Propelling phenomenon revealed by electric discharges into layered Y123 superconducting ceramics

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Abstract. Electric discharges of several megawatts were applied, at 77 K, to a Y123 superconducting ceramic having two layers of different critical temperatures (50 K and 90 K). During the discharges, the ceramic was pushed in the direction opposite to the electron flow. The ceramic was apparently propelled by its emission of a momentum-bearing flux of an unknown nature. This flux weakly accelerated distant irradiated matter and created several physical effects not yet reported. The emitted beam had no electric charge, and traveled through materials without apparent absorption or dispersion, at a speed greater than 1% the speed of light. The kinetic energy transferred by the propelling momentum of the ceramic to an external mass, was proportional to the square of the electric energy of the discharge. The energy of the mechanical output could be increased to a value close to the energy of the electric discharge during several microseconds. No artefactual effects were found which could explain these phenomena. We conclude that the propelling energy could not come from the energy of the electric discharges and that its source is still unknown.

1 Introduction

The motivation for the present work originates from two independent lines of enquiry.

First, three decades ago, one of us (C.P.) proposed a quantized model of gravity [1] based on brief bilateral exchanges of momentum between elementary particles of matter and relativistic quanta from an isotropic gravitational energy field. According to this model, accelerated matter particles (e.g. electrons) should emit, in the direction of their acceleration, a momentum-bearing flux of neutral gravitational quanta. Consequently, the flux produced by an intense current of strongly accelerated electrons, for example inside a thin layer of a high temperature superconductor, should propel the superconductor itself and also accelerate distant irradiated matter.

Second, two groups of authors [2,3] observed a weak acceleration of matter, at a distance from a superconducting material. Podklenov et al. observed this effect fortuitously in 1992 with a rotating superconducting disc in an alternating magnetic field [2], then with discharges into a static superconductor [4]. Tajmar et al. [3] observed it in 2002 with rotating superconducting cylinders submitted to angular accelerations (see also [5–7]). The weak acceleration of distant matter reported in [2,3], proportional to the acceleration of the superconducting materials, was compatible with our model attributing this effect to the free electrons accelerated with the disk.

The present experimental work was undertaken in 2006 to test this idea. A static superconducting material was used with internal free electrons strongly accelerated during electric discharges of short duration. In the experiments reported here, both distant acceleration of irradiated matter and propulsion of the emitting material were observed. The second effect, the most conspicuous, has not been reported before.

2 Experimental setup and methods

2.1 Principle of the experiments

The experiments (Figs. 1 and 2) consisted in the application of high-voltage electric discharges (megawatts) of direct current lower than the critical current, generated from a bank of charged capacitors, into a patented [8] superconducting ceramic material bathing in liquid nitrogen. The time course of the discharge current was related to the charge voltage of the energy storage capacitor C and to the values of the real elements of the circuit (Fig. 2). We chose and measured: $C = 46.86 \, \mu\text{F}$, $R_c = 0.081 \, \Omega$,
2.2 Superconducting ceramics

The role of the ceramic was to accelerate strongly (> 10^{15} \text{ m/s}^2) numerous electrons (> 10^{21}) in the vertical up \rightarrow down direction, during short (\approx 3 \times 10^{-5} \text{ s}) electric discharges, without decelerating all of them in that same direction at the end of the discharge. Two kinds of ceramics were fabricated and tested.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig1}
\caption{
Principle of the experiment. A 46.86 \pm 0.01 \mu F energy storage capacitor \( C \) is charged by a dc generator \( G \) to a voltage chosen between 0 and 4000 V. Then a thyristor electronic switch connects the capacitor to the layered ceramic through electrodes \( e^- \) and \( e^+ \) for a fast discharge. The ceramic is immersed in liquid nitrogen not shown here. A small value amortization resistor \( R \) (0.13 \pm 0.005 \Omega) prevents an oscillating discharge. Layer S1 is superconductive during the discharges, layer S2 is not. \( Z_t \) is the narrow transition zone between the two layers. \( \Phi \) is the vertical axis of the ceramic.
}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig2}
\caption{
Equivalent circuit generating the discharge. Electric energy of the discharges is stored into capacitor \( C \). The circuit has a distributed inductance \( L_c \) and a distributed resistance \( R_c \). The discharges are sent into the ceramic emitter \( EM \) through the remotely-controlled thyristor \( Th \). A fixed resistor \( R_s \) is added to avoid oscillation of the discharge current. This resistance is also used as a shunt to measure the current. \( R_s = 0.130 \ \Omega, \ L_c = 0.80 \ \mu \text{H}. \) Our ceramics \( EM \) (see below) have a fixed internal resistance of the order of 0.009 \Omega that is proper to each ceramic.

We observed physical effects of the discharge directed both upward, on the ceramic support, and downward along the vertical axis \( \Phi \) of the discharge current, with several detectors located far from the ceramic (Fig. 3). Sets of measurements were made for different discharge voltages, with different ceramics or with different kinds of normal conductors replacing the ceramic, inside liquid nitrogen or in the air. Experiments of the same type were done during the cooling down and the warming up of the ceramics, when the state of the S1 layer changed from conductive to superconductive and vice versa. We also observed discharges in other kinds of materials, such as piezoelectric devices.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig3}
\caption{
Experimental system. It uses four parts: – A ceramic support with elastic copper bars conducting the discharge current and holding the ceramic in liquid nitrogen. – A discharge system, with a high voltage power supply, energy storage capacitors, thyristor switch, cryostat Dewar, and boiling liquid nitrogen. – A rotating horizontal pendulum, with a slightly larger tip mass in contact with the vertical copper bar supporting the ceramic. – Measuring devices enclosed in a double Faraday’s cage, under the cryostat, along the vertical ceramic axis \( \Phi \). Eight sensors measure essentially the vertical acceleration of matter, the electric field induced inside dielectrics, and the current induced inside longitudinal conductors.

Thick layered ceramics. These ceramics were made of two high temperature superconductive material layers S1 and S2 of similar chemical compositions (Fig. 1). The useful acceleration of electrons is thought to occur mainly inside the grains at the transition zone \( Z_t \) (which is not a layer) between S1 and S2, where the electric field was the largest. Layer S1 had a higher superconducting critical temperature (\approx 90 K) than the boiling temperature of liquid nitrogen (77 K). Layer S2 had a lower superconducting critical temperature (\approx 50 K) than liquid nitrogen. This property was obtained by adding traces of rare earth oxides in S2 material, starting from a S1 type raw material. The sintered material of layer S1 was a classical cuprate \( \text{YBa}_2\text{Cu}_3\text{O}_{7-\delta} \) whose method of fabrication has been described by many authors [9–12]. Cerium and Samarium, replacing 5 to 20% of the Yttrium atoms in the ceramic, have been successfully tested in layer S2.

Our method of fabrication was classical: micron size ground powders of \( \text{Y}_2\text{O}_3 \), \( \text{BaCO}_3 \), \( \text{CuO} \) were mixed and heated up during 24 h at 830 °C under partial vacuum (2 to 30 kPa) and oxygen flow (120 \mu g/s). For S2 layer, 10% of the \( \text{Y}_2\text{O}_3 \) powder mass was replaced by \( \text{Sm}_2\text{O}_3 \) (for example). The S1 and S2 powders, heated separately, were stacked and cold pressed in a mould at 65 MPa, then sintered during 40 h at 900 °C, under the same partial vacuum and oxygen flow. We made and tested sixty such bi-layered ceramics numbered EM1 to EM60 with variations in size, composition and thermal treatment, in order to get the optimum effects described thereafter.

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A typical ceramic had a diameter of $17 \pm 0.5 \text{ mm}$, a length of $23 \pm 0.5 \text{ mm}$ and a mass of $21 \pm 0.5 \text{ g}$.

**Thin-film ceramics.** In a second series, we made and tested forty ceramics composed only of the transition zone Zt. These flat ceramics (area $9$ to $50 \text{ cm}^2$) were based on the same principle as the plain layered ceramic, except that they reproduced, at macroscopic scale, between two thin films made of the same superconducting material, the conditions presumably existing between pairs of grains at the transition zone Zt. To make these flat ceramics, a thin layer ($30 \mu\text{m}$) of the S1 cuprate material was spread over a copper foil, then sintered at $900 \degree \text{C}$ as explained before. The copper support plays the role of the S2 layer, and the cuprate film the role of the superconducting layer S1. A typical flat emitter of this kind, such as 77YC25, displayed propelling performance proportional to the film area (here $25 \text{ cm}^2$). Two similar electrodes were joined by cryogenic glue or by insulated screws. The square electrodes were 5 cm on a side and the total thickness was $2.5 \text{ mm}$ for the ceramics used here.

### 2.3 Ceramic support

The ceramic was attached at the tip of a metallic support (Fig. 3). This support offered a low electrical resistance to the intense discharge current, and transmitted the momentum from the ceramic to a rotating horizontal pendulum. It was made of two flat elastic L-shaped copper bars, with a horizontal part forming a parallelogram attached to the setup, and a vertical part maintaining the ceramic axis in position while permitting a slight vertical movement of a few mm only. Copper bars and tubes had a $40 \pm 2 \text{ mm}^2$ section. Because of this mechanical configuration, the ceramic, its electrodes, and their support could not move independently.

### 2.4 Discharge system

The $46.86 \pm 0.01 \mu\text{F}$ energy storage capacitor C (Figs. 1 and 2) was made of ten polypropylene $4.7 \mu\text{F} \pm 5\%$ capacitors, insulated to $7500 \text{ V}$, and connected in parallel. It could be charged up to $4000 \text{ V}$ by an external dc power supply. Discharges of up to $10000 \text{ A}$ were made through a large thyristor, insulated to $4500 \text{ V}$, and capable to withstand a $13000 \text{ A}$ surge current.

### 2.5 Ceramic momentum sensor, the horizontal pendulum

The momentum from the ceramic was carried up by the copper support and transferred to the non-ferromagnetic, flat horizontal pendulum rotating around its central ball bearing as shown in Figure 3. The transfer stopped the movement of the ceramic support which remained macroscopically at rest. In order to obtain an efficient momentum transfer, the total moving masses of the pendulum were chosen equal to the total moving masses of the ceramic support.

The diamond shape horizontal pendulum had a total mass of $794 \pm 1 \text{ g}$ and a length of $588 \pm 0.5 \text{ mm}$. It was made of an aluminum alloy and had lead masses ($M = 320 \text{ g}$) at its two tips. The right tip received a supplementary mass ($m = 1.498 \pm 0.002 \text{ g}$) after careful adjustment of the pendulum static balance. At rest, this tip remained in contact with the insulated top of the vertical copper bar supporting the ceramic.

During a discharge, the pendulum right tip jumped up to a height $h$ proportional to the square of the total momentum transferred to it. The maximum height $h$ attained, and the corresponding momentum and potential energy, were determined from video images and calibrations. The horizontal pendulum had a large moment of inertia, so it rotated slowly enough to have its movement recorded accurately by the video camera at 25 images/s. Because of its flat shape and low velocity, its aerodynamic drag was minimal.

The pendulum had a potential energy calibration factor of $14.4 \pm 1 \mu\text{J}$ per mm of jump height $h$. It reached vertical position at $3.9 \pm 0.1 \text{ mJ}$. The calibrated momentum versus jump height was $7.3 \pm 0.2 \text{ g m/s} \text{ per mm}^{1/2}$. Its moment of inertia was $2.90 \times 10^{-2} \pm 0.01 \times 10^{-2} \text{ m}^2 \text{ kg}$. The largest value of the momentum directly measurable from the height $h$ of the pendulum, corresponding to a full rotation of the pendulum, was $125 \text{ g m/s}$. However, measurement of its initial angular velocity was possible with the video camera by comparing successive images, and its kinetic energy could then be deduced knowing its moment of inertia.

### 2.6 Detectors in the double Faraday’s cage

Detectors were shielded from electromagnetic fields by a double Faraday’s cage made of two 0.8 mm-thick aluminum enclosures. Inside the cage (height 1 m), eight drawers were put up for detectors. The bottom of the upper drawer was $26 \pm 0.5 \text{ cm}$ under the ceramic level. Four kinds of detectors performed measurements far from the ceramic, along its vertical axis $\Phi$ (Fig. 3). (i) Several accelerometers with piezoelectric and inductive sensors, delivering voltages proportional to the acceleration or to the speed of tiny non-ferromagnetic masses placed along the axis $\Phi$. (ii) Flat capacitors with electrodes perpendicular to $\Phi$. (iii) Electric conductors aligned with $\Phi$. These three kinds of sensors were compensated for the residual electromagnetic field existing inside the Faraday’s cage during discharges. (iv) A flat tank of water whose surface waves were followed with a light beam reflected on water at grazing incidence and recorded by a video camera. For the sake of brevity the measurements from these detectors will not be described, except those from the piezoelectric accelerometer, as it helped showing the existence of an emitted propelling flux and measuring one of its characteristics.
Piezoelectric sensor accelerometer. Accelerometers measuring very short accelerations (several microseconds) are not commercially available, so we built and calibrated our own. The detector was moved around, in order to determine the intensity distribution of the propelling flux along the propagation axis or at some distance from it (29 to 95 cm away). Its piezoelectric sensor was able to measure a force less than one μs in duration and more than 0.02 mN in intensity. Its calibration factor was 0.07 ± 0.01 m s⁻²/mV or 0.048 ± 0.001 mN/mV. A 0.687 ± 0.002 g mass of non-ferromagnetic metal was fixed on the piezoelectric sensor in order to get an accelerometer. The dependence of the force on the nature and value of this mass were checked. The detector was calibrated by the impact of a tiny body of known mass falling from several known heights.

2.7 Data recording

Mechanical phenomena evolving slowly were recorded by a distant video camera at rate 25 ± 0.01 frames/s, and electric phenomena evolving rapidly were recorded by a digital memory oscilloscope (256 levels or ±0.4% of full scale), enclosed in an independent double Faraday’s cage, and triggered through an optoelectronic circuit.

The time window of the oscilloscope was chosen short enough (from −30 to +70 μs) for the aerial sounds and mechanical vibrations, caused by the discharge, to travel less than 2 cm during this time, and so to avoid their recording by the sensitive sensors inside the Faraday’s cage.

2.8 Electromagnetic effects on the Faraday’s cage sensors

The intense and brief discharge current emitted a strong electromagnetic field which was not completely eliminated by the double Faraday’s cage. A voltage was induced in some of the sensors by the residual electromagnetic field, and this had to be taken into account in order to detect the signal induced by the phenomenon under study. As shown below, the voltage induced in the detectors by the electromagnetic field was proportional to the discharge voltage, while the signal induced by the phenomenon under study was proportional to the square of the discharge voltage. So they could be discriminated by varying the discharge voltage as follows. First, the detectors output signals were recorded during several discharges into the ceramic bathing in the liquid nitrogen. Next, they were recorded with the same current discharged into an aluminum cylinder (control) replacing the ceramic, and creating only the electromagnetic field.

2.9 Experimental protocol

Physical phenomena occurring during the discharges being quite brief, the displays of the digital instruments, the slow movement of the pendulum and the screen of the memory oscilloscope were recorded by a digital video camera for subsequent analysis on a computer. The following protocol was systematically used:

(i) The tested ceramic was fixed on its copper support and the support bolted on the experimental setup. The cryostat was filled with liquid nitrogen and completed from time to time to compensate for evaporation. Forty minutes without any action were needed to reach thermal equilibrium. Then the video camera was started for permanent recording of the instruments during phases (ii)–(iv).

(ii) The storage energy capacitor \( C \) was charged up to 600 V by the external power supply. The digital memory oscilloscope was put in waiting mode, to be triggered by the thyristor command circuit. The automatic command circuit of the thyristor was started. Experimenters went away for safety, and for preventing induced vibrations. Within 10 s, vibrations of the experimental system were damped and ceased completely. At the end of a 10-s waiting period, the thyristor and the oscilloscope were automatically triggered. After the discharge a zoom was manually made on the screen of the memory oscilloscope for a better ultra slow reading accuracy.

(iii) All steps in sequence (ii) were repeated with a 200 V increase of the charge voltage of \( C \).

(iv) After a charge voltage of 3600 V was reached, the experiment was repeated once again starting at 600 V.

3 Results

More than 2600 discharges were recorded and analyzed from April 2007 to March 2010, with 98 different ceramics. For examples, see the video movie in supplementary material².

² Available at http://www.epjap.org.
3.1 Experimental conditions

Typical ceramic voltage and current waveforms during a discharge (Fig. 4) show that the ceramic was only resistive, and the total duration of the discharge (30 ± 5 µs) was almost the same for each ceramic. The time course of the instantaneous electric power applied to this ceramic (Fig. 5) shows that the total energy transferred to the ceramic was 3 to 4% of the stored energy. The peak current was equal to the charge voltage divided by 0.44 Ω.

The time width of the discharges, at half the peak power, was 12 ± 5 µs, and 90% of the stored electric energy was discharged from 6 to 22 µs after the onset of the discharge. The peak power of discharges was generally observed 10 ± 2 µs after their onset. The similarity of the discharge parameters resulted from the internal resistance (Rc + Rs) of the discharge circuit, which was much larger than the ceramic resistance, and imposed by the non-oscillating current constraint [(Rc + Rs) ≥ 2(Lc/C)^1/2].

Four percent of the energy stored into the capacitor bank was dissipated in the ceramic as heat, mainly from the electrical contacts between copper terminals and the ceramic ends. One third of these 4% was dissipated by the ceramic conductive layer. Most of the stored energy (95%) was dissipated as heat by the other components of the discharge circuit, including the amortization resistor of 0.13 Ω. A small part of the stored energy (<1%) was radiated as electromagnetic field.

3.2 Effects observed during discharges

3.2.1 Propulsive momentum

The main physical effect observed was an upward propulsive momentum of the ceramic, in the opposite direction to the flow of electrons. During all discharges in the layered ceramic larger than 800 V, the horizontal pendulum always jumped up. For example, during a 2863 ± 1 V discharge in ceramic EM8, the horizontal pendulum moved slowly up (85° in 7 s), reached its maximum height (293 ± 1 mm) and the propulsion momentum was 125 ± 5 g m/s.

The pendulum movement was recorded on many (175) 40-ms video images and was sufficiently slow to neglect aerodynamic friction. In this example, the mechanical potential energy was 3.9 ± 0.4 mJ. The kinetic energy of the horizontal pendulum, when it ceased contact with the ceramic support was also 3.9 ± 0.4 mJ. The discharge duration being 16 µs, the corresponding average propulsive force was 7800 ± 375 N, and the average acceleration of the ceramic support was 15 600 ± 750 m/s^2.

Figure 6 shows that, for several ceramics, the measured momentum was proportional to the square of the discharge voltage. The curves correspond to small variations in the composition of ceramics. The dot size corresponds to the measurements error (one σ).

Similar results were obtained with all plain and thin-film ceramics. The variability between different ceramics shown in Figure 6 appeared to be related to the area of the transition zone Zt. The size of the ceramic grains seems to have a positive impact on the momentum for a given voltage. When the ceramic was turned upside down (reversed current direction) the momentum did not change and its direction remained opposite to the electron flow.
3.2.2 Effect on the distant accelerometer

During discharges several smaller physical effects were observed inside the double Faraday’s cage at a distance from the ceramic, along the $\theta$ axis of the discharge current, especially with the accelerometer. A typical example of the output signal of the piezoelectric accelerometer as a function of the discharge voltage is shown in Figure 7. This accelerometer was negligibly affected by the residual electromagnetic field. During discharges applied to a normal conductor creating the same electromagnetic field, it showed no output signal, only noise (200 $\mu$V peak). During experiments of Figure 7, at a discharge voltage of 2900 $\pm$ 1 V, the sensitive mass fixed to the top of the piezoelectric rods was accelerated to 0.125 $\pm$ 10% m/s$^2$. This corresponds to a transferred momentum of $8.8 \times 10^{-8}$ kg m/s ($\pm 10\%$) to the top sensitive mass of 0.687 $\pm$ 0.002 g. From the tests described in Section 2.6.2, the force acting on the piezoelectric sensor was found to be proportional to the mass irradiated by the propelling flux (this is an acceleration) and to be independent of the nature of the irradiated mass of the accelerometer.

3.2.3 Other physical effects

Three other physical effects were simultaneously observed during discharges into the ceramics: emission of sound, emission of light and pushing of free electrons inside Faraday’s cage sensors.

**Sound.** During all discharges larger than 500 V, a particular sound was heard and recorded. This was a short (<300 ms) and powerful whiplash-like sound, with an abrupt start (<25 ms). It was recorded by the video camera at 44 kHz sampling rate (listen to it in supplementary material). No definite source was found for this sound which was apparently emitted by the whole experimental apparatus. Its intensity was correlated with the observed propulsion momentum. No such sound was heard or recorded during discharges applied to metallic conductors or devices other than the tested ceramics.

**Light.** During all discharges larger than 1000 V, a brief flash of light coming from inside the cryostat was noticed. This flash was recorded by the video camera, at least when the electronic shutter of its CCD sensor was not closed at the discharge instant. It was only visible on a single video image per discharge with unknown automatic individual exposure duration of less than 40 ms. The light flash was too brief for obtaining an exploitable spectrum with our equipment. A rough RGB photometry of the emitted light was obtained from the video image. The photometry ratios suggest, by comparison with nitrogen spectroscopic tables, a compatibility with nitrogen emission lines in visible light. The agitation of the boiling surface of liquid nitrogen did not allow exploitable pictures of the light source. The best we have been able to do was to use the shadows projected by the light on the front face of the instruments, to determine an approximate size and position of the light source inside the cryostat. Shadows geometry suggests the light source volume was small (<5 cm$^3$, 15 $\pm$ 5 mm height and 20 $\pm$ 5 mm diameter) and located between the lower end of the ceramic support, and the bottom of the cryostat. No light was observed during discharges into a metallic conductor or device other than the tested ceramics. No light was observed during discharges in our layered ceramics in the absence of ceramic momentum, for example during the ceramic cooling down.

**Pushing of electrons and of water molecules.** Appropriate detectors placed inside the Faraday’s cage, such as a triple capacitor and a double solenoid, showed that the propelling flux displaced electrons inside dielectrics and conductors, and that it was not made of charged particles. The propelling flux created tiny waves on the surface of irradiated water, when its intensity was sufficient. These effects will not be discussed here.

3.3 These physical effects are specific to the tested ceramics

Three hundred discharges have been recorded in other materials than the tested ceramics: (i) in normal conductors made of aluminum, brass or copper, both at room temperature and in liquid nitrogen (see the video movie for two discharges applied to a cooled aluminum cylinder). (ii) In ceramics of the same type of material, but of a different chemical composition. (iii) In fully superconductive ceramics with no layers of different critical temperatures. (iv) In ceramics where the two kinds of materials, used to fabricate the layers, were mixed together before the final sintering treatment. (v) In piezoelectric and ferroelectric materials such as BaSrTiO$_3$, PZT, and PLZT, at room temperature, with a 300 $\pm$ 10% $\Omega$ resistance in parallel, allowing the discharge, as these materials are dielectrics.
During discharges in these materials, none of the effects described previously were observed.

These physical effects disappeared when the ceramic layer was not superconducting. Discharges were applied to layered ceramics at variable temperature. While the ceramic was cooling down or warming up, respectively when liquid nitrogen was poured into the cryostat, and when it had evaporated, the progressive appearance and disappearance of the effects described previously was recorded. The full evolution took about 30 ± 5 min. For stable effects, the ceramic had to be at thermal equilibrium, at a temperature chosen between the critical superconducting temperatures of the two layers. The present results were obtained with stable thermal equilibrium of the ceramics during all discharges. This is the reason why 40 min waiting time were allowed in the experimental protocol.

3.4 Properties of the emitted flux

Properties of the flux were determined from the detectors located inside the Faraday’s cage.

The radiance diagram of the ceramic was determined with the piezoelectric accelerometer. This sensor measured the variation of the acceleration of irradiated matter, during constant discharge voltage (2500 ± 1 V), at a variable lateral distance from the vertical axis of the ceramic, along several azimuths. The area of the sensor was smaller than that of the ceramic (diameters Φ1 ± 0.01 mm respectively). Its output voltages, at constant distance from the ceramic (490 ± 1 mm) and variable lateral distances from Φ (up to 60 ± 1 mm), gave a rough radiance diagram. Repeating these measurements at different azimuths (0 to 360° by 30 ± 3° steps), we observed that the radiance diagram was symmetrical around Φ. The output voltage of the accelerometer was almost constant (±5%) in a circular area about the size of the ceramic vertical projection, the acceleration diminishing away from the axis. An attenuation of 10% was recorded at 2° ± 0.2° from Φ, 20% at 4.9° ± 0.2°, 50% at 5.8° ± 0.2°, and 67% at 7° ± 0.2°. The radiance diagram had a 11.6 ± 0.4° summit angle for a 6 dB attenuation. The propelling flux propagation was anisotropic, with an axis and a direction extending from the electron flow axis into the ceramic.

The minimum propagation speed of the flux was determined from the output signals of two detectors, insensitive to the residual electromagnetic field of the discharge, placed inside the double Faraday’s cage as far apart as possible, their vertical distance being 95 ± 0.1 cm along Φ. They were recorded simultaneously at a scale of 10 ± 0.01 μs per division on the horizontal axis. Figure 8 shows the result of such an experiment repeated many times with different detectors. These measurements showed no time difference, up to ±0.3 μs, between the onsets of the voltage variations on both detectors. With a propagation of 0.95 ± 0.001 m in less than 0.3 ± 0.01 μs, the speed of the flux was greater than 3.17(±0.01)×10⁶ m/s, i.e. larger than 1% of c.

No absorption of the propelling flux by inserted matter was found in sets of two successive discharges in the same ceramic, at the same voltage (2500 ± 1 V), while recording the output signal of the piezoelectric accelerometer and of other detectors in the Faraday’s cage. Before the second twin discharge, various thick pieces of matter: steel, wood, stone, paraffin wax, granite, aluminum, water, brass etc., were inserted above the accelerometer and other detectors, in the upper drawer position. No difference in the recorded output signals, with and without insertion of matter, was found up to the accuracy of our measurements (±0.4%).

3.5 Kinetic energy transferred to the horizontal pendulum and energetic efficiency

3.5.1 Thick layered ceramics

With the layered ceramics, we found the following momentum, as shown in Section 3.2:

\[ P = 1.12 \times 10^{-8} U^2. \]  (1)

Consider a mass \( m \) lifted up to a height \( h \) by momentum \( P \), as in the case of the pendulum in the present experiments. Its initial vertical speed \( V \) is \( V = P/m \). The height \( h \) attained in the earth gravitational field of acceleration \( g \), when using the plain ceramics obeying expression (1), is:

\[ h = V^2/2g = P^2/2gm^2 = 1.25 \times 10^{-16} U^4/2gm^2. \]  (2)

The kinetic energy \( E_m \) transferred to \( m \) is:

\[ E_m = mV^2/2 = mgh = 6.27 \times 10^{-17} U^4/m. \]  (3)

The kinetic energy displayed by the horizontal pendulum resulting from the propelling effect in the ceramic, was proportional to the square of the electric energy of the discharge. Indeed, the electric energy \( E_e \) stored into the discharge capacitor \( C \) is proportional to \( U^2 \):

\[ E_e = U^2 C/2. \]  (4)
Therefore, the energetic efficiency of the experiment $\eta = E_m/E_e$ was:

$$\eta = 1.25 \times 10^{-16} U^2/mC. \tag{5}$$

The factor $1.25 \times 10^{-16}$ appearing in (5) is not a dimensionless constant. It is the square of the experimentally-determined factor appearing in (1). With a small $mC$ value, and by increasing the discharge voltage $U$ it appears possible to get a positive energy balance between the kinetic energy of the lifted mass $m$, and the electric energy, under the condition that the critical current density into the ceramic is not attained. The $\geq 100\%$ energy efficiency condition would be given by:

$$U \geq 8.93 \times 10^7 (mC)^{1/2}. \tag{6}$$

**Verification of the relationship between the experimental energetic efficiency and the discharge voltage.** Experimental results (3) and (5), apparently violating energy conservation, we first suspected that the measurement of the momentum with the horizontal pendulum was incorrect. So we checked the form of expression (3) by replacing the horizontal pendulum by a small linear alternator rated to 100 W. First, we made sure that it delivered an output voltage proportional to the velocity of its mobile magnets, and found that this was obtained with an energy efficiency of 92%. This type of energy conversion alternator was also found to exhibit an excellent linearity when measuring a pulsed momentum ($\pm 0.1\%$).

The alternator, replacing the horizontal pendulum, was a Qdrive 1S102M model. It had mobile magnets with a mass of $432 \pm 1$ g. When briefly pushed by the ceramic support, the mobile magnets suspended by flat steel springs, freely oscillated up and down because of an ejected spacer. So the stator coil delivered an alternating voltage whose peak amplitude was proportional to the vertical speed of the magnets. After a momentum transfer from the ceramic support, this alternator delivered an amortized ac voltage of several volts, at 50 Hz, during almost half a second. The peak voltage of the first oscillation was proportional to the transferred momentum. Its experimentally-determined calibration factor was $35.4 \pm 0.5$ g m/s per peak volt. Measured with this alternator, discharges into a plain bi-layer ceramic (S51+S54+BV) yielded a mechanical kinetic energy proportional to the square of the electric energy stored into the capacitor C (see Fig. 9 for an example). This confirmed the form of expression (3).

We could not check expression (6) with discharges into layered ceramics because, with $m = 1.498 \times 10^{-3}$ kg and $C = 46.86 \mu F$, the energy efficiency would exceed 100% for $U > 23600$ V; this voltage cannot be attained with our present experimental system, which is limited to 4000 V discharges.

3.5.2 Thin-film ceramics

However, with 25-cm² thin-films ceramics such as 77YC25, we found

$$P = 2.4 \times 10^{-7} U^2 \tag{7}$$

so expression (6) becomes:

$$U \geq 4.17 \times 10^6 (mC)^{1/2}. \tag{8}$$

Expression (8) shows that, with the same values of $m$ and $C$ as before, the energy efficiency should exceed 100% for $U > 1100$ V, which can be checked with our present experimental system. Experiments with thin films ceramics and the horizontal pendulum, up to $U > 1100$ V, yielded an increasing energy efficiency, confirming expression (5), and a value of the pendulum kinetic energy approaching the input electric energy (see the movie showing such a progression up to 1152 V).

However, we could not measure correctly the kinetic energy with discharges over 1000 V because the rotating movement of the pendulum became violent and the pendulum tip left the ceramic support before full transfer of the ceramic momentum. Consequently, the ceramic and its support jumped up macroscopically, ejecting drops of liquid nitrogen out of the cryostat and condensing the surrounding atmospheric water vapor as fog. Even the heavy (1.5 kg) cryostat itself jumped up, because the residual movement of the ceramic support, inside liquid nitrogen, became apparently supersonic. Increasing further the input electric energy being potentially dangerous, the discharge voltage was limited to $\sim 1150$ V. Condition (8) could not be obtained with the linear alternator replacing the pendulum, because, with its mobile mass $m = 0.432$ kg, $U$ should exceed 18760 V. The experimental system will have to be considerably modified to continue this kind of verification.
4 Discussion

4.1 Comments about the observed physical effects

When powerful electric currents were discharged at 77 K in superconducting ceramics having two layers of different critical temperatures (50 K and 90 K) four physical effects were observed: propulsive momentum, distant acceleration of matter, emitted sound and emitted light inside the cryostat. They can be tentatively interpreted as resulting from the emission by the ceramics of a propelling flux which propagated at high speed and was apparently not absorbed by intercalated materials.

Propulsive effect: due to the mechanical configuration of the setup, only a vertical movement of the whole ceramic, pushing up its copper support, could cause this effect. The propulsive momentum was produced by the discharge current inside the ceramic, because it was not observed when the ceramic was replaced by other materials, and because its amplitude increased with the discharge current, and disappeared with it. The propulsive momentum remained the same when the ceramic was turned upside down, its direction being always opposed to the direction of the electron flux. This momentum, created without ejection of matter, suggests the emission by the ceramic of a downward flux bearing this momentum. This “propelling flux” should be detected along its propagation path, towards the nadir, under the ceramic.

Distant acceleration of matter: the propelling flux momentum was proportional to the square of the discharge voltage (Fig. 6). So if this flux was able to transfer a part of its momentum to matter inserted along its path, the transferred momentum should also be proportional to the square of the discharge voltage and this was actually observed (Fig. 7). Because of momentum conservation, the flux was expected to bear the whole momentum of the ceramic. However, the flux transferred only a small part (≈ 10^-6 per gram of irradiated matter) of its own momentum to the piezoelectric accelerometer mass. This fact was not caused by absorption of the propelling flux by the Faraday’s cage, as shown in Section 3.4, which indicates a weak interaction cross section of the propelling flux with irradiated matter. Our results show that the propelling flux weakly accelerates matter, as the force was proportional to the mass of the irradiated matter. The flux pushed matter inserted along its propagation path. Podkletnov et al. [2,4] and Tajmar et al. [3] observed also this phenomenon with the same properties.

Sound emission: a low time resolution oscillogram of that sound revealed an abrupt front (< 20 μs) suggesting a supersonic shock wave. This sound wave might have been emitted by the whole experimental apparatus located under the ceramic level, when irradiated by the propelling flux. This could explain why no definite source of this sound was found.

Light emission inside the cryostat: the voltage applied to the ceramic was only a fraction of the discharge voltage. During 2200 ± 1 V discharges, ~ 400 ± 40 V were applied across the 23 ± 1 mm long ceramic. This was not sufficient to ionize liquid nitrogen. The emission of light inside the cryostat could result from the excitation of nitrogen atoms by the electromagnetic radiation emitted by the accelerated electrons (bremsstrahlung effect). However it is unlikely that this low energy radiation (<3 keV) could have travelled through the dense ceramic material and the copper electrodes before reaching nitrogen atoms. So this light emission resulted more likely from the propelling flux itself, since it was not absorbed by the inserted matter. The ionization would result from the pushing action of the flux on electrons of nitrogen atoms. No light emission was observed in the air (the atomic density is about 700 times larger in liquid nitrogen than in the atmosphere).

The fact that no flash of light was observed during ceramic cooling down, while there was not yet any ceramic momentum, supports the hypothesis of an effect caused by the propelling flux. For this hypothesis to be correct, the interaction of the propelling flux with nitrogen atoms should transfer a kinetic energy to the electrons of the ionized nitrogen atoms greater than several electrons-volts.

Minimum propagation speed of the propelling flux: the twin-signal experiments showed that the propelling flux propagates at a velocity greater than 1% of c. Many repetitions of this experiment with different pairs of detectors confirmed this minimum propagation speed. If the propelling flux would propagate at the speed of light, the time difference between two events inside the Faraday’s cage would be ~3.3 nanoseconds, a time interval too short to be measurable with our detectors and oscilloscope.

Absence of absorption by inserted matter: no noticeable absorption of the propelling flux was found with any of the different samples we tested. The thickness, mass and density of the inserted matter had no observable effect, up to the ±0.4% accuracy of our measurements. However, the propelling flux interacted weakly with the inserted matter, as shown by the piezoelectric accelerometer signal. Gravitation is the only known interaction which is insensitive to the insertion of matter along its path and which interacts weakly with matter.

4.2 Analysis of possible artefacts

4.2.1 Artefacts concerning the propelling momentum of the ceramic

Several artefactual sources for the ceramic momentum were examined:

Piezoelectric effect. A reverse piezoelectric effect creates a tiny movement of the opposed sides of a piezoelectric crystal to which a voltage is applied. However, if
a piezoelectric force was present the relationship between momentum and applied voltage would be linear and not quadratic as observed (Fig. 6). Moreover, a piezoelectric material should be a dielectric, whereas the tested ceramics were conductive, almost short circuits.

**Electromagnetic effect.** An electromagnetic field creates strong forces on currents in conductors and on ferromagnetic materials such as iron. However, electromagnetic forces are proportional to the current generating the field, not to the square of the current; no ferromagnetic materials were used; and no propulsive effect was observed when the ceramic was replaced by a normal conductor, of the same dimensions, submitted to the same current discharges.

**Interaction with the Earth magnetic field.** The interaction between the discharge current and the Earth magnetic field can create a force. However, the copper bars configuration would create a small torque, instead of a propelling force greater than 80 000 N (largest peak force observed). Again, the force should be proportional to the current intensity, not to its square.

**Thermal effect.** A strong thermal effect inside liquid nitrogen could create an intense evaporation, and the nitrogen vapor could push the ceramic support out of the cryostat. However, the discharge duration being extremely short (30 µs), the vapor could not move sufficiently up to create the observed effect in synchrony with the discharge current. Moreover, the electric energy transferred to the ceramic is small, only 4% of the stored energy (<100 J). So, the amount of liquid nitrogen that would change phase with the available thermal energy (less than 3 J) would be insufficient to account for the observed effects, as liquid nitrogen needs 160 J/cm² for evaporation. Note also that during intense discharges, the heavy (1.5 kg) cryostat jumped up, which is unlikely from a thermal effect.

**Solid-state physics effect inside the ceramic material.** Control experiments done with fully superconducting ceramics of the same composition (but with no layers) did not show the effects found with our specific ceramics. No effects were observed with discharges applied to ceramics made of only the S2 layer type of material. Effects internal to the ceramic cannot account for the acceleration of distant matter inside the Faraday’s cage.

**Effect resulting from the electric field applied to liquid nitrogen.** When the coolant was poured into the cryostat, the propelling effect appeared after at least 10 min and then increased progressively, during each discharge, until the ceramic temperature became uniform. The full evolution required about 30 min. When liquid nitrogen had evaporated, the propelling effect diminished also progressively during 10 to 15 min while the temperature inside the ceramic was rising above the critical superconducting temperature. The thermal inertia of the ceramic and its copper support was clearly involved.

4.2.2 Artefacts about the propelling flux effects inside the Faraday’s cage

Several possible artefactual effects on the Faraday’s cage sensors were also examined:

**Electromagnetic effect.** A strong electromagnetic field was radiated by the discharge current around the discharge circuit and induced currents in surrounding conductors as well as electric fields in surrounding dielectrics. According to Maxwell’s equations, these inductions should be proportional to the derivative of the discharge current. The effects of this electromagnetic field were limited by using a double Faraday’s cage. The cage sensors were designed to be almost insensitive to the residual electromagnetic field. Nevertheless, weak electromagnetic field effects were recorded. However, by comparing results of discharges applied to our ceramics and to normal conductors, two effects were clearly distinguished, one arising from the electromagnetic field and the other, proportional to the square of the discharge current. The second effect disappeared completely when discharges creating the same electromagnetic field were applied to a normal conductor instead of the ceramics.

**Effect of a flux of known particles.** A flux of known elementary particles (such as electrons or protons) emitted by the ceramic could push matter and induce currents or electric fields. However, the energy of these particles should be smaller than 3 keV in all experiments reported here. Particles with kinetic energy that small could not travel through materials placed along their path. Moreover, usage of flat capacitors showed that the hypothetic propelling flux could not be made of charged particles, and relatively low energy electric discharges in matter are not known to trigger the emission of neutrons.

**Pushing effect from a continuous spectrum of electromagnetic radiation** caused by the Bremsstrahlung emission from accelerated and decelerated electrons. The photons of this emission could not have an energy greater than that of the accelerated electrons (<3 keV) so they could not travel through the interposed materials of the cryostat (1 mm thick stainless steel), Faraday’s cages (2×0.8 mm thick aluminum), plus several wood supports (15–20 mm thick).

4.3 Does the ceramic interact with an external energy source?

The discharge circuit appears as a “closed system” that should not generate an external momentum. However, the reported experiments showed a momentum transfer and the ceramic support was submitted to accelerations reaching up to ten thousands g’s. The effects observed are consistent with the emission by the ceramic of an anisotropic propelling beam accelerating distant matter. It would explain why the ceramic was pushed up, and the propelling flux should bear all the propelling momentum of the ceramic. This raises the question of the origin of the energy
carried by the flux. The source of energy was likely neither the ceramic, because it was not progressively destroyed, nor the electric energy stored in the capacitors, because of the close to 100% efficiency found in the experiments reported in Section 3.5 (expressions (3) and (5)). The energy could come from an external source, for example the liquid nitrogen, but this is not consistent with the persistence of the propelling effect after complete evaporation of nitrogen. Therefore, we suggest that an unknown interaction was triggered through the accelerated electrons inside the ceramic and that the experimental setup was an open system interacting with an external energy source. The nature of this interaction can be studied from the experimental properties of the propelling flux as summarized now.

5 Conclusion: main experimental properties of the propelling flux and consequences

- The flux bears a momentum proportional to the energy of the electric discharge transferred to the ceramic.
- It propagates in the direction of the electron acceleration inside the ceramic.
- The flux momentum seems to be proportional to the electron acceleration inside the ceramic.
- The flux is neither absorbed nor scattered by matter at rest, however it does weakly accelerate matter placed along its path (it pushes matter).
- A small fraction (\(\approx 10^{-6}\) per gram) of the momentum borne by the flux is transferred to irradiated matter.
- The fraction of momentum transferred by the flux is proportional to the mass of irradiated matter.
- The propagation speed of the flux is not known (it is greater than 1% of \(c\)).
- The flux is not made of charged particles.
- It creates a sort of supersonic shock wave, when propagating through materials.
- It apparently pushes water molecules, and electrons in dielectrics and in conductors.
- It apparently ionizes liquid nitrogen if sufficiently intense.

These results indicate the possibility to propel a mass by applying electric discharges to a superconducting ceramic without ejecting matter in space, and using only electric energy. They also suggest the possibility to extract energy from an unknown surrounding source, thus raising questions about the nature and properties of this source. However, this possibility needs further confirmation in experiments with a larger efficiency.

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References

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