry [27] in the device, related to the size of the contraction of a piezoelectric layer. That feature, associated with the fact that one of the circular faces is in mechanical contact with the bottom glass face of the acoustic shield, causes the electric dipoles of the piezoelectric material to induce a net force upward by decreasing the value of the gravitational acceleration measured by the Z-sensor of the accelerometer.

Considering this, one of the ways to theoretically calculate the magnitude of induced non-local force is to consider each piezoelectric layer and the contact surfaces (metal) as being a dielectric layer positioned between electrodes in order to compose a symmetric capacitor. It was shown in our previous works [12,13] how to calculate the magnitude of non-local dipole force on symmetric capacitors.

So, we apply in the present physical system the formulation for symmetric capacitors described in [12]. But it is known that for high values of $e_r$ [31], as the case of PZT ceramics used in our experiments, the application of Clausius-Mossotti relation in the calculations does not provide us consistent results with the experimental values because in those cases there is the contribution of the ionic polarizability in addition to the atomic or electronic polarizability. So, the dipole force needs a modification.

The capacitance of each piezoelectric layer (35 nF) was measured and, considering its diameter (15 mm), it was possible to evaluate its dielectric constant (1317.86) and its thickness (0.07 mm). Through the oscilloscope, the peak voltage (13.2 V) of the signal that fed the device was measured and as it is considered a square wave with a duty cycle of 50 %, the effective voltage considered for the calculation of the magnitude of the electric field that crosses the thickness of the piezoelectric layer was $VRMS=V_{peak}/2=6.6$ V [32]. When such mentioned variables are applied in the equation of the nonlocal dipole force for the piezoelectric material used we have

$$F = \frac{\varepsilon_r - 1}{16\pi^2}\varepsilon_0 A E^2, \quad (1)$$

so that we obtain the value of force 0.131913 mN.

As the mass of the accelerometer is 16 g, we have an acceleration magnitude induced by the piezoelectric device a = 8.2445 mm/s$^2$. This value is compatible with the mean of the force variations(0.18 mN) obtained by the acceleration measured between the device activation and deactivation and also with the standard deviation of the force (0.05 mN) as showed in the Table 2, even considering a possible misalignment between the piezoelectric device and the z sensor (vertical axis) sensor of accelerometer.

Another way to calculate the non-local force induced by the piezoelectric device is by means of the parameters of the piezoelectric material as also already shown in our previous work [1], but with a certain refinement.

The first step is to calculate the magnitude of the electromechanical expansion or contraction force that the piezoelectric layers of the device will suffer from the application of the square-wave alternating voltage whose frequency is 200Hz and whose effective value is 6.6V, as previously calculated.

According to [32], such a magnitude of force can be calculated by considering $e_r$ = 1317.86, as previously obtained, with the usual dielectric constant $e_0$ = 8.85 x 10$^{-12}$ F / m, the piezoelectric parameter $d_{33}$ of the piezoelectric material of type PZT432, the circular area A whose radius is 8 x 10$^{-3}$ m and finally the thickness t = 0.07 mm as mentioned above, that is

$$F = \frac{V}{\frac{d_{33}}{\varepsilon_0 \varepsilon_r}}\frac{A}{t} = \frac{VA}{t}\frac{\varepsilon_0 \varepsilon_r}{d_{33}}, \quad (2)$$

The magnitude of the electromechanical force calculated is 749.49 N, caused by the application of the variable electric voltage of 6.6 V effective value. According to [1], the next step is to calculate the internal binding force Fs of the material that affects the electric dipoles of the piezoelectric material, given by

$$F_s = \frac{Y_{PZT4}}{A} \quad (3)$$

where $Y_{PZT4}$ is the Young's modulus of the piezoelectric material used, whose value is 7.8 x 10$^{10}$, according to [32], and $A$ is the area of the dielectric layer, as calculated previously. The internal force $F_s$ has a calculated value of 1.568 x 10$^7$ N.

The net force f induced externally by the electric dipoles of the piezoelectric layer will be calculated by the quotient

$$f = \frac{F^2}{F_S 16\pi^2}. \quad (4)$$

The term 1 / (16 x $\pi^2$) is always present in our calculations [15] and it is the refinement of the calculations mentioned above and is also closely linked to the Schröndiger Hamiltonian equation [33]. The value of f is then calculated to be 0.2268 mN and considering the mass value of the accelerometer (16 g) which undergoes the nonlocal force induction produced by the piezoelectric device we have an acceleration a=f/m = 14.17 mm/s$^2$.

This value is also compatible with the mean of the force variations (0.18 mN) obtained by the acceleration measured between the device activation and deactivation and also with the standard deviation of the force (0.05 mN) as showed in the Table 2, even considering a possible misalignment between the piezoelectric device and the z sensor (vertical axis) of accelerometer.

TABLE II. Experimental results from our setups earlier described. For two emitters (column 1 in which E is the abbreviation to Emitter, PD to piezoelectric disc and LS to loudspeaker) of different sizes (column 2) we performed some measurements of average values of the variations detected in the accelerometer to the setups of 10cm, 24cm and 25cm, beside the variations of the standard deviations where was used the piezoelectric disc as an inductor of forces at distance. Additionally the values of the acoustic perturbations generated by the loudspeaker are also shown. The average values are given in column 3 and 4, the standard deviations (SD) for on and off phases are given in columns 5 and 6, respectively. The difference of the values for the phases on and off (SD "on" - SD "off" or SD Diff.) are given in column 7 and 8 for the samples labeled in column 9. In last column, we see the period of time T in seconds for the measurements performed to each setup. The values of the mean force were obtained according to the measured values of the mean acceleration and also via Newtonian relation f = ma, where m is the mass of the accelerometer (16 g).

| E | Size(cm) | a(mm/s$^2$) | F(mN) | SD "on" (mm/s$^2$) | SD "off" (mN) | SD Diff. (mm/s$^2$) | SD Diff. (mN) | Samples | T(s) |
|---|---|---|---|---|---|---|---|---|---|
| PD | 10 | 12.63 | 0.20 | 22.90 | 29.35 | -6.45 | -0.10 | 169 | 4 |
| | 10 | 38.68 | 0.62 | 44.07 | 16.90 | 27.18 | 0.43 | 85 | 2 |
| | 24 | 6.16 | 0.10 | 23.08 | 14.08 | 9.00 | 0.14 | 83 | 2 |
| | 24 | -1.60 | -0.03 | 39.47 | 34.65 | 4.82 | 0.08 | 86 | 2 |
| | 25 | 15.43 | 0.25 | 20.37 | 27.91 | -7.53 | -0.12 | 178 | 4 |
| | 25 | -5.51 | -0.09 | 26.53 | 35.86 | -9.33 | -0.15 | 89 | 2 |
| | Average | 10.96 | 0.18 | 29.40 | 26,46 | 2.95 | 0.05 | | |
| LS | 2 | 95.66 | 1.53 | 26.98 | 27.97 | -0.98 | -0.02 | 89 | 2 |
| LS | 2 | 15.20 | 0.24 | 47.27 | 47.47 | -0.19 | -0.003 | 87 | 2 |

It is noteworthy that by means of two different forms of calculation - one using the non-local dipole force equation given by (1) with its capacitance parameters and another using equations involving piezoelectric parameters -, it was possible to obtain values of force magnitude close to the experimental values. We also emphasize that the phenomenon cannot be explained with basis on known interactions (mainly electromagnetic one) so that the possible mechanism must be the quantic one. Besides, the concept of quantum witnesses reported in literature [24] is a good candidate to explain the effect, as mentioned in our earlier works [12-20].

## V. CONCLUSIONS

In this work, we present new experiments which reinforce the understanding of the peculiar characteristics of the piezoelectric materials used like emitters of forces at distance. The accelerometers used like detectors indicate that there is not practically any acoustic or electromagnetic interaction between them, as earlier shown in our US patent [11] and in our previous works [1,2], but without tests with higher accuracy, as we have done here.

The new experimental setups were assembled to avoid any possibility that acoustic and electromagnetic interactions generated by the emitter could reach the detector. In this situation, the fact that the emitter is still able to induce a signal in the detector opens new possibilities of application where the known interactions are not present. It is precisely this possibility mentioned that allows the use of the methodology involving emitters like piezoelectric materials and detectors like accelerometers - presented in our US patent [11]- can be applied in principle in metrology and remote sensing.

The new experimental setups also reinforce the understanding of the peculiar characteristics related to the variation of the standard deviation of the acceleration inducted in the accelerometer used like a detector where it can be increased or decreased respectively according to the reverse or direct polarization of the piezoelectric ceramic used like a emitter.

In relation to the source of the force, our experimental study has reinforced that no classical mechanisms can be the responsible for that effect because so mechanical interactions as electromagnetic one cannot generate such an anomaly at distance. So, our conclusion is that only quantic mechanisms can be the source for that and the phenomenon of quantum witness is a consistent theoretical explanation for that. Some earlier studies have reinforced such a point of view, as in [12,13,24]. In fact, this effect is directly associated with the variation of a laser beam profile shape such as shown in [2]. It is also very impressive that by means of two possible classical calculations given as valid by GQE - that is, by means of piezoelectric parameters of the material or by means of a dipole force of capacitors- one can obtain values of force at distance which are very consistent with the experimental results presented within the margin of errors. The connection of those peculiar characteristics of the device with the theory GQE shown in the mentioned previous articles for other systems are strong, although there was not still a demonstration for that. In addition to the suppression of electromagnetic and acoustic interactions, the fact that the theoretical results are consistent with the experimental results through the use of macroscopic quantum observables such as the permittivity (also associated with electrical susceptibility that is a witness

to quantum entanglement and its relationship to susceptibility magnetic) in the calculation -as also shown in our previous works [12,13]- demonstrates that the existing nonlocal interaction has high possibility to take place according to the GQE theory. It is worth to say that the effect can be more profoundly studied in cases involving other piezoelectric materials and enhancement of the piezoelectric effects [34,35].

Further, the most important issue for a patent application is its characterization and it was realized in the US patent [11] and here reinforced with our new experiments. It is relevant to describe that other similar cases as type II superconductors are not well understood theoretically yet but its characterization allows its technological application, for example. Other example is related to the Giant Magneto Resistance.

## References


[1] E. B. Porcelli, and V. S. Filho, "Induction of forces at distance performed by piezoelectric materials," J. Pow. Eng. En., Vol. 6(1), pp. 33–50, 2018.

[2] E. B. Porcelli, and V. S. Filho, "Analysis of possible nonlocal effects in laser beams generated by piezoelectric ceramic," J. Pow. Eng. En., Vol. 6(2), pp. 20–32, 2018.

[3] J. Holterman, and P. Groen, An Introduction to Piezoelectric Materials and Applications, Stichting Applied Piezo: Apeldoorn, The Netherlands, 2013.

[4] W. C. B. Jaffe, and H. Jaffe, Piezoelectric Ceramics, Academic Press: London, 1971.

[5] Aerotech, "Piezo engineering tutorial," https://www.aerotech.com/productcatalog/piezo-nanopositioners/piezo-engineering-tutorial.aspx Access in 01 Oct. 2018

[6] G. Gautschi, Piezoelectric Sensorics, Springer Berlin Heidelberg: Berlin, Germany, 2002.

[7] K. A. K. R. E. Newnham, L. J. Bowen, and L. E. Cross, "Composite piezoelectric transducers," Mat & Design, Vol. 2, pp. 93-106, 1980.

[8] K. Uchino, Piezoelectric/Electrostrictive Actuators, Morikita Publishing:Tokyo, Japan, 1986.

[9] G.-Y.W. M. Karpelson, and R. J.Wood, "Driving high voltage piezoelectric actuators in microrobotic applications," Sensors and Actuators A: Physical, Vol. 176, pp. 78-89, 2012.

[10] K. Uchino, Piezoelectric Actuators and Ultrasonic Motors, Kluwer Academic Publishers: MA, USA, 1987.

[11] E. B. Porcelli, "Induction of force performed by the piezoelectric materials," U.S. Patent No. 2015/0188026 A1, 2015.

[12] E. B. Porcelli, and V. S. Filho, "On the anomalous forces in high-voltage symmetrical capacitors," Phys. Ess., Vol. 29, pp. 2-9, 2016.

[13] E. B. Porcelli, and V. S. Filho, "On the anomalous weight losses in high voltage symmetrical capacitors," arXiv:1502.06915, 2015.

[14] E. B. Porcelli, and V. S. Filho, "Characterisation of anomalous asymmetric high-voltage capacitors," IET Sci. Meas. Tech., Vol. 10(4), pp. 383-388, 2016.

[15] E. B. Porcelli, and V. S. Filho, "Anomalous effects from dipole-environment quantum entanglement," Int. J. Adv. Eng. Res. Sci., Vol. 4(1), pp. 131-144, 2017.

[16] E. B. Porcelli, and V. S. Filho, "Induction of forces at distance performed by semiconductor laser diodes," Amer. J. Eng. Res., Vol. 6(5), Vol. 35-48, 2017.

[17] E. B. Porcelli, and V. S. Filho, "Theoretical study of anomalous forces externally induced by superconductors," Nat. Sci. J., Vol. 9(9), pp. 293-305, 2017.

[18] E. B. Porcelli, and V. S. Filho, "Analysis of possible nonlocal forces in superconducting materials," J. Pow. Eng. En., Vol. 6(1), pp. 85-95, 2018.

[19] E. B. Porcelli, and V. S. Filho, "Explaining anomalous forces in dielectric em drives," IET Sci. Measur. Tech., Vol. 12(8), pp. 977-982, 2018.

[20] E. B. Porcelli, and V. S. Filho, "On the anomalous forces in microwave cavity-magnetron systems," J. Eng., Vol. 2019(10), pp. 7279-7286, 2019.

[21] A. Zeilinger, "Experiment and the foundations of quantum physics," Rev. Mod. Phys., Vol. 71, pp. S288-S297, 1999.

[22] A. O. L. Amico, R. Fazio, and V. Vedral, "Entanglement in many-body systems," Rev. Mod. Phys., Vol. 80, pp. 517-576, 2008.

[23] S. D. H. H. R. V. Buniy, "Everything is entangled," Phys. Lett. B, Vol. 718, pp. 233-236, 2012.

[24] C. B. M. Wiesniak, V. Vedral, "Magnetic susceptibility as a macroscopic entanglement witness," New J. Phys., Vol. 7, pp. 258 1-8, 2005.

[25] A. Medeiros, "Aulas 07 e 08 - vidros," http://paginapessoal.utfpr.edu.br/arthurmedeiros/materiaisdeconstrucao/AULA%2006%20e%2007%20%20VIDROS.pdf/at_download/file Accessed in 06 June 2020.

[26] Missing Author, "The soundproof windows," https://thesoundproofwindows.co.uk/noisereduction-products/noise-reduction-glazing Accessed in 06 June 2020.

[27] A. Kruusing, "Analysis and optimization of loaded cantilever beam microactuators," Smart Mater. Struct., Vol. 9, pp. 186-196, 2000.

[28] H. Conrad, "A small-gap electrostatic micro-actuator for large deflections," Nature Commun.Vol. 6, pp. 10078 1-7, 2015.

[29] E. Company, "Bimorph actuators," http://www.elpapiezo.ru/eng/curve_e.shtml Accessed in 06 June 2020.

[30] Q.-M. Wang, Q. Zhang, B. Xu, R. Liu, and L. E. Cross, "Nonlinear piezoelectric behavior of ceramic bending mode actuators under strong electric fields," J. Appl. Phys., Vol. 86, pp. 3352-3360, 1999.

[31] R. Feynman, "Feynman lectures," http://www.feynmanlectures.caltech.edu/II_11.html Accesse in 06 June 2020.

[32] D. M. E. University of Pittsburgh, "Piezoelectricity," http://www.pitt.edu/_qiw4/Academic/MEMS1082/Lecture%208-1.pdf Accessed in 06 June 2020.

[33] P. W. Atkins, Quanta: A handbook of concepts, Oxford University Press, 1974.

[34] N. P. Sherlock, L. M. Garten, S. J. Zhang, T. R. Shrout, and R. J. M. Jr., "Nonlinear dielectric response in piezoelectric materials for underwater transducers," J. Appl. Phys., Vol. 112, pp. 124108, 2012.

[35] R. Guo, C.-A.Wang, A. Yang, and J. Fu, "Enhanced piezoelectric property of porous lead zirconate titanate ceramics with one dimensional ordered pore structure," J. Appl. Phys., Vol. 108, pp. 124112, 2010.