Model for Understanding the Substructure of the Electron

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Using a simple electromagnetic model, the electron is described as circulating electromagnetic wave with an internal twist as Moebius ribbon. Mathematically, the Moebius loop is required for the spin ½, as the model requires two revolutions to fulfill one phase. The positive half wave stays on the inside and partly compensates itself in a way that the negative field of the wave always is on the outside. The ratio of the field energy responsible for the charge to the total particle rest energy is the dimensionless figure 1/137, which is the fine structure constant. The model of the rotating photon does not contradict current models and offers a great simplification by using a deterministic mind set.

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Introduction

Various disciplines of physics have been concerned with the investigation of structure and reactions of leptons and hadrons for decades. Higher and higher energies were used in order to examine matter with increasing resolution. Despite the tremendous intellectual and financial effort, however, a realistic model or a physical description of the fundamental quantum characteristics of a quark or electron, as spin or charge, has not been found yet. There is a strong motivation to find a model of the electron since its discovery, from the begin of elementary particle physics to basic lectures of physics and chemistry at today's universities. R. Gross[1] describes several approaches to find reasonable properties of the electron based on the classical electron radius and states that they "lead to no reasonable result" applying laws of classical physics. Even if physics and chemistry can exactly describe the probability distribution of the electrons around the nucleus it is still open of what they describe the probability of occurrence. At present, the electron is a "black box" with abstract quantum properties. The box has an unknown size or diameter, it has a property called "Spin" and it exhibits two variations of the spin (+1/2 h-bar and –1/2 h-bar), each time it enters an asymmetric magnetic field. It shows an external electrical field which is not correlated with its mass or spin and is defined as the elementary constant e^-.

Several approaches for a quantum reality of the electron have been published, e.g. a model with mass less particles circulating each other with the speed of light[2] or a model which regards the electron as a solid charged shell rotating with the speed of light[3]. These models, however, cannot predict the elementary charge or the correct spin nor could the existence of the mass less particles be proven. A solid shell or mass, however, has never been observed to move with c, either.

A model of the electron should further be able to reduce the number of the elementary constants (now approx. 20)[4]. If merely the electron mass, spin or elementary charge could be correlated with each other this would be regarded as substantial progress according to some authors[5,6].

The Electron

What is the electron? What is a rotating charge cloud with a negative electrical field, which behaves like a wave in interference experiments and can expel photons from some substances? Such a structure or particle wave electron could be imagined, if the negative field of the electron were formed as part of an electromagnetic wave, in which the negative part of the electrical field always is on the "exterior" and where the positive half wave remains on the inside somehow hidden, i.e. a rotary or „wound up" photon. The energy of the electromagnetic field entirely forms the mass equivalent of the electron in this model.

How does the field of an electromagnetic sine wave look like? The electric field is defined as the direction in which a test charge would move; the intensity of the field per definition corresponds to the acceleration the test charge is subjected to. Along the path of the wave, the field strength corresponds to the classical sine wave as given in fig. 1.

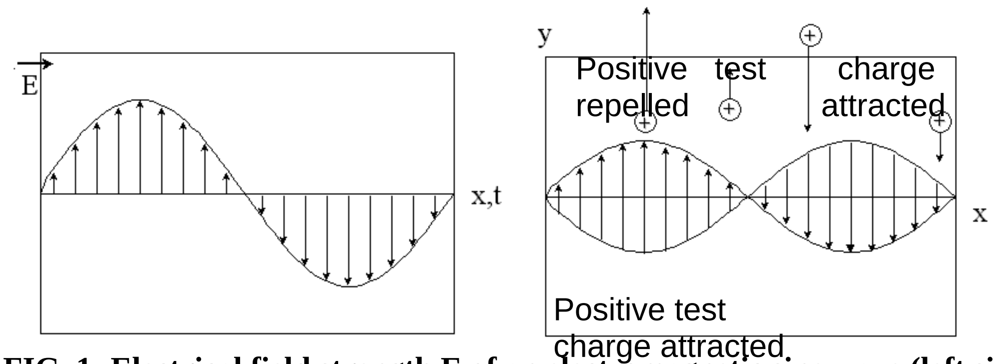

FIG. 1: Electrical field strength E of an electromagnetic sine wave (left side). Right side: Vector field of E in the x-y plane (z-axis out of plane): the vectors give the direction and magnitude of the acceleration of test charges

If looked at in space (Fig. 1 right side), the field has an underside, and the field strength is defined as the length of the vector. The positive test charge above the x - axis (x-z - plane) is repelled by the field of the positive half wave into the direction of the arrows, i.e. the field of the positive half wave acts like a positive charge "above" the plane. The same test charge, however, is drawn upwards, if placed below the path of the wave in the x-z plane. This, per definition, is the action of a field that attracts the positive test charge, a negative field. The following negative half wave now attracts the positive test charge above, but acts as positive field geometrically below the plane.

A possible construct for a particle that is "always" negatively charged (on the outside) and has the positive part somehow hidden on the inside can be imagined, if the wave turns upside down after one half phase. Fig. 2 schematically shows a Moebius ribbon as path of such a circulating electromagnetic wave with one internal torsion per revolution. The ribbon could also be a segment of a spherical wave in reality, but the internal twist of the zero transition is harder to visualize in a sphere. Therefore the model of the ribbon is kept in the further. The field intensity has the maximum of one half sine on the right and a zero transition. It shows the internal torsion of the Moebius ribbon. The field is perpendicular to the surface; the normal vector would give the direction, in which an assumed test charge would move.

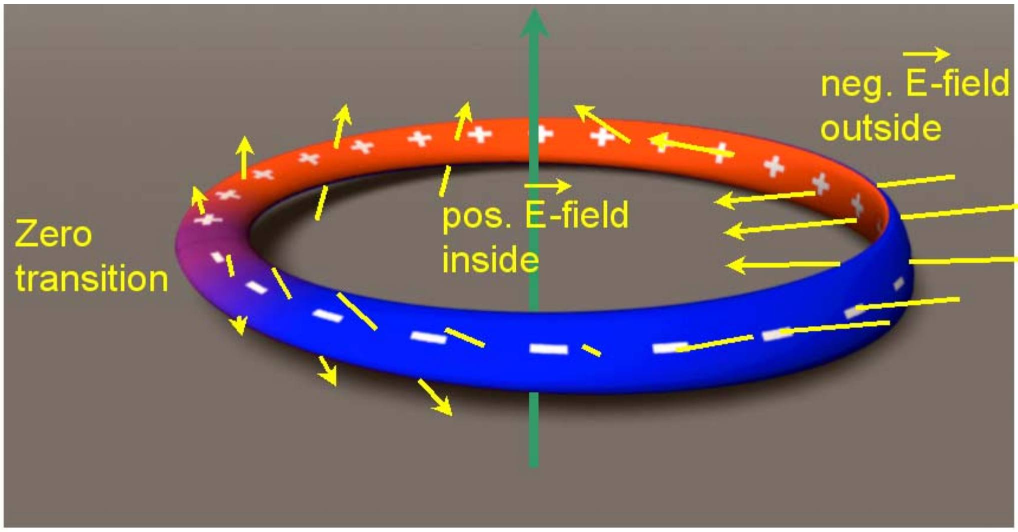

FIG. 2: Path of the rotating electromagnetic wave forming the electron in shape of a Moebius ribbon. The field strength and field direction are drawn in as arrows

Although there are no smaller test charges than the electron itself, this is a permissible thought experiment. The internal torsion of the Moebius ribbon ensures that only the negative half wave is outside and after zero transition the „lower surface" of the positive half wave is on the outside, which is again negative from their effect.

The field of any photon or wave is compensated in the long range effect over space and time by the field of the next half wave, so it is electrically neutral. The rotating construct discussed here should be neutral, too. However, the positive inside field - in case of the electron - propagates through the diameter. The field component which is exactly in the plane is counteracted by the positive field of the next revolution pointing in the opposite direction. All out-of-plane positive and negative field effects are assumed to compensate themselves in larger distances, too. The field strength in radial direction E_r of the Moebius ribbon surface is

$$E_r = E_o \cdot \sin \varphi/2 \cdot \sin\varphi/2 \qquad \text{Equation (1)}$$

which mathematically always is positive. The field strength E decreases with $1/r^2$, which is not regarded in the graph below in the first place.

Fig. 3 shows the vectors in the plane of rotation of the wave for an assumed starting time t = 0 and for the time, when the effect of the positive field emitted at t = 0 has reached the other diameter with c. The wave then has passed an angle of 114.59 degrees, at which the arc length equals the diameter. A certain fraction of the external negative field then cannot be compensated in the long range and forms the external field of the particle. This fraction will be assessed mathematically below.

This rotating photon of the current model is suggested to be called “c-tron” because of the peripheral speed of light c.

Properties and Variations of the C-Tron

The field rotates around its axis - therefore the particle has a spin. During one revolution of the field along the path of the Moebius ribbon only the first half of the sine wave is accomplished. The second half wave is completed after the internal turn during the second revolution. It is a very remarkable property of this model that two revolutions are necessary, in order to accomplish a full cycle or phase. This is the definition of the spin 1/2! The fact that some quantum particles need 2 revolutions to perform one full phase fills pages in physics books. The strange phenomenon is described with the analogy as if the earth needed 720 instead of 360 degrees to have turned completely. This abstract quantum feature clearly is met by this model.

The ribbon loop can exist in two variations: with an outward torsion with respect to the direction of revolution and with an inward torsion seen in the same direction. The same can be imagined for the positron. If the field rotation is counter clockwise in Fig. 2, the torsion is shown as outward. An additional magnetic moment results from the change of the field orientation at the zero transition. This additional moment is different, if the torsion goes inward. In an external magnetic field, this moment will divert the c-tron either “up” or “down” in the magnetic field, representing the "spin up" and "spin down“ leptons. The particle further can have the negative field or the positive field on the outside, thus representing the electron or the positron (see Figs. 2 and 4). The field of a circulating wave without internal torsion is negative in one revolution and positive within the next one, thus altogether neutral and regarded a candidate for the neutrino.

The model offers photons and leptons in a unified structure: as linearly propagating photons and as circulating photons or c-trons. The latter occur with internal torsion as electrons or as positrons, each with spin up or down, or consequently as neutrinos with no internal torsion.

The change of the electric field induces a magnetic field which has its maximum at the zero transition of the electric field. It can be imagined that a closed loop of the magnetic field is formed - see fig. 4.

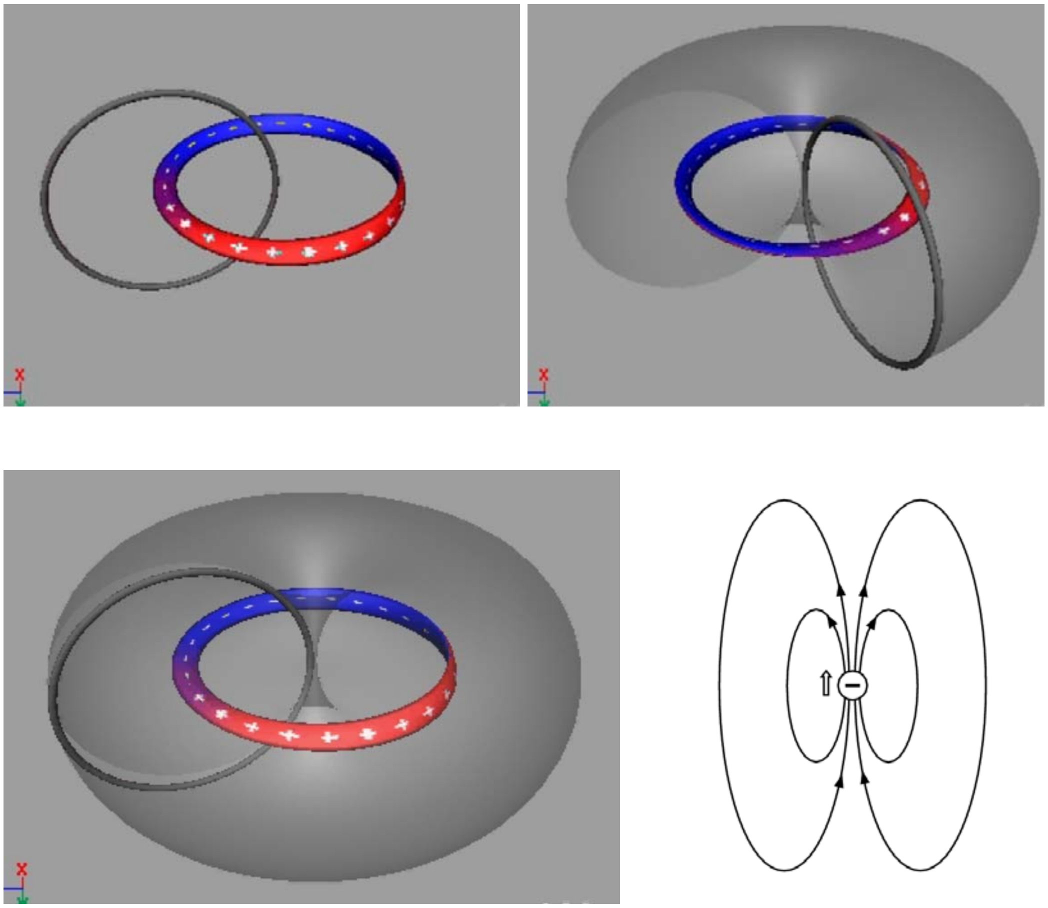

FIG. 4: Schematic formation of the magnetic field of the positive c-tron in three steps with the classical notation of the electron as tiny magnet (lower right).

The similarity with the well known picture of the electron as small bar magnet is compelling. The paths of the magnetic fields form a figure "eight" during one full phase and the electric field passes the circumference twice. It is this synchronizing of the radial frequency of the magnetic field with the tangential frequency of the electric field that might ensure the stability of the particle.

This model of a circulating wave so far shows all characteristics of the electron:

- A negative electrical field on the exterior
- its positive antiparticle
- a spin and a magnetic moment, north and south pole
- the spin amounts to 1/2, as 2 circulations are necessary for a full phase
- the electron mass as per $E = m_{el}\, c^2 = h\,\nu$, which can "impact" to other materials and interact like a particle
- may behave like a wave in interferometer experiments, as it is a wave

Radius Determination from Spin

As a test of this model it is examined whether characteristics like the spin are associated with the mass of the electron, if the mass equivalent of the electromagnetic field rotates with speed of light „c". The classical electron radius is derived from the capacity of the electron as sphere condenser with charge e:

$$r_e = \frac{e^2}{4\,\pi\varepsilon_0 m_e c^2} = 2{,}81 \cdot 10^{-15}\,\text{m}$$

Equation (2) after: Mohr & Taylor[7]

The equatorial peripheral speed v of this classical electron would exceed the speed of light in several approaches, although it is a postulate of quantum mechanics not to contradict the classical mechanisms. The classical approach leads to "no meaningful result" according to the own statements of modern physics (R. Gross[8]).

The peripheral speed „v" in the current model is assumed as speed of light „c". This approach is strictly forbidden according to the standard model, since no „mass" can move with speed of light. Only „mass less" particles or photons which nevertheless are provided with an exactly defined mass/energy equivalent can move with c. If the approach is wrong, it should therefore lead to an unreasonable result.

The angular momentum L of a mass (e.g. m_{el}) around an axis and the radius r is defined as: $L = r \cdot m_{el} \cdot v$

The mass of the electron m_{el} (= field energy $/c^2$) rotates with „c" around the radius "r" in a first approximation. With v = c and with m_{el}=0,51 MeV/c^2 the angular momentum L becomes $L = r \cdot m_{el} \cdot c$ $\quad$ $L = r\,(0{,}51\,\text{MeV}/c^2) \cdot c = r \cdot 0{,}51 \cdot 10^6\ /c$.

The electron spin is defined as $L = 1/2 \cdot h/2\,\pi$. Now the radius is the only unknown parameter and can be calculated:

$$r = \frac{1}{2} \cdot \frac{h}{2\,\pi\, m_{el}\, c} = \frac{1}{2} \cdot \frac{4{,}14 \cdot 10^{-15} \cdot 3 \cdot 10^{8}}{2\,\pi \cdot 0{,}51 \cdot 10^{6}} \quad \left[\frac{\text{eV s m}}{\text{eV s}}\right] \qquad \text{Equation (3)}$$

which gives $r = 1.93 \cdot 10^{-13}$ m .

This radius corresponds to a measured value for the scattering of an individual photon at the electron. The quantity $d = 2\,r = 3{,}86 * 10^{-13}$ m is well known as Compton wavelength and also has been determined as electron diameter by Giese[9] and Mills[10]. What, if the Compton wavelength were more than a historical observation without further meaning? It should be considered that the analysis of atomic distances with x - rays is a usual procedure in physics and e.g. metallurgy. The measured Compton wavelength according to this model becomes a measurement of the diameter of the circulating wave of the electron.

The computation of the electron radius from the spin as rotation of the mass/ energy of the electromagnetic field with speed of light "c" around the radius "r" leads to a meaningful result in contrast to classical computations of the electron radius.

There are plenty of data suggesting that the diameters of electrons, protons or neutrinos are below a certain size of e.g. 10^{-15} m. This would certainly be correct if looking for the small "stone with charge". It should be regarded, however, that the diameter will decrease at increasing energies of the particle/ c-tron. An electron accelerated to 1 GeV total energy has a diameter of 1.9 * 10^{-16} m according to eq. 3, which perfectly fits to the current model and to the observations concerning measured particle diameters or effective cross sections at high particle energies.

The radius determined before has to be compatible with the classical quantum physics observations as the de Broglie wavelength and the mass energy equivalence. One full phase of the c-tron of the current model is completed after passing the circumference "C" of the particle twice, i.e. $\lambda = 2 \cdot C = 2 \cdot \pi \cdot d$. With the electron diameter d = 2 r = 3,86 * 10^{-13} m derived from the spin, the wavelength can be calculated to λ = 2.425 * 10^{-12} m and with $\nu = c/\lambda$ the circulation frequency of the particle in rest to $\nu_0 = 1.237 \cdot 10^{20}$ Hz. It is interesting that this rest mass frequency often is cited in physics books, but its nature rarely is explained or commented[11].

In a very clear way the natural frequency ν_0 by de Broglie for an electron in rest gets a realistic meaning as the true frequency of the c-tron of the energy $E_0 = h\nu_0$.

In the model, the c-tron wavelength of $2.4 \cdot 10^{-12}$ m differs from the de Broglie wavelength of an electron of 1 eV (5.92 10^5 m/s) of ca. 10^{-9} m. The de Broglie wavelength of a moving particle, however, is interpreted as the group velocity of matter waves. It is assumed that the displacement of the **E** - field maximum of the circulating wave for a certain particle velocity is identical with the de Broglie wavelength.

The fraction 1/X of the field energy of the c-tron that forms the external charge to the total field energy $E = h \cdot \nu_0$ can be calculated. The electron is regarded as sphere capacitor with the stored energy E = ½ Q^2 /C.

$E_{charge} = 1/2\, Q^2\, /C = 1/X \cdot h \cdot \nu_0$. With the capacity $C = 4\,\pi\,\varepsilon_0 r_{el}$, the charge Q is

$$Q = \sqrt{\frac{1}{X} 2\, h\nu_0\ 4\pi\varepsilon_0\ r_{el}} \qquad \text{Equation (4)}$$

With the values for the de Broglie frequency ν_0, the electron radius r_{el} determined above and the factor 1/X = 1/137, the electron charge is calculated correctly to 1.603 10^{-19} C. The dimensionless fraction 1/X equals the fine structure constant α, whose derivation may have been similar to the above approach. The figure 1/137 could be coincidence, too. If, nevertheless, the known formula of $\alpha = e^2 / 2\,\varepsilon_0\, hc$ is inserted into eq. 4, the product inside the root equals to $e^2 \cdot 1$ and Q = e. The coupling constant

. α perfectly confirms the current model.

Above approach is regarded the quantum realistic origin and meaning of the coupling constant as the ratio of the electric field energy forming the charge of the electron to the total field energy $h \cdot \nu_0$.

Conclusions

The interpretation of the electron as a circulating wave or photon leads from one elementary constant, the spin of the electron, to the elementary charge using another well known dimensionless factor, the fine structure or coupling constant. It gives a realistic meaning to the spin up and down characteristics and provides an approach for the neutrino.

The model solves the mystery of the application of the equation $E = h\,\nu$ to solid matter, which led to the wave aspects and the de Broglie wavelength of matter. At the same time it opens a door to the equivalence of energy and matter itself, $E = m\, c^2$. Electromagnetic energy and matter are equivalent because they are of identical nature, at least shown for leptons so far. The application to hadrons or quarks in a similar approach is assessed elsewhere[12].

The consequences of the model are the following:

- The particle can behave as a wave, as it is a wave. Nevertheless it has the mass of $m=E/c^2$, which can cause all effects a solid particle can cause.
- As the field revolves with the speed of light c, a macroscopic prediction of the results other than with the statistical methods of quantum mechanics is hardly possible.
- The Zeeman Effect is the effect of the c-tron oscillating around the nucleus in reality.
- There is a real sense of rotation in c-tron particles. In collision experiments, a parity violation must be observable due to superposition of the local field strength – The decay of W+ or W- particles exactly shows this effect: These can only decay into leptons with matching helix direction[13].
- The fine structure constant $\alpha = 1/137$ is the fraction of uncompensated field energy (charge) to total field energy. α should therefore increase, if the proportion of the total rotating field that is effective for an interaction increases e.g. for small distances to the rotary electromagnetic field or for high energies. This is exactly what is found[14].
- The model describes matter as closed loops of electromagnetic waves, which do not have a point like centre and therefore are free of singularities. Mathematical problems in dealing with point-like mass concentrations therefore are eliminated.
- The old question why the electron accelerated on its path around the nucleus shows no emission of energy is solved: no charge circles the atom but an electromagnetic wave with some excess field on the outside.

The model presented is based solely on the definition of the electric field itself and on classical equations of physics and early quantum physics. The model offers a great unification and simplification for the quantum world of the leptons so far.

Experimental Verification

Experimental verification to verify or falsify a basic concept is required for every new theory. Absolutely identical to proposing new experiments is the requirement that a theoretical model shall fulfill the results of experiments already performed – if it offers simplification compared to the assumptions required by the old theory.

The natural and realistic explanation of the spin 1/2 is a strong aspect in favor of the current particle model. The experiments proposed would have been to observe the spin balance in particle collision experiments and watch for the law of spin conservation with the postulated spin ½ for the electron.

All formulations and correlations between e.g. charge and fine structure constant have already been found. The formula for α had been found earlier – but with what interpretation? Here the interpretation is given in a simple and realistic way.

An oscillating movement of the electron and the interaction with the magnetic field of the nucleus - the Zeeman-effect - already has been discovered. Fine and hyperfine structures in the spectra of light emitted by atoms had been found and interpreted in this way. In the c-tron model it can easily be visualized that each of the small loops or ripples on the orbit[15] corresponds to one field rotation with the De Broglie frequency.

The Moebius ribbon has another remarkable property, which was found experimentally: a set of eight paper ribbons was produced, which were marked with a polarity – red or black for positive or negative field, both pointing up and down, all twisted either to the left or to the right before closing the loop with paper adhesive in identical manner. Table 1 shows the results of this little experiment.

marking (inside)	-	-	-	-	+	+	+	+
spin direction	↑	↑	↓	↓	↑	↑	↓	↓
ribbon twist	←	→	←	→	←	→	←	→
particle polarity outside	e+	e+	e+	e+	e-	e-	e-	e-
seen clockwise	cwi	cwo	cwi	cwo	cwi	cwo	cwi	cwo
seen counter-clockwise	cco	cci	cco	cci	cco	cci	cco	cci

TABLE 1: All possibilities of making a paper strip Moebius ribbon. “cwi” and “cwo” is seen clockwise with inward, respectively outward torsion, “cci” and “cco” are the same seen counter-clockwise.

There are four positive and four negative combinations. Basically they contain two groups either being the clockwise inward or clockwise outward type. Each particle has the property “inward” torsion and “outward” torsion at the same time. It shows an inward twist if observed from one side and outward twist if seen from the other side in space. This means that each beam of electrons will sort itself into two beams in a Stern – Gerlach experiment. Each split beam, which is allowed to loose its orientation in space (having been aligned by the magnetic orientation), will have – again – both properties of inward torsion and outward torsion depending on the orientation of the individual particle as it enters a next quantum separator. This is exactly what is been found experimentally.

As usually a continued split up of every filtered beam in two beams is observed, it might be worth while looking at the results under the aspect of the current model. The + and – spin directions classically should be identical in magnitude and energy and differ only in the sense of rotation. The c-trons might show different energy levels with the twist inward or outward and stay that way if filtered once. Any splitting of the beam from then on would have to be attributed to a randomization of the orientation between the filters and a sorting in the next magnetic field depending on how they enter this field. There are experiments to verify the model, e.g. the existence of the two basic versions of the electron with torsion outwards and torsion inwards to give an additional magnetic moment. It already has been performed - the Stern Gerlach experiment led to the description of the properties "spin up" and "spin down".

Experimental verification of the proposed model can be performed with a Stern - Gerlach type of experiment, too, where first the clockwise-inward are sorted from the clockwise outward electrons. Then one beam can again be sorted in two, if the electrons are allowed to randomize - e.g. by thermal movement, by interaction with other magnetic fields or by gaps in the magnetic field keeping the alignment.

If, however, the electrons are e.g. cooled and the orientation in the magnetic field constantly is kept aligned, the filtered beam should not spilt in two, again. Extremely low energy electrons with low beam densities should be preferable in this test, no interaction with magnetic fields of nearby atoms or neighboring electrons can be allowed.

Proposed for verification further is a three dimensional, time dependent field simulation to show the statistical - like behavior of the c-tron in collision experiments. It cannot behave other than the observed quantum waves; however, interactions are strictly local and causal.

Second, mathematical integration over volume and time of the field of the wave circling the Moebius ribbon (e.g. based on eq. 1) is proposed. It should prove that 1/137 of the total field-energy and mass equivalent of the electron of eq. 2 are sufficient to form the field of the elementary charge, stipulated that E_0 is determined from another source.

There is no accepted formulation for the structure of the electron, rather than effort to avoid this crucial question by using the abstracted "black box" with quantum properties. The current formulation of the electron is a basic concept and is not in contradiction to accepted theories.

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