another possibility for such a test, one which we feel has potential, is the proposal to use[12] a ring-laser interferometer to measure the frequency difference of the counterpropagating beams in a Sagnac-type experiment, with the possibility of testing both the geodetic and motional precessions.

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9/84

Pair theory in QED

This past year (October 1983 to April 1984) I engaged in a losing battle to communicate with physicists at large through a theoretical paper in *Physical Review Letters*. Rejection of manuscripts for that journal is certainly commonplace, but the nature of my paper and the correspondence associated with its rejection was certainly not. The first rejection was a form letter accompanied by no comment whatsoever from the referee or editor. The second rejection was almost as brief—the suggestion that perhaps if it were expanded it might be publishable somewhere, but certainly not *Physical Review Letters*. Both the divisional (particles and fields) and staff editors concurred. Although my two resubmittal letters repeatedly pointed out the significance of the very simple findings contained in the manuscript, I met a stone wall of silence. There was not a single comment offered throughout the correspondence on the accuracy of the mathematical results in the manu-

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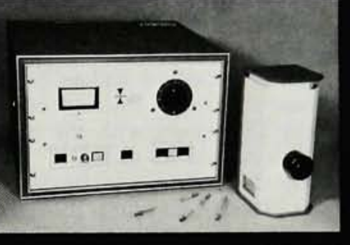

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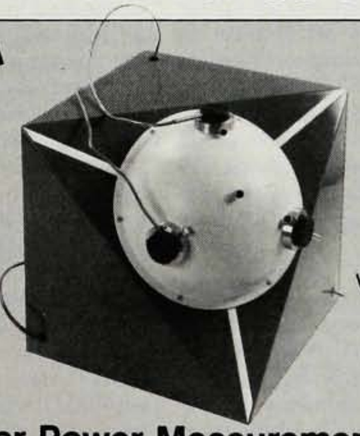

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script, no criticism of the experiments suggested, nor comments on the discussion or conclusions. I have doubts that a longer paper would be acceptable to the referees, and if published only in *Physical Review D*, would probably not reach many in the physics community anyway.

My purpose in writing that manuscript was dictated partly by a rather unusual ethical question. Although I have published[1] elements of this theory over a decade ago, they have been ignored or summarily dismissed by field theorists. A challenging low-energy experiment suggested[2] at that time has not been performed. Meanwhile my confidence in the accuracy of the ideas has steadily increased to nearly 99%. I find the beauty and simplicity of the concepts involved overwhelming. The ethical question arises because, with these subjective feelings, should I not share the theory with the community of physicists at large?

In any case, this current letter is another attempt to reach the physics community with some very simple yet profound ideas, which touch on an unbelievably long list of the *bêtes noires* of current physical theory, including: the classical radiative reaction problem, infinite renormalizations of mass and charge, the heavily populated vacuum, the difficulty in quantizing the electromagnetic field covariantly with only two degrees of freedom, conservation rule problems in QED,[3] the non-invariance of amplitudes in field theory under complex Lorentz transformations, the failure of field theory to explain very low energy pion–nucleon interactions, the source of Cooper pairs in superconductors, *zitterbewegung*, and, especially, the nature of time. This theory I call simply *pair theory*.

One not-surprising acknowledgement is necessary first. The ideas underlying pair theory have been drawn heavily from the philosophy of, and techniques developed by, Richard P. Feynman. Indeed my own receptivity to pair theory probably stems from attending an inspiring course that Feynman taught[4] at Cornell in 1958.

Here are the bare elements of pair theory, for those who recoil from a multiply-infinite number of degrees of freedom at each point of the continuum (the modern ether) or from dozens of unobservable quarks (the modern celestial spheres):

▶ Every particle has a rest frame within the complex Lorentz group. That is, it is always possible to find a Lorentz plane and a complex Lorentz angle for a transformation that reduces the three space coordinates of the momentum to zero. If the particle momentum is timelike, the resulting fourth component (remember—all particles are slightly off the mass shell) is real; if the particle is spacelike, the resulting fourth component is imaginary.

▶ It is thus possible to associate a direction of time with every particle, real or virtual—namely its proper time.

▶ With respect to its own proper time, a photon, or other elementary boson, is created or destroyed only by the annihilation or creation, respectively, of a particle–antiparticle pair. (This is the pair hypothesis.)

▶ With this hypothesis, all emitted radiation arises from the degrees of freedom associated with the relative displacement of point particles in space–time. It is not necessary to distort the elementary particles themselves—no Poincaré stresses, no runaway electrons.

The form of the electromagnetic coupling alone seems to dictate the pair hypothesis if we invoke the Lorentz condition. (Because then $\epsilon\cdot\mathbf{k} = 0$, $\epsilon\mathbf{k} = -\mathbf{k}\epsilon$, and thus ϵ couples fermion states with positive energy with respect to the photon's proper time, defined by $\mathbf{k}$, only to fermion states with negative energy with respect to $\mathbf{k}$.) Also, it is easy to prove that the initial and final scattering states of any lowest-order scattering event (for example, Coulomb scattering) are precisely the positive and negative energy states with respect to the field, whether the field is massive or massless. (Conceptually, just rotate the Feynman diagram by 90 degrees; algebraically, look at the Dirac equation in Hamiltonian form with the time axis along $\mathbf{k}$.)

What does the pair hypothesis do for us? For one thing, vacuum processes become impossible. The photon and pair are always complementary in space–time. The creation (destruction) of a photon occurs only by the annihilation (creation) of a pair, so that with no particles present, no interactions can occur. Also, an electron cannot interact with itself *except* after a rescattering event because of this space–time complementarity. Feynman diagrams with curved photon lines are forbidden because photons keep complex microscopic time in quantum electrodynamics. A "self-interaction" that survives is the Coulomb attraction of a just-created electron–positron pair—which is equivalent to the vertex correction yielding $g-2$ on rotation of the Feynman diagram by 90 degrees in complex space–time. Compton scattering and bremsstrahlung, for example, occur only through virtual pair formation so that there is no need for classical radiative reaction and the accompanying runaway solution to the equation of motion. Also, *zitterbewegung* disappears.

The specific predictions of pair theory that I have been able to derive to date—in each case using two nontrivial (but unsatisfactory) projection operators with each propagator—are:

▶ Coulomb scattering and bremsstrahlung, accounted for in the Born approximation limit[5]

▶ The Klein–Nishina formula[1]

▶ A gauge invariant(!) photon self-energy (misnamed as vacuum polarization)—the result is finite (without recourse to renormalization), but it is an incorrect beta function

▶ Reasons why quantum electrostatics—the determination of energy levels—may be exact in its current renormalized form.

Also found, however, is a rather special class of experiments that might show deviations from the predictions of QED. These are asymmetry measurements[2] in scattering of or by polarized electrons, where the spins of *both* the initial and final electrons lie in the scattering plane and thus have a component along the photon momentum. If the deviations occur at all, they will probably occur in all such processes—Compton scattering, bremsstrahlung and so on. These asymmetries do not appear to be tested in static measurements.

What is holding back further progress has been my failure to date to find a propagator for the Dirac equation that vanishes outside of a wedge in differential space–time. The problem appears to involve the product of five distributions.

Field theorists are understandably skeptical that any such dramatic departure from current theory could work. The agreement with current quantum electrostatic measurements is of the order of one part in 10^8. But Occam's razor holds that the minimum number of assumptions should be made that are consistent with the explanation of physical phenomena. Pair theory is roughly one-fourth as minimal as conventional field theory: only two of the eight possible time orderings[6] of the three lines at a simple Feynman vertex survive in pair theory. To be able to omit three-fourths of the interactions and still obtain Coulomb scattering, the Klein–Nishina formula and the bremsstrahlung cross section is remarkable. Moreover, the three-fourths of the interactions omitted are *not* those required to obtain $g-2$ or the Lamb shift. Nor are the omitted interactions required by Lorentz invariance, gauge invariance or unitarity. Rather, the physical and mathematical evidence is strong that they are the interactions giving rise to the infinities which are subtracted out of the current theory. Causality is enhanced by their omission—the vacuum again becomes a bona fide vacuum in pair theory. Moreover, a simple physical reason why the electron does not explode is provided. Surely nature has not introduced the four fieldlike and two inverted pairlike interactions (the two classes of interactions forbidden in pair theory) just so that field theorists can study the properties of the renormalization group!

Pair theory deserves a thorough airing. The easiest way to accomplish this would be to open up *Physical Review Letters* to papers on the subject. If the field theorists will not allow that, my feeling is that all of physics is the poorer.

The history of science should teach us that it is imprudent to assume that everything is known about any subject—and certainly about a subject with as many mathematical difficulties as quantum electrodynamics. Nature is usually very simple if the right perspective can be found. A postulate as sweeping as the pair hypothesis should be disprovable almost immediately. If not, it should be examined exhaustively both experimentally and theoretically. Its simplicity and beauty demand no less.

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6. S. S. Schweber, *An Introduction to Relativistic Quantum Field Theory*, Harper & Row, New York (1961) p. 425. Only diagrams (e) and (f), and complex rotations thereof, contribute according to the pair hypothesis.

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THE EDITORS REPLY: We regret that Stabler's recent submission to *Physical Review Letters* was not publishable, but the refereeing his paper received, which was expert and thorough, was also unanimous in recommending that it not be accepted. Other channels of publication are not foreclosed to him by this action; in particular, the meetings of The American Physical Society are open to his contributed papers if he chooses to submit them.

GEORGE H. VINEYARD
GEORGE L. TRIGG
10/84 *Physical Review Letters*

Nuclear tip from Canada

We noted with interest the letter from Carroll Mills (September, page 117). The Radiochemical Company of Atomic Energy of Canada Limited is the manufacturer of the Slowpoke-2 Research Reactor to which Carroll refers, and we are, of course, delighted to read his proposal.

For the record, it should be stated that the success of the Slowpoke-2 programs in universities owes a great deal to the owners and users concerned, especially because of the ways they have matched research and teaching programs to the reactor's capabilities. It is also true to say that the Slowpoke's purchase price and operating costs are considerably lower than those for conventional research reactors.

It will be of interest to many of your readers to know that, in view of the controversy that exists over the use of highly enriched uranium fuel in research reactors, we have developed a low-enriched uranium fuel for Slowpoke.

The first Slowpoke-2 fueled with low-enriched uranium will be installed in 1985, and this fuel can also be fitted into existing Slowpoke-2 reactors. We have changed our fuel-loading procedure as well, so that owners of new or refueled Slowpokes will be able, under normal operating conditions, to run their reactors for about 20 years before new fuel is required.

Given these developments, the proposition set out by Mills makes even more sense.

MICHAEL SPENDER
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Corrections

October, page 66—in the article by Malcolm Beasley and Theodore Geballe, figure 6 was adapted from a paper by H. W. Meul, C. Rossel, M. Decroux, O. Fischer (University of Geneva), G. Remenyi (Grenoble) and A. Briggs (Grenoble), Phys. Rev. Lett. **53**, 497 (1984). Because of an editorial oversight, throughout the article, beyond figure 1, figure n in the text corresponds to figure $n+1$.

December, page 27—First-generation magneto-optical recording devices are expected to feature data access times of 50 msec, not 50 nsec. □

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