Influence of an electrostatic potential on the inertial electron mass

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ABSTRACT. A new independent experiment confirms the conclusion of a previous one, namely that the inertial mass of an electron is changed when the electron is placed anywhere inside a charged spherical shell at a static potential V. In the present case, this effect, stemming from Weber's electromagnetic theory, is observed through the expected linear variation of the frequency of a Barkhausen-Kurz generator with the magnitude V of the voltage.

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41.90.+e : other topics in electromagnetism ; electron and ion optics

1 Introduction

In this article, we describe a second experiment devoted to the problem of the effect of an electrostatic potential on the inertial mass of a charged particle. This effect, stemming from Weber's theory of electromagnetism, has been theoretically described by Assis [1] and Costa de Beauregard [2]. In our previous experiment [3], a glow-discharge plasma (neon lamp) was used to evidence the mass defect of an electron placed inside a charged spherical shell.

In the present experiment, the frequency of Barkhausen-Kurz oscillations [4] is used as a mean of observation of the electron motion. *The principal distinction between these experiments is that in the first one we investigate the behaviour of a glow-discharge plasma but now we have to do with a pure flux of mobile elctrons.*

The Barkhausen-Kurz oscillator, which may be considered as a forerunner of high frequency generator tubes, is based upon the oscillatory motion of the electrons in a valve, around a positive grid placed in front of a less positive anode (see fig.1) (retarding field configuration).

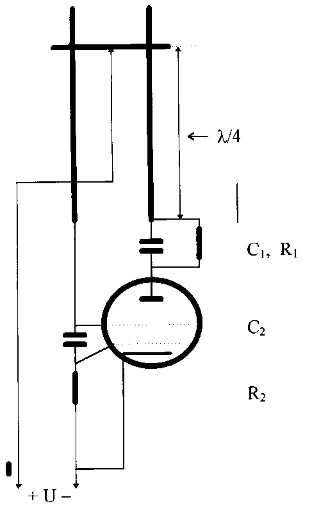

Figure 1: Barkhausen-Kurz's generator. The valve type is 6Э5П. The anode-cathode distance is $\ell = 0.6$ cm. The voltage u (see text) is 108 V. The frequency at $V = 0$ is $f_0 = 256$ MHz (wavelength $\lambda_0 = 117$ cm). $R_1 = 12\mathrm{k}\Omega$; $R_2 = 1.3\mathrm{M}\Omega$; $C_1 = C_2 = 24$ pF.

The frequency of these oscillations is essentially governed by the transit time of the electrons from the cathode to the anode. It is given by [5,6]:

$$f = \sqrt{\frac{e\,u}{2m}}\,\frac{1}{\ell} \tag{1}$$

where e is the electron charge, m is the electron mass, u is a fixed voltage difference between the second (positive) grid and the anode, and ℓ is the cathode-anode distance. As regards the m dependence of f, one gets :

$$f = \frac{A}{\sqrt{m}} \tag{2}$$

where A is a constant characteristic of the tube.

From Ref.[1] it follows that when a particle of charge e and mass m_0 in free space is placed anywhere inside a spherical shell biased at some Coulomb potential V – the potential being chosen such as it is zero at infinity – then it has an *effective* mass m given by :

$$m = m_0 - m_w \tag{3}$$

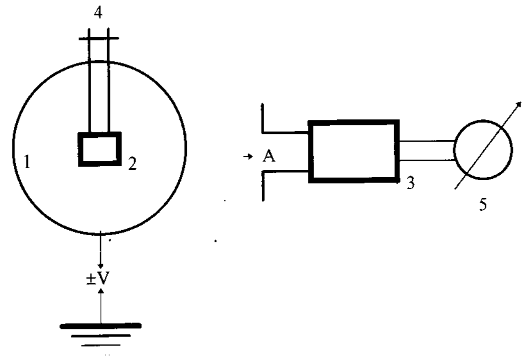

Figure 2: Scheme of the experimental set up : (1) is the spherical shell (it is an In-Ga coated glass sphere) ; (2) is the Barkhausen-Kurz generator ; (3) is the receiver of antenna (A) ; (4) is a quarter-wave resonator ; (5) is a microammeter (output current I).

where, in this special geometry, the quantity m_w, called the Weber's mass, is :

$$m_w \;=\; \frac{eV}{3c^2} \tag{4}$$

Hence if e and V have same (opposite) signs, then a decrease (increase) of the particle effective mass should be observed. From Eqs (2-4), we get :

$$f \;=\; A\, m_0^{-1/2}(1 \;-\; m_w/m_0)^{-1/2} \tag{5}$$

Using realistic experimental conditions, one has : $m_w \ll m_0$, therefore :

$$f \;\approx\; A\, m_0^{-1/2}\left(1 \;+\; \frac{eV}{6m_0c^2}\right) \;=\; f_0\left(1 \;+\; \frac{eV}{6m_0c^2}\right) \tag{6}$$

where f_0 is a constant representing the frequency obtained for $V = 0$. According to this last formula, a change of the electric potential V of the sphere results into a change of the frequency f. This is the basic principle of our experiment.

2 Experiment

A scheme of the experimental device is shown in Fig. 2. The radio-frequency emitted by the Barkhausen-Kurz generator (2) supplies a $\lambda/4$ short-circuited portion of a transmission line (4). The generator itself is placed inside the spherical shell (1), whereas a part of the quarter-wave stub lies outside this shell, which allows us to detect the radiation emitted by the generator by means of an antenna (A) connected to a receiver (3). The distance between the shell and the receiver is typically a few meters. The spherical shell itself consists of a glass sphere coated with In-Ga.

The receiver signal, i.e. its output current I, is proportional to the frequency deviation Δf : $I = k\Delta f$, where k is a controlled parameter, depending in particular on the tuning and on the frequency response of the receiver. Under such conditions, absolute measurements would require a calibration of the detector, namely an exact knowledge of the k factor. This is not our goal, at least at present. Nevertheless, an estimation of this factor can be obtained from the plot of I as a function of V: $k \approx 10^{-3}\mu$A/Hz. The output current has the form :

$$I = k\, f_0\, \frac{e}{6m_0c^2}\, V = B\, V \tag{7}$$

where B is an apparatus constant. Finally this linear variation of I as a function of V is a direct consequence of Eq. (4) and it can be used to test its validity.

The retarding-field valve used as a generator is the 6Э5П tetrode . With such a tube, the grid-leak circuit (R_2C_2) is a necessary element for cathode current limitation. Other choices are possible : any other valve able to work as a Barkhausen-Kurz generator in the frequency range 200-400 MHz is usable. The criterion to get oscillations takes the general form (readily derived from Eq.(1)) : f^2/u =constant. Moreover a frequency within the prescribed range can always be obtained by a proper choice of the distance ℓ. An interesting alternative would be the use of a reflex-klystron generator.

The output current I of the receiver has been measured as a function of the potential V of the spherical shell in the range 0 – 1.25 keV. The results are shown in fig.3. Each point in this figure is actually a group averaging of 15 measurements the dispersion of which is less than 10%. The two sets of points (solid and open circles) correspond to two distinct experimental runs. It is seen that the experimental data fit well with a straight line, in good agreement with Eq. (7). Therefore we can consider that the V-dependence of the Weber's mass (Eq.(4)) is confirmed by the experiment, at least in relative values.

One may notice that in fact the use of a R-F oscillator allows us a wide variety of detection modes. For example we successfully used a low-frequency (in the acoustic range) alternating voltage : $V = V_0 \sin\omega t$, giving rise to a frequency modulation of the carrier frequency of the generator. The effect can be then observed (heard) in the output signal of a receiver operating in the FM mode. More accurate measurements should be performed by using the beat note between the generator frequency f and the fixed frequency f_s of a standard generator.

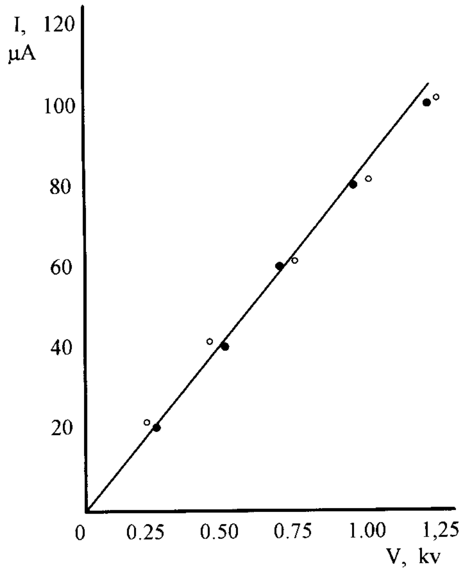

Figure 3: Plot of the output current I as a function of the voltage V on the spherical shell. The experimental points are the group average of 15 measurements, the dispersion of which is about 10%. The 2 sets of points (solid and open circles) correspond to 2 independent experimental runs.

3 Conclusion

In the present experiment, the contribution of a field-less electrostatic potential V (the origin of which being such that it is zero at infinity) to the electron inertial mass has been clearly evidenced. A linear dependence on the potential of the mass change has been observed, in agreement with the theoretical prediction. This new independent experiment entirely confirms the results obtained in an earlier experiment using an afterglow discharge [3]. Up to now, both experiments show the existence of the mass change and its linear dependence on V. Obviously a decisive progress would be to perform an absolute measurement of the Weber mass and definitely confirm the theory.

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