CHAPTER 6

The Quantum Underworld

Introduction

The underworld of space, that invisible medium which pervades what we call the 'vacuum', but which we are here bold enough to refer to by its proper name, the 'aether', is the seat of quantum activity, the physical forum in which energy is packaged into quanta which have interplay with matter at the atomic level.

The best known energy quantum in physics is that denoted $h\nu_o$, where h is Planck's constant of action and ν_o is the Compton electron frequency. Tables of physical data usually list the measured value of the Compton electron wavelength as $2.42631058(22)x10^{-10}$ cm, along with the speed of light $2.99792458x10^{10}$ cm/sec, from which one calculates that ν_o is $1.2356x10^{20}$ per second.

That energy quantum $h\nu_o$ is equal to the rest-mass energy m_ec^2 of the electron and so the aether is the stage on which the electron and its partner the positron are created, perform and then may die by mutual annihilation. The aether is a world seething with energy, but energy that is, in the main, held in a state of equilibrium, with a very small proportion of it involved in fluctuations as it searches for a stable home in the vastness of space.

Now, much of this chapter will merely repeat what I have disclosed in chapters 6 and 7 of my book *'Physics Unified'* published in 1980, where I began by explaining that in 1932 Dirac delivered his Nobel prize lecture under the title: *'The Theory of Electrons and Positrons'* in which he said:

> 'It is found that an electron which seems to us to be moving slowly, must actually have a very high frequency oscillatory motion of small amplitude superimposed on the regular motion which appears to us. As a result of this oscillatory motion, the velocity of the electron at any time equals the velocity of light. This is a prediction which cannot be directly verified by experiment, since the frequency is so high and the amplitude so small.'

> I then noted in that work, on p.87, that:
> 'Similar proposals had been made earlier by both Einstein and Schroedinger. Einstein imagined the electron as belonging to a Galilean reference frame oscillating at a frequency determined from the electron rest mass energy and the Planck relationship, and being everywhere synchronous.'

Now, for my part, I cannot accept that electrons can share such a concerted rhythmic motion unless there is something that makes it energetically desirable for them to keep in step, as it were. That something has to be electrical in character but electrically neutral overall and it must be omnipresent, all-pervading and uniform through space. It is, of course, the presence in the aether of that lattice system of charges referred to in chapter 3 as quons and our task now is to explore the form of that aether and discuss the part it plays in governing wave mechanical processes.

Our Aether

Remembering what was said about Earnshaw's theorem in chapter 1, our aether must comprise a uniform continuum of electric charge density σ which is populated by a uniform cubic-structured array of aether lattice particles of unitary charge, here denoted q, and of charge polarity opposite to that of the continuum.

We can set up an electric field in a vacuum, so how might the presence of such a field of uniform strength V affect the aether? It will displace those charges q through a distance D relative to the continuum charge σ. Each charge will move through that distance D as from a point on one side of a planar slice of the continuum to a point on the other side of this planar slice.

Since the relative spacing between those charges q will be unchanged by this collective displacement there will be no change in the Coulomb force on any particle due to the action of its neighbours. They move in register with one another locally and remote actions balance anyway owing to the large scale distortions of the lattice structure governed by the charge producing V and boundary conditions.

By Gauss' theorem a planar slice of charge density σ and thickness D has a total normal electric field density of $4\pi\sigma D$ of which half is directed one way and the other half the opposite way. Hence $4\pi\sigma D$ is the change in field density experienced by a lattice particle in going from O to P owing to the action of the field V. The restoring force on q is therefore:

$$4\pi\sigma qD \quad \text{..... (6.1)}$$

This is equal to Vq. The energy stored by this displacement per charge q is:

$$(4\pi\sigma q)D^2/2 \quad \text{..... (6.2)}$$

because the restoring force rate is linear with displacement. The energy density represented by (6.2) is then found by multiplying by σ/q since the space medium is electrically neutral and there are just as many particles of charge q in unit volume as are needed to balance σ. Thus the energy density is given by:

$$4\pi\sigma^2D^2/2 \quad \text{..... (6.3)}$$

But, since Vq equals (6.1), we know that D is $V/4\pi\sigma$. Putting this in (6.2) gives the energy density:

$$V^2/8\pi \quad \text{..... (6.4)}$$

This is the formula for energy stored by the electric field of intensity V. Its derivation in this way means that the aether as the medium subjected to the action of a system of charge is able to deploy energy from the field of that charge and store that energy by the displacement of those charges q, the quons which form the structured lattice system set in that background continuum of charge density σ. Here then is the basis for the displacement currents we associate with Maxwell's theory. As to the magnetic field properties of the aether, which Maxwell attributes as the accompaniment of the field energy of propagating electromagnetic waves, one should really think instead in terms of the kinetic energy associated with oscillations of the quon lattice system represented by those waves.

Now consider the aether with no externally applied electric field presence and ask yourself whether our basic aether devoid of matter has an energy density. Consider first the energy we associate with electrostatic interaction between σ and the lattice charges q and also that between the q charges themselves and that of the self-interaction of the continuum charge σ. Without engaging in this analytical exercise, which is deferred for the moment, it can be reasoned that each q charge sits in its own cubic cell of charge density σ and that it will be attracted electrostatically towards the centre of that cell. Each such cell together with its q charge forms an electrically neutral unit and so there should be very little electrostatic energy owing to mutual interaction between such cells. What this means is that the net electrostatic energy density of the aether would be negative if such a condition prevailed.

Since it does not seem feasible for the space medium itself to have a state of negative energy density, especially as that state is one where each of those charges q sits rigidly at the centre of each space cell, meaning no motion and no time rhythm, we must, if we are to make any sense of involving the aether in this account of physics, accept that Mother Nature will not allow a negative interaction energy condition to prevail. The fact that we can tolerate negative energy

conditions, as exemplified by the force of gravity and electrodynamic potential where matter is involved, does not affect this argument because these actions are set in what must be a slightly positive energy density background of the aether itself. The positive energy density condition must prevail overall.

A crucial example of this emerges from our later derivation of that factor N as the odd integer 1843 as we come to formulate the theoretical value of the fine structure constant.

What all this means is that those aether lattice charges q are all displaced in unison from the centres of those cubic cells of continuum charge, displaced just enough to assure a positive, rather than a negative overall interaction energy density state. The restoring force involved in this can be set in balance with the centrifugal forces of the q charges, given that they each have mass m_o. This gives us the link between frequency, the timing of their orbital motion around those centres and the radius r of those orbits. We are then well on the way to establishing the role the aether plays in quantum theory.

The aether has become a charge system sustaining the cyclical motion of the system of the aether charges q in circular orbits with the continuum charge and its associated graviton population moving in dynamic balance also in circular orbits. Since the mass density of both the graviton system and the aether lattice charge system is the same, for space devoid of matter, we know that both systems describe circular orbits of the same radius, the radius being designated by the symbol r.

In my book *'Physics Unified'* at page 91, and also in what follows below, I prove this equality of mass density on the basis that the combined kinetic energy of these two systems in their orbital motion is a maximum, consistent with electrostatic interaction energy being a minimum.

The displacement distance between the q lattice system, which we define as the E-frame, and the system of the continuum charge σ,

which we define as the G-frame, is 2r and, from the restoring force expression (6.1), this allows us to write:

$$4\pi\sigma q(2r) = m_o\Omega^2 r \quad \text{..... (6.5)}$$

by equating that force to the centrifugal force. Here Ω is the angular velocity $2\pi\nu_o$.

So we have two frames moving as if they are diametrically opposed to each other in circular orbit of radius r and, by accepting that matter, if present, such as an electron, shares the motion of the E-frame, we can see that all matter has an intrinsic state of jitter at that frequency ν_o.

In his 1929 book *'The Nature of the Physical World'*, Eddington wrote on p. 220:

'A particle may have position or it may have velocity but
it cannot in any exact sense have both.'

This was his way of saying that, when probing in the physical underworld to locate an electron, say, we cannot pinpoint its exact position because it has a high frequency jitter, but here Eddington was referring to the Heisenberg Principle of Uncertainty of quantum mechanics. The experimental support for quantum theory indicated that, for the electron, the product of uncertainty of momentum and uncertainty of position is $h/2\pi$, h being Planck's constant.

So an electron moving in those circular orbits with the E-frame will have an uncertainty of position by as much as 2r and an uncertainty of momentum of $2m_e\Omega r$, the product of which should be $h/2\pi$. This gives us insight into how the aether determines Planck's constant.

If we now ask how the aether determines a characteristic speed c it is fairly evident that a likely candidate is the relative velocity between the E-frame and the G-frame, meaning the quantity $\Omega(2r)$ and so we derive the relationship:

$$r = h/4\pi m_e c \quad \text{..... (6.6)}$$

This is an important step which gives physical foundation for Dirac's surmise concerning the oscillatory jitter motion of the electron, but we now have the quantum underworld of the aether in our sights and the stage is set for detailed analysis of its electrical form.

The Aether: Solid or Fluid?

Historically at the time when the aether was accepted without question, physicists nevertheless pondered on whether it had a kind of solid form or fluid form. Although we cannot sense any resistance to motion through the aether, its property in determining the speed of light was seen in the context of an analogy with the way in which the speed of light through glass or water is a function of the physical structure of those media.

There was a property of the electromagnetic wave that required a feature characteristic of propagation through a crystalline solid and yet our freedom of motion through the aether implied it could only be a fluid, a fluid of extremely low mass density.

Now, instead of trying to force the aether into the mould which we see applies to our material world, we should piece together the clues and accept the aether for what it is. It is a sea of energy with nowhere to go because that energy fills all space, almost all of it having found equilibrium and settled in a state of order, but, thankfully, as mankind would not otherwise exist, there being the ripples and fluctuations occasioned by creation and decay of certain electrical charge components of that aether which keep the aether alive with activity.

It is logical in physical terms for the aether to develop its own crystalline form because that is an optimum energy condition and, as already indicated, it must avoid a negative energy density state and so sustain a state of motion confined to that Heisenberg jitter activity. It must therefore exhibit in some measure the properties we associate with a solid. This does not preclude motion of material objects

present in the aether because those objects may nucleate their own crystalline aether territory, meaning that the aether picture before us is one of a solid moving through a solid. Is that really possible?

The answer is surely "Yes" because we are not here suggesting that energy can move through energy. The energy density of the aether devoid of matter is uniform and we can have two regions of a liquid medium of uniform mass density incorporating a crystal formation, with those crystal formations having relative motion. A laboratory analogy, were we to build it, would be a liquid crystal substance in which the liquid is crystallized by two extraneous electric fields (signifying the presence of matter) moving towards one another. It is not the liquid which moves but rather the factors which determine whether or not it is optimum in energy terms for it to adopt the crystal form. At the collision boundaries the energy would redeploy into other form but its density would remain constant.

There is nothing to be gained by speculating as to the details of such a process. All we need concern ourselves with is the evidence that emerges from the theory. Undoubtedly, at collision boundaries the ubiquitous muons have a way of absorbing energy resulting from mutual annihilation of a corresponding amount of continuum charge and the quons involved in the collision, whereas the ubiquitous muons at the separation boundaries can create new quons and add continuum charge as needed. That assumes that the continuum charge shares any translational motion of the quon lattice. If that assumption does not hold and the continuum charge is truly at rest in an absolute frame of reference, then the muons themselves have to share in the charge balance at those boundaries. The only consideration of relevance here is the fact that energy density of the aether medium remains uniform, whereas the aether lattice inertia is balanced by the inertia of the muons that provide a balance by migrating slowly in the opposite direction.

We will come back to this latter topic of aether lattice particle motion in chapter 9 in the context of the Michelson-Morley

experiment and merely mention here that a reader interested in the formulating the speed of light in terms of aether lattice structure could refer to pp. 102-104 of the author's book *'Physics without Einstein'*, published in 1969.

Electron theory as applied to solids gives a formulation of the refractive index of a substance in terms of its atomic structure, the number of atoms per unit volume and the natural oscillation frequencies involved. A version of the formula is:

$$(c/v)^2 = 1 + \varphi \quad \text{..... (6.7)}$$

where φ is an expression involving parameters specific to that substance. Here v is the speed of light through the solid, which is of course smaller than c. However, if we ignore the presence of that solid material substance by writing φ as zero, then that unity term in equation (6.7) can be said to be the corresponding φ formulation of aether parameters.

There is no escape from the fact that the aether must have structure, which is why our insight into the exception to Earnshaw's theorem, as discussed in chapter 1, meaning the need for that uniform background charge continuum σ is so important.

Planck's Law

Whereas, in deriving (6.4), we were concerned with the effects of the field V set up by an intruding presence of charge disturbing the aether, we now need to consider the dynamics and energy properties of the undisturbed aether. The charges q move in synchronism circular orbits of radius r governed by a balance of centrifugal force and the restoring force attributable to their displacement relative to the continuum charge of density σ. This gives:

$$4\pi\sigma qx = m_o\Omega^2 r \quad \text{..... (6.8)}$$

from (6.1). Here x is the separation distance between the σ continuum and the q charge, m_o is the mass of the quon and Ω is the angular frequency of the aether's rhythmic activity. Thus the expression (x-r) is the orbital radius of the cyclic motion of the graviton and σ

continuum system. The σ continuum and the gravitons are best regarded as an integral system statistically smeared into a uniform whole as far as interaction with the q system is concerned. Since the gravitons are deemed to be relatively massive, they need only have a sparse population compared with the lattice particles, the quons. Let m_g denote the mass of the continuum-graviton system per lattice particle. Then:

$$m_o\Omega^2 r = m_g \Omega^2(x-r) \quad \text{..... (6.9)}$$

The kinetic energy density of these E and G frame constituents of the aether is proportional to:

$$m_o r^2 + m_g (x-r)^2 \quad \text{..... (6.10)}$$

because the aether frequency Ω is constant. We may then expect the electrical potential energy of such a system to have minimized, so determining x, and the rest mass energy to have been deployed between m_o and m_g to maximize (6.10), inasmuch as kinetic energy is drawn from a source of potential energy and, with energy conservation, minimization of the latter means maximization of the former.

Write M as $m_o + m_g$ to obtain from (6.9):

$$x - r = (m_o/M)x \text{ and } r = (m_g/M)x \quad \text{..... (6.11)}$$

Put these in (6.10) to obtain:

$$m_o(1 - m_o/M)x^2 \quad \text{..... (6.12)}$$

Since M and x are constant, we may now differentiate this energy expression with respect to m_o to find its maximum value by equating the differential to zero. This gives:

$$1 - 2m_o/M = 0 \quad \text{..... (6.13)}$$

from which we deduce that m_o and m_g are equal and, from (6.11) that x equals 2r.

The E frame and the G frame describe orbits of equal radius r. As their relative velocity is c, they move at speed c/2 in orbit. As the aether frequency is, by assumption, deemed to be the Compton electron frequency at which quantum theory tells us that electrons and positrons are created, namely $m_e c^2/h$, the value of Ω is given by:

$$\Omega = 2\pi m_e c^2/h \quad \text{..... (6.14)}$$

The radius r is then known, because Ωr is c/2. Thus, again, as for equation (6.6) we find that:

$$r = h/4\pi m_e c \quad \text{..... (6.15)}$$

What has been said above about the electron in the context of Heisenberg's Principle of Uncertainty does imply that the electron has an intrinsic motion when at rest in the E frame. Its own angular momentum is $m_e cr/2$ but there is a connected angular momentum due to the dynamic balance afforded by the G frame. Thus the total angular momentum intrinsic to the electron and due to the underlying jitter motion of the aether is $m_e cr$, which, from (6.15), if $h/4\pi$. This is the well known quantity associated with so-called 'electron spin'.

Curiously, this is not the quantum of angular momentum that is paramount in governing the orbital motion of an electron in an atom, Bohr's quantum unit, which is double the spin quantum. To understand this we need to address the problem of the photon, as it is this, rather than the electron, which is the regulator of action between aether and matter. The photon is not an elemental form of matter intruding into the aether. It is a feature of the aether itself which arises from a disturbance, albeit by the intrusion of an electrical charge, typically that of the electron, and we need next to examine the theory of the photon.

Photon Theory

Apart from deciphering Nature's coded messages and providing what surely is a comprehensive unified field theory, we will in this work come to see how a electric field can induce what I refer to as a state of 'aether spin'. If there is to be a spin-off of practical, technological importance, from this theoretical study, I feel sure it will be the cyclical induction of aether spin aimed at inducing the inflow of aether energy which we can utilize in our efforts to secure a sustainable pollution-free environment while meeting our escalating energy needs.

'Aether spin' exists, both on a grand scale, within our stars and planets, and on a microscopic scale as the photon.

The universal rhythmic motion of the aether at the angular frequency Ω defines a fixed direction in space. A direction anisotropy in the properties of space is not in evidence so far, though one wonders if researchers have really been looking for such a phenomenon. When we come to study the large-scale rotation of the aether medium, as with body Earth, it will then be seen that the Earth's magnetic field indicates that the axes appropriate to Ω are approximately normal to the plane in which the planets move around the Sun. It is probable from this that the circular motion of the E frame and G frame of the aether, though Ω has the same magnitude throughout all space, may be directed in different, possibly opposite, directions in the environment of different and widely spaced stellar bodies. There may be space domains measured in dimensions of many light years and within which Ω is unidirectional . Yet its direction may vary from one domain to the next.

I did, in my earlier pursuit of this theory, think that this, being linked to an electrodynamic action, might account for the force of gravity not being effective across the boundaries separating adjacent space domains, thereby limiting the range of gravity to action between matter in a common space domain. As we proceed, however, it will be seen when we come to discuss space domains and evaluate their size along with the creation of stars, that the essential difference between two adjacent space domains is the fact that in one the proton has a positive charge and the electron a negative charge, with the continuum charge positive and the quon charge negative, whereas these charge polarities are all reversed in the other space domain. In a sense, we can say that we have here the picture of space and anti-space together with matter and antimatter. This would also mean that gravity, as an electrostatic force phenomenon, could not be deemed to act across space domain boundaries.

Possibly, for interaction between matter in adjacent domains, there could be a repulsive gravitational interaction, the long range effect of which, as scaled over many space domains would mean that gravitational potential within a particular domain arises, in effect, solely from the presence of matter located within that domain. This proposition is supported by the explanation of the cosmic background temperature already introduced.

A further point of very special relevance concerns a theme we shall discuss in chapter 9 by reference to the Neumann potential. There are strong reasons which confine what we regard as electrodynamic forces to action as between leptonic currents in the sense that electric current flow in the circuits we use to produce magnetic fields or to detect such fields involves electrons active in a quantum-electrodynamic pair creation and decay process. Such electrons may be those active in atoms, where their apparent orbital motion about an atomic nucleus is really a quantum relocation as a newly created electron-positron pair in the path ahead of an electron involves the positron in annihilating that electron to leave the newly-created electron in a forward position. In any event, the point at issue is that the aether itself devoid of the presence of matter is not subject to electrodynamic activity. In spite of Clerk Maxwell's interpretation of electromagnetic waves as comprising components of electric field energy and magnetic field energy, one can just as easily argue that the electric field energy which is seated in oscillating charge displacement has an associated kinetic energy and that accounts for what Maxwell regarded as magnetic field energy. Accordingly, our onward analysis will address the aether and its properties as if magnetic properties do not exist and so confine the energy analysis to its electric field and kinetic energies. Concerning Earth's magnetic field, this is a clue to the most important feature of the aether, which is that a state of spin, as of a large spherical bulk of the aether, will induce electric charge displacement radial from the axis of spin. So if Earth sits in a coextensive aether that spins, there will be an electric charge density

belonging to the aether that is neutralized by a compensating displacement of electron charge in body Earth. We cannot sense the presence of that charge by its electric action but we can sense it by the geomagnetic field it produces. In determining the geomagnetic moment much then depends upon the angle subtended by the Earth's spin axis in relation to the aether spin axis and the vector direction of that underlying quantum jitter motion at angular frequency Ω. We will come back to this topic in chapter 8 but keep in mind that aether spin implies electric charge induction and vice versa and also the point that the vector direction of Ω is of no significance to the analysis in this and the next chapter. The aether behaves as an isotropic medium in its quantum mechanical interactions with the atom. An electromagnetic wave is a propagated disturbance of the aether particle lattice formed by those charges q, the quons. The lattice can be disturbed if a discrete non-spherical unit of it rotates and so sets up radial pulsations. This will rotate if an intruding electric charge is present along with a quantum of energy activity that is being shed or absorbed by that charge. The aether spin thus suggested will be the smallest possible symmetrical cubic unit of aether that has the ability to disturb surrounding aether lattice and that has to be a unit of 3x3x3 lattice particles.

Referring to this cubic unit as a 'photon', seen as an event when such a group of 24 quons spins about a central axis defined by 3 quons, our task now is to relate this spin to the frequency of the propagating disturbance which it causes. We will defer the detailed explanation of why it spins until chapter 8 but note here that a radial electric field acting from its centre or near-centre will so displace the superimposed E-frame orbits of the quons as to cause them to lose synchronism with Ω unless their centres of those orbits are slightly displaced and they move transversely in a rotational sense about the charge inducing that radial field.

It is a simple exercise in mathematics to show that the moment of inertia of such a 3x3x3 unit is independent of the axis about which

it spins [see page 94 of my book *'Physics Unified'*] and one can see that the pulsating disturbance of surrounding lattice will be at four times the frequency of that state of spin. The point of interest then arises if one wonders about the effects of a high spin speed which is such that the frequency of the pulsating disturbance is at or close to the frequency $\Omega/2\pi$. In a sense one can imagine that the latter is a more likely circumstance, given the quantum rhythmic motion of the aether lattice at that high frequency. Then one might consider a circumstance where a slight modification in the photon spin frequency can set up electromagnetic wave propagation at the difference frequency ν. In the context of electrons in atomic orbit I have explored this notion on the assumption that a pair of such photon units, one seated with the nucleus, spin in opposite sense but cooperate in propagating electromagnetic wave radiation. That, however, goes beyond the scope of this work on Creation and I can but give reference to this theme as pp. 70-73 of my book *'Physics without Einstein'*.

We will proceed by terming a photon unit spinning at $\Omega/4$ as a 'standard photon unit'. Now when an energy quantum E is added to the dynamic state of the aether it will, as with any linear oscillator, be shared equally between the potential energy and the kinetic energy. With the constant angular frequency Ω, this means that E/2 is added to the kinetic energy. That is:

$$E/2 = H\Omega/2 \quad \text{..... (6.16)}$$

where H is the corresponding quantum of angular momentum. Thus even though the energy E may become dispersed throughout the aether medium it introduces a related angular momentum given by:

$$H = E/\Omega \quad \text{..... (6.17)}$$

We believe that angular momentum is conserved, which means that this event cannot occur without there being a reaction, and so our photon must be characterized by such a relationship linking an energy quantum and angular momentum.

The space medium, whether one refers to it as the vacuum or the aether, is known to react critically to certain energy quanta related to

the mass of the electron or positron at rest. It somehow permits the creation of electrons and positrons at these exact energy levels, as if there is some kind of resonance at the characteristic frequency of the space medium. It seems essential to connect this phenomenon with the standard photon unit, especially so in view of the clear connection evident from equation (6.14). The standard photon unit must be associated with this energy quantum $m_e c^2$. Thus, from (6.17), H is $m_e c^2/\Omega$, which, from (6.14), is:

$$H = h/2\pi \quad \text{..... (6.18)}$$

Denoting I as the moment of inertia of the standard photon unit, H is given by:

$$H = I(\Omega/4) \quad \text{..... (6.19)}$$

which, from (6.18), gives:

$$I = 2h/\pi\Omega \quad \text{..... (6.20)}$$

Taking now a photon unit rotating at a much lower angular speed ω, this is related to the frequency radiated by:

$$4\omega = 2\pi\nu \quad \text{..... (6.21)}$$

and since the angular momentum H of this photon unit is $I\omega$, which (6.20) plus (6.21) show to be:

$$I\omega = h\nu/\Omega \quad \text{..... (6.22)}$$

we find, from (6.17) that:

$$E = h\nu \quad \text{..... (6.23)}$$

which is Planck's radiation law.

At the outset of this work we set our sights on decoding three basic messages from Mother Nature. One of these was that hidden by the numerical quantity referred to as the fine-structure constant, this being $2\pi e^2/hc$, the reciprocal of which is 137.0359.

It is self-evident that we cannot decipher the meaning of this quantity without first understanding the physical basis for the existence of the photon and so that has been our task in this chapter. The problem ahead is to exploit this insight into the 3x3x3 quon structure of the photon and its relationship with Ω by moving on to the real numbers that factor into the relationships between the various

components of the aether, the continuum charge density, the muons, the quons and their charges and masses, as well as that angular frequency Ω and c, the relative speed of the G and E frames. The electron is not present in the basic make-up of the aether but its properties provide a basis of reference in our material world. Our analysis in the next chapter has to be rigorous, as we seek to decipher the primary numerical quantities, the proton-electron mass ratio and the fine-structure constant to part per million degree of accuracy.