The Wave Structure of the Electric Field

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Maxwell's equations describe the interactions of the electromagnetic field at a macroscopic level. In the 1920s, Louis DeBroglie demonstrated that every moving particle (including an electron) has a wave nature, and we know from Einstein that every wave has a particle nature, which we call the photon. Later in the 1930s, Paul Dirac's development of the famous Dirac equation showed the quantum nature of the electron at relativistic speeds. Then in 1948 Richard Feynman and Julian Schwinger extended these concepts in the development of quantum electrodynamics which gives a full accounting (although a very strange one) of how an electron can borrow energy from the vacuum of space and return it legally as long it does so within limits of the uncertainty principle.

If Maxwell put his finishing touches on his equations over 120 years ago and Feynman worked out many more concepts of quantizing the electric field only 50 years ago, could it be that the final chapter has been written on quantum mechanics and electromagnetism? Dr. Carver Meade of California Institute of Technology believes there is still more to write. In his book "Collective Electrodynamics" Dr. Meade describes the nature of the electron not just as a wave from DeBroglie's definition of a moving particle, but rather he shows how the electron is always a wave even when it is not moving (essentially a standing wave).

Erwin Schrödinger, author of the famous Schrödinger equation, felt that his wave equation which governs most of quantum mechanics, described an actual wave in space when he stated, "What we observe as material bodies and forces are nothing but shapes and variations in the structure of space. Particles are just schaumkommen (appearances)."

Based on these concepts, an experiment has been devised to test the wave nature of the electron by measuring the interference of many stationary electron waves (an electric field) with a gamma ray that has the same wavelength as the Compton wavelength of the electron (2.4×10^{-12} m). The theory is that a high-intensity electric field will consist of many electron standing-waves which provides a greater probability for interference with a gamma ray of the same wavelength, which is also easily detected by a Gieger counter.

We first look at the matter waves of an electron, which has a charge of 1.6 x 10^{-19} Coulombs and a mass of 9.11 x 10^{-31} Kg. The Compton wavelength of the electron is found as:

$$mc^2 = hc / \lambda \qquad (1)$$

Where h is Planck's constant, m is the mass of the electron, c is the speed of light and $\lambda = 2.4 \times 10^{-12}$ m. This is the theoretical wavelength of the standing waves in the electric field which will interfere with the gamma ray source. For the gamma ray source we choose Na-22, which is also known as a positron emitter. The nucleus of Na-22 emits positrons - antimatter versions of the electron which, when they interact with other electrons, will annihilate both the electron and positron and produce two gamma rays which each have a wavelength of $\lambda = 2.4 \times 10^{-12}$ m. Cs-137 is also a gamma source that can be used for this wavelength.

The experimental arrangement is shown in Figure 1. Gamma rays produced by the annihilation of matter and antimatter are generated from the source at exactly $\lambda = 2.4 \times 10^{-12}$ m, which then pass through the electric field to reach the Geiger counter, which has a metal shield to reduce the effects of the electric field during operation. The gamma rays have a higher probability of interference with the electric field as the angle of trajectory of the gamma rays relative to electric field lines approaches zero. The experiment is setup so that the incident angle is 10 degrees. The equipment used in the experiment is the following:

1. United Nuclear Digital Geiger Counter (measures 0-999 micro-rems/hour)
2. Na-22 laminate disk sources (1 microcurie each - Spectrum Techniques)
3. Tesla coil at 50 kV with + and - terminals attached to two parallel plates (6" x 6") spaced 17" apart.

The apparatus supplies an electric field (50 KV) between two square (6" x 6") plates and a Na-22 gamma source is placed on one side of the plates. A digital Geiger counter on the other side of the plates measures the counts from the gamma ray source (40 seconds of averaging are included in all measurements). The gamma rays have to pass through the electric field to get the counter. In its measurement position on one side of the high-voltage plates, the Geiger counter shows a background radiation (no source present and electric field turned off) of 18 counts.

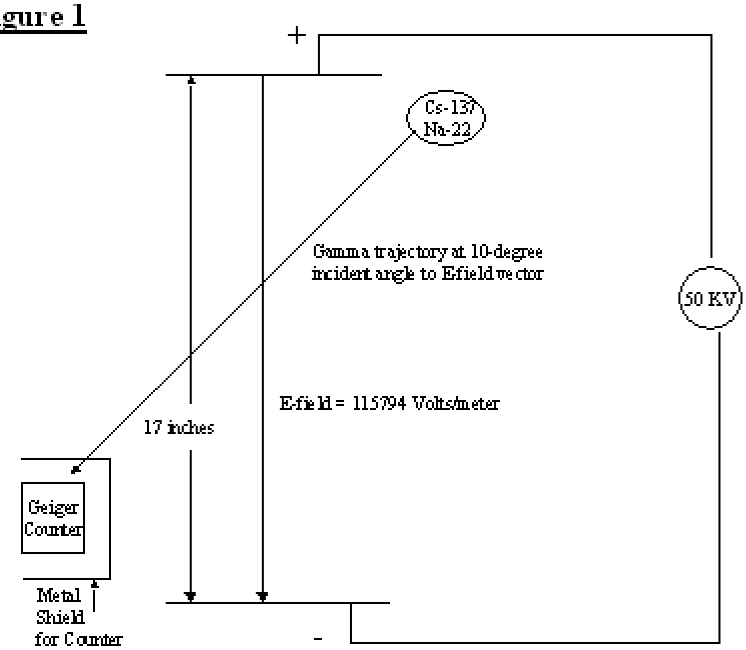
A control on the experiment is implemented to remove the effect of the electric field on the Geiger counter (which is reduced somewhat by the shielding to begin with). In the control, the gamma ray source is removed from the environment but the Geiger counter remains in its designated position measuring background counts. With the electric field off in the control case (no radiation source present), the counter reads 18 counts which is effectively the measured background. When the electric field is turned on the Geiger counter shows an increase from 18 to 22 counts (20% increase) and it decreases again to 18 counts when the field is turned off (20% decrease).

Next, the Na-22 source is placed on the other side of the electric-field plates from the Geiger counter so the path of the gamma rays to the counter is intersecting the field vector at a 10 degree angle. The electric field is turned on and the counter then reads 24 counts. The electric field is turned off and the counter goes up to 30 counts. The experiment is performed seven times giving a consistent result (see Table I).

Electric field Parameter	**Gammay ray source absent**	**Gamma ray source present**
Electric field off	Measured 18 counts (background)	Measured 30 counts
Electric field on	Measured 22 counts (experimental control)	Measured 24 counts

Table I Experimental Results

Figure 1



The results of the experiment are consistent with the hypothesis that the electric field is interfering with the gamma ray source. The Geiger counter readings decrease when the electric field is present and increase when the electric field is turned off. When the gamma ray source is not present the electric field works to increase the count value (it causes false activity). The counter never decreases in count when just the electric field is present - it only decreases when radiation is passing through the electric field to the counter. This agrees with the theory that the electric field is interfering and attenuating the gamma ray source.

The questions first asked by Louis DeBroglie and Erwin Schrödinger are still being investigated today by Carver Meade and others who question exactly the wave nature of a particle. Richard Feynman once said "I think I can safely say that nobody understands quantum mechanics". This implies that we need to do more experiments like the one described above in order to understand the underlying nature of waves and particles.