along H of one of the mode-fields in the sample with the transverse component of the other. In principle F can be of order unity. ΔH_1, ΔH_2 are the line widths of magnetostatic modes 1 and 2; Q_1, Q_2 are the Q's of the cavity modes. K is a factor of order (operating frequency/$4\pi\gamma M$).

In spite of superficial similarities between this device and the three-level maser proposed by Bloembergen,[9] the present device operates quite differently; in somewhat oversimplified terms it relies on modulation of the real part of a susceptibility, rather than on reversal of the normal populations of two levels. However, in common with the three-level maser, the present device should have a low noise figure.

Finally, we stress that the same principle of amplification will apply to any system in which appropriate parameters can be varied, be it through anharmonic behavior of the physical system or otherwise. Since there are many such systems (e.g., anharmonically bound molecules) there may be a great many frequency ranges where this principle might find application.

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Some Consequences of *TCP*-Invariance

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RECENT experiments[1] have shown that parity (P) in the usual sense is not conserved in some weak interactions. There are strong indications that charge conjugation (C) invariance is also violated. According to a general theorem,[2] invariance with respect to the product TCP follows for a wide class of field theories from invariance with respect to the proper Lorentz group alone. Here T denotes the anti-unitary operator of Wigner time reversal. It is therefore important to investigate which connections between properties of particles and antiparticles follow from this general invariance and which can only be deduced from more severe invariance requirements (e.g., CP).

First we show that masses and (for unstable particles) also lifetimes of particles and antiparticles are equal as a consequence of TCP. The validity of this statement is not based on any perturbation expansion. We write the Hamiltonian as

$$H=H_S+H_W, \tag{1}$$

where H_S contains the free-field part and the strong interactions, while H_W represents the weak interactions. Mass and lifetime of a particle can be obtained from an investigation of the following expectation value:

$$(\psi, (\lambda-H)^{-1}\psi), \tag{2}$$

regarded as a function of the complex variable λ. Here ψ is an eigenstate of H_S, which represents one particle with momentum zero. For $H_W=0$, the mass of this particle corresponds to a singularity of (2) on the real axis. Under the influence of H_W the singularity shifts and, for an unstable particle, moves off the real axis. For particles with a simple exponential decay, mass and lifetime are given by the real and imaginary parts of this singularity.

Using the symbol Θ for the product TCP, one notices that $\Theta\psi$ describes one antiparticle at rest. From the general theorem it then follows that

$$(\Theta\psi, (\lambda-H)^{-1}\Theta\psi)=(\psi, (\lambda-H)^{-1}\psi), \tag{3}$$

so that the two expressions have the same singularities. To show (3), we go through the following steps:

$$\begin{aligned}(\Theta\psi, (\lambda-H)^{-1}\Theta\psi)&=(\Theta^{-1}(\lambda-H)^{-1}\Theta\psi, \psi)\\ &=((\lambda^*-H)^{-1}\psi, \psi)=(\psi, (\lambda-H)^{-1}\psi),\end{aligned} \tag{4}$$

where proper use has been made of the anti-unitarity of Θ. The equality of the masses of stable particles and of the lifetimes to first order in H_W had previously been stated by Lee, Oehme, and Yang.[3]

Second, we investigate under what circumstances the equality of branching ratios for the decay of particle and antiparticle into corresponding channels also can be concluded from the general invariance. For the sake of brevity we consider H_W only to first order. The branching ratios are essentially obtained from $|(\varphi^{\text{in}},H_W\psi)|^2$, where ψ is the same state as in (2) and φ^{in} is an incoming eigenstate of H_S representing the decay products. Since Θ transforms φ^{in} into an outgoing state of the corresponding antiparticles, the equality of branching ratios cannot be concluded in general. It can be shown to hold, however, if the scattering processes induced by H_S do not involve transitions between different decay channels.

The previous remarks can be applied to the decay of charged K mesons if we assume that τ, τ', and θ represent decay modes of the same particle. The experimental equality of masses and lifetimes of K^+ and K^- would not insure invariance of H with respect to C or CP. Also the branching ratios for the decays into two and three π mesons would be equal for either charge if the spin of the K meson were zero. In that case these channels would have opposite parity and could not be mixed by a parity-conserving H_S. But even for higher spin these branching ratios could be expected to be equal to a high accuracy if only the general invariance would hold, because H_S is very likely to produce practically no transitions between states of two and three π mesons. Such transitions are strictly forbidden because of a generalized Furry theorem, if we neglect electromagnetic interactions and assume as is customary that H_S is invariant with respect to C and to rotation in isotopic spin space.[4] This forbiddenness breaks down in the presence of electromagnetic interactions, but the effect on the branching ratios would be extremely small. From these arguments, however, it could not be concluded that the distribution of the three-π mode into τ and τ' would be the same for K^+ and K^-. Finally, equal spectra of the τ^+ and τ^- decay could not be predicted from TCP alone since H_S certainly will lead to a scattering of three π mesons.

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Parity and the Polarization of Electrons from Co^{60}†

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Lee and Yang[1] recently proposed that parity may not be conserved in weak interactions and suggested various experiments to verify their hypothesis. Two of the experiments have since been performed with positive result—the asymmetry of the electron emission from aligned nuclei[2] and the polarization of muons.[3,4] In a second paper,[5] Lee and Yang discuss a two-component theory of the neutrino and consider some more experimental tests. Among these, they list the measurement of momentum and polarization of electrons emitted in beta decay. If parity is not conserved, the electrons should be longitudinally polarized. For tensor and scalar interaction, the degree of polarization is simply equal to (v/c).[6,7] We have found this polarization in the case of Co^{60}.

The observation of the expected longitudinal polarization of the electrons is difficult. However, by means of an electrostatic deflector, the longitudinal polarization can be transformed into a transverse one.[8] The transverse polarization can be measured by scattering the electrons with a thin foil of a high-Z material (Mott scattering). Because of the spin-orbit interaction, the elastically scattered electrons show a strong left-right asymmetry, especially at scattering angles between 90° and 150°.[9] From this measurable asymmetry, the initial longitudinal polarization can be calculated.

The experimental arrangement is housed in a cylindrical vacuum chamber of 30-cm diameter. The electrons from a Co^{60} source are deflected in a cylindrical electrostatic field (radius of curvature 6 cm) by about 108° and then impinge on the scattering foil. The left-right asymmetry of electrons scattered into the angular interval 95° to 140° is measured with two end-window Geiger counters (3.5 mg/cm^2 mica windows). Two electroplated Co^{60} sources are used, one of about 1 mC strength on aluminum (1.7 mg/cm^2), the other of 6 mC strength on a silver-covered rubber hydrochloride film (0.6 mg/cm^2). The electrostatic deflector is designed so that electrons of about 100-kev energy completely change their polarization from longitudinal to transverse. The scattering foils (0.05 mg/cm^2 gold, 0.15 mg/cm^2 gold, 1.7 mg/cm^2 aluminum, all backed by 0.9 mg/cm^2 Mylar) can be interchanged from the outside.

For an ideal arrangement, the left-right asymmetry in the counters would be $L/R=[1+Pa(\theta)]/[1-Pa(\theta)]$.[10] P is the initial longitudinal polarization of the electrons and $a(\theta)$ the polarization asymmetry factor after scattering by an angle θ in the analyzer foil. In the actual experiment, however, the determination of P from L/R involves corrections for (1) the asymmetry of the two counters, (2) the finite extension of scatterer and counters, and (3) incomplete transformation from longitudinal to transverse polarization. The first correction was performed experimentally by using the nearly isotropic scattering from aluminum foils; the second and third corrections were calculated in a first approximation. A correction for depolarization in the source and the analyzer was neglected completely.

The results of some runs are given in Table I. Even though these data are only very preliminary, some conclusions can be drawn.

Table I. The polarization of electrons from Co^{60}.

Electron energy kev	$\beta=v/c$	Gold scattering foil mg/cm^2	Left-right asymmetry L/R	Longitudinal polarization P
50	0.41	0.15	1.03±0.03	−0.04
68	0.47	0.15	1.13±0.02	−0.16
77	0.49	0.05	1.35±0.06	−0.40
77	0.49	0.15	1.30±0.09	−0.35