

Thrust from Symmetric Capacitors using Quantised Inertia: Version 2.

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Abstract

It has been found, by some experiments, that during internal field emission, capacitors thrust anomalously towards their anodes. It is shown here, using an argument based around the well-known Casimir effect, that this thrust is predicted by quantised inertia, a theory that also predicts galaxy rotation without dark matter. One experiment has claimed that the capacitors' thrust was as large as 120 N/kW, and quantised inertia predicts that this is further enhanceable, making this a potential launch system.

1 Introduction

Special relativity predicts that accelerating objects see a Rindler horizon behind them because of the limitations of information transfer to the speed of light, and this horizon splits virtual particles from the vacuum forming so called Unruh radiation (Unruh, 1976).

A theory has been proposed suggesting that the horizon damps the Unruh radiation on one side of the object causing an Unruh radiation imbalance that pushes the object back against its acceleration (McCulloch, 2007, 2013). This theory, called quantised inertia, and models inertia as an asymmetric Casimir effect, provides the first mechanistic explanation for inertia and predicts galaxy rotation without dark matter (McCulloch, 2017). Quantised inertia also predicts that instead of horizons, metal structures can be used to damp the Unruh radiation in such a way as to produce a thrust that does not require propellant (McCulloch, 2018).

It was observed by Canning *et al.* (1990), T. Musha (2008) and Becker and Bhatt (2018) that capacitors which undergo highly-accelerated discharges or, in Becker and Bhatt's case field emission, thrust towards their anodes. The thrust

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is many orders of magnitude larger than that expected from ion drift and many times more than possible given that no ablation of the plates was seen. A good summary is available in Martins and Pinheiro (2011).

Becker and Bhatt (2018) attempted, after some liaison with the author, to demonstrate that quantised inertia predicts the thrust they saw. However, although it was useful qualitatively, their derivation was unfortunately flawed because they used an uncertainty relation with \hbar not $\hbar/2$ which gives an answer 12.5 times too large and they used another erroneous assumption resulting in a formula that predicted well because these two errors cancelled (no offense to Becker and Bhatt who should be commended for their technical skill & effort).

In this paper a derivation is presented and it is shown that quantised inertia predicts the thrust from the capacitors and its dependence on plate separation and power very well, though some aspects, such as the reduction of thrust seen when the cathode was thickened remain unmodelled.

2 Method

Figures 1a and 1b are schematics showing the difference between the behaviour of an electron, in quantised inertia, in both open space (1a, first panel) and in a capacitor (1b, second panel). Figure 1a shows that normally, in quantised inertia, an accelerated electron sees more Unruh radiation in front (the orange area) because there is no horizon there damping it, and less Unruh radiation behind (the yellow area) because it is damped by the Rindler horizon (the vertical black line). So the electron sees a radiation imbalance pushing it back against its acceleration and it has what we refer to as inertia.

Figure 1b show the situation in the capacitor. The electrons are accelerated to the right by a potential difference between the plates. Again they see a Rindler horizon, shown on the left by the vertical black line. The electron cloud will see Unruh waves, but these will be deselected between the capacitor plates so that the normal gradient is reversed and now there are more Unruh waves behind (the yellow area) so the electrons get an extra kick forward which is translated to the anode. In a sense the electrons' inertial mass reverses. The corresponding gradient to the right outside the capacitor is far less important because, given the acceleration, most of the electrons are on the left hand side of the gap and the dynamics of the deceleration when hitting the anode are different: there is a far higher deceleration than acceleration (see discussion).

In the derivation that follows we start from the Casimir effect (Quantised inertia's technical name has always been a Hubble-scale Casimir Effect, and the Hubble horizon can be replaced by metal plates). The Casimir force (from the normal vacuum) pushing together two parallel plates is

$$F = \frac{\hbar c \pi^2 A}{240 d^4} \quad (1)$$

where A is the plate's area and d is their separation. Now instead of the normal zero point field that the Casimir effect assumes we take account for the fact that the electrons see a much more energetic zero point field due to their acceleration, but which is still damped between the plates to pull the electrons forward. We can model this by replacing the \hbar (units Js) in the original Casimir effect by the energy-time we are putting in electrically. The assumption is that all this energy accelerates the electrons, and ends up as Unruh radiation which is then damped between the plates

$$\hbar \rightarrow E\tau = \frac{Ed}{v} = \frac{P\tau d}{v} = \frac{Pd^2}{v^2} \quad (2)$$

where E is the energy between the plates, τ is the time it stays between the plates and P is the power applied. The electrons' acceleration is $a = q_e V/m_e d$ so their final speed across the gap is $v = at = q_e Vt/m_e d = q_e V/(m_e(v/2))$ ($v/2$ is the average speed across the gap). So that $v = \sqrt{2q_e V/m_e}$ and so their average speed is half that, so $v^2 = 1/4(2q_e V/m_e)$

$$\hbar \rightarrow \frac{2Pd^2 m_e}{q_e V} \quad (3)$$

So the force is

$$F = \frac{2Pd^2 m_e}{q_e V} \frac{c\pi^2 A}{240d^4} \quad (4)$$

Since $P=IV$ we have

$$F = \frac{0.082IAm_e c}{q_e d^2} \sim \frac{0.00014IA}{d^2} \quad (5)$$

This is the thrust predicted by quantised inertia and will be transmitted by electron impacts to the anode and the capacitor structure. The electron acceleration occurs as the electron passes between the plates. The deceleration at the anode is much larger, but the Rindler horizon in that case is very close (higher acceleration) so the Unruh waves to the right are fewer or similar to those seen between the plates, so there will be an extra thrust rightwards (see Fig.1, fourth panel). Note that Eq. 5 has no arbitrary parameters.

3 Results

Figure 2 shows the results of the experiment of Becker and Bhatt (2018) as the black diamonds. The observed thrust is on the y axis as a function of the separation of the capacitor plates on the x axis. The error bars are also shown. Figure shows the predictions of quantised inertia by the squares. The error bars on the predictions, of 30%, assume an error in the current of 20% plus an

error in the estimate separation of 10% (Becker and Bhatt, pers. comm.). The predictions agree within the error bars of the data.

It can be seen that the thrust increases exponentially as the plate separation is reduced and the largest observed force (on the left) was about $6 \times 10^{-3}N$ for a voltage of 5000V and a current of $10\mu A$ which implies a power of 0.05W. This means that this capacitor has a thrust of 120 N/kW. If a thruster was built using for example a Lithium-air battery that is capable of 1.8kW/kg then an upwards force of 180N would be achieved, much larger than the downwards force from the battery ($1kg=10N$) and thruster (a weight of up to $1kg = 10N$). These results therefore show that this thruster could be used to launch significant payloads into space. From Eq. 5 it is clear that the best way to enhance the thrust would be to reduce the separation of the plates.

4 Discussion

Eq.5 predicts that the thrust depends most strongly on plate separation, but also linearly on current and power. The predicted thrust does not depend on the voltage, because although a higher voltage increases the amount of power between the plates it reduces the time the electrons spend there by the same proportion. Indeed Becker and Bhatt (2018) found a linear dependence with both current and power, which suggests that indeed voltage was not important. Eq. 5 also predicts a dependence on capacitor area.

It should be noted that this is only an approximate model, that assumes, for example, that metal plates completely block Unruh radiation. A factor which is simply unknown. The model cannot cope with more complex arrangements. For example, when the cathode was thickened, the result was that the thrust reduced and when a neutral conductor was positioned between the cathode and the Rindler horizon the force reversed (Becker and Bhatt, 2018). The reason for this is not clear.

In the case of the capacitor itself, it was assumed that the plates completely enforce a node on the Unruh waves at the position of the plate. In the case of arbitrary arrangement of metal plates this is more difficult to model since more than one node will be enforced and the thickness of the plates and the damping factor will have to be considered.

Finally, a metal plate placed to the right of the calculated position of the Rindler horizon caused a reversal, but when the plate was placed to the left of the Rindler horizon it had no effect. This makes sense in quantised inertia since events beyond the horizon cannot be 'known' by the accelerated electrons by definition. Therefore this test by Becker and Bhatt (2018) may be the first direct observation of a Rindler horizon.

5 Conclusion

Capacitors with electron field emissions show unexplained thrust towards their anodes.

It is shown, by analogy to the Casimir effect, that quantised inertia (QI) can predict this thrust.

The experimental results show the thruster is potentially a launch system.

QI predicts exponentially more thrust for closer plates.

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Figures

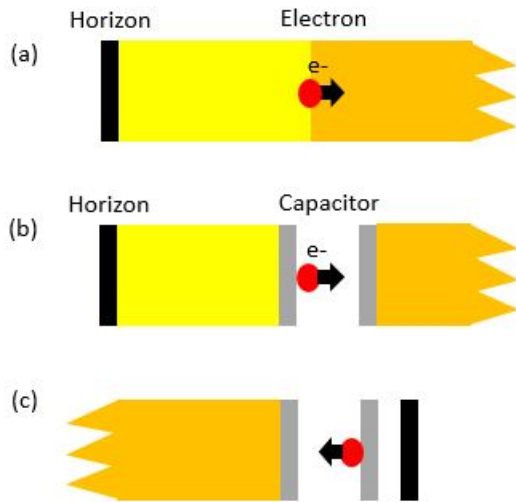


Figure 1. Schematic showing (a) an electron accelerating to the right under quantised inertia. It sees more Unruh radiation in front of it (orange) since there are no horizons there. It sees less Unruh radiation to the left (yellow) as it is damped by the horizon (black line). This pushes the electron back against its acceleration - inertia. In the capacitor (b) the opposite occurs. The accelerating electron sees few Unruh waves in front as they are damped by the capacitor plates (white area) and more waves behind (yellow) so the electron is pushed forwards more than expected and pushes the anode plate. The deceleration is more abrupt when the electron hits the anode (c) which enhances the rightward thrust.

OBSERVED THRUST & THAT PREDICTED BY QI

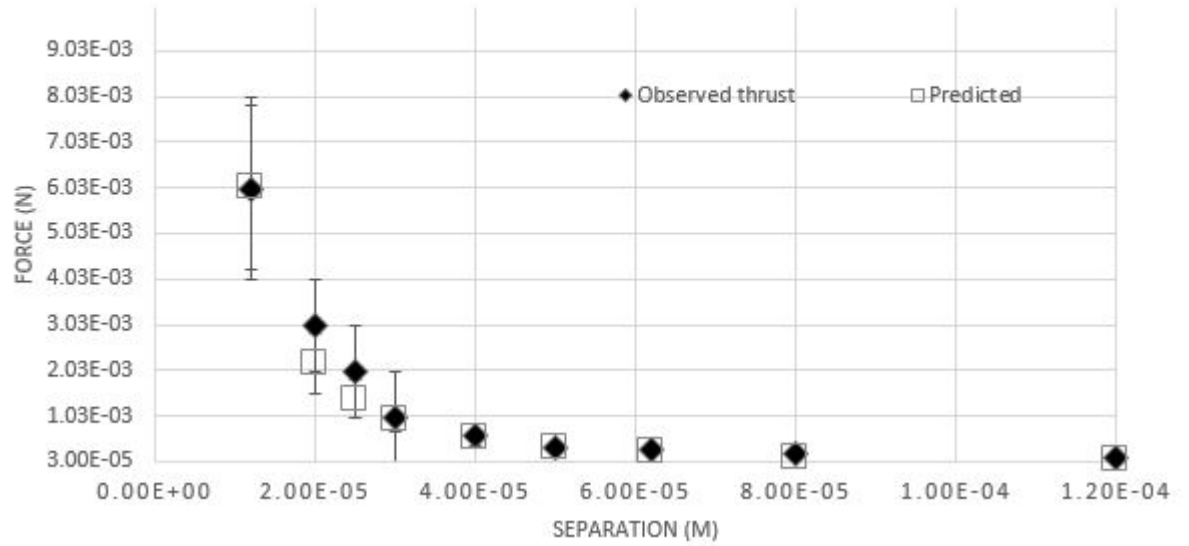


Figure 2. Results. The observed thrust from Becker and Bhatt (2018) (black diamonds), and that predicted by QI using Eq. 5 (squares).