rank. Certain interesting results follow by considering these as the coordinates appropriate to the quantum mechanics of the electron. In a short comment on Snyder's paper,[4] it was suggested that x_5 should denote the fundamental length h/m_0c, but it now appears that it denotes the length e^2/m_0c^2. It will be noted that this length lies along the direction of motion of the particle. If the third term be examined for the case of a particle in uniform motion in the direction taken as the axis of z, and the values of $\psi^\dagger i\beta\alpha_x\psi$,[5] etc., be determined, it appears that $\psi^\dagger i\beta\alpha_z\psi$ vanishes so that this displacement is always at right angles to the direction of motion and is, therefore, represented either by $(\hbar/2m_0c)\psi^\dagger i\beta\alpha_x\psi$ or $(\hbar/2m_0c)\psi^\dagger i\beta\alpha_y\psi$. The proper values of the operators in these expressions are $\pm\hbar/2m_0c$ and, since they have no intermediate value, it is suggested that the third term represents a fundamental length $\hbar/m_0c$ lying at right angles to the direction of motion.

Thus in the coordinate operators the fundamental lengths e^2/m_0c^2 and $\hbar/m_0c$ appear. The former represents a relativistic length, x_5p/m_0c being the ordinary length when the particle is moving with velocity v ($p=mv$), and its occurrence means that in the direction of motion no smaller length can be considered in the mechanics of the electron. Similarly $\hbar/m_0c$ may be interpreted as a limiting length, directed normally to the direction of motion.

If an electron moves in a circle it would appear impossible to consider a radius less than $\hbar/m_0c$ and the circumference could thus not be less than h/m_0c. This is an example of an earlier statement[6] that in the mechanics of the electron no meaning can be attached to intervals of proper time less than h/m_0c^2.

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One to Two Millimeter Wave Spectroscopy. I*

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SPECTRAL lines have been measured at many positions between 1.37-mm and 2.3-mm wavelengths (220 kMc/sec to 130 kMc/sec). The highest spectral transition previously measured with microwave electronic techniques[1] was at 128 kMc, reported earlier from this laboratory.[2] Like the previous measurements, the present results were obtained with silicon crystal multipliers driven by Raytheon klystrons. Hence, the same precision, resolution, and convenient frequency-sweep techniques are inherent in the method as those characteristic of centimeter wave spectroscopy.

Table I lists several measurements of rotational frequencies of OCS, with estimated limits of error, and the redetermined spectral constants. (Similar measurements have been made on methyl fluoride and are in progress on HCN and other molecules.) D_J is determined to a considerably higher accuracy than that previously obtainable with lower J lines. This results partly from the larger contribution of the stretching term at the higher frequencies and partly from the fact that the remarkable broad-bandedness of our multiplier and detector makes it possible to display several rotational lines (with different harmonics of the source power) on the scope-face at once. See Fig. 1. The multipliers can be tuned, however, so as to favor certain harmonics, as illustrated in Fig. 2,

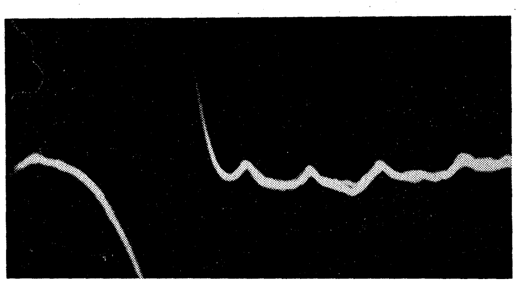
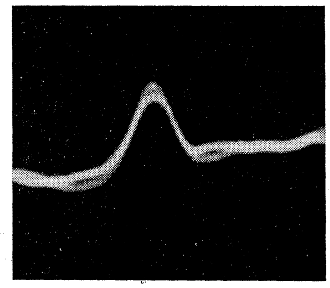


FIG. 1. Simultaneous display of the 8th, 10th, 12th, 14th, and 16th rotational lines of OCS at frequencies of 97, 121, 146, 170, and 194 kMc/sec from left to right, respectively.



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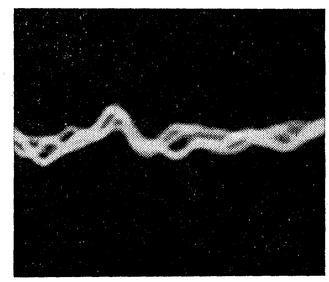

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FIG. 2. The upper curve is the 16th rotational line of OCS at 1.54 mm (195 kMc/sec); the lower is the 18th rotational line of OCS at 1.37 mm wavelength (219 kMc/sec).

and, of course, the lower harmonics can be filtered so as to show only the higher frequencies.

A wide-banded audioamplifier (~6-kc band width) was used in these observations. A factor of thirty or more in signal to noise can be gained by use of a narrow-banded amplifier with the automatic recording technique previously described.[3] Also, since these results were obtained with the first model of a newly designed multiplier and detector, we believe that spectral transitions as high as 300 kMc/sec (one-mm wavelength) are now feasible.

TABLE I. Observed transitions of $O^{16}C^{12}S^{32}$. $B_0=6081.490$ Mc/sec, $D_J=1.294\pm0.005$ kc/sec.

Transition	Frequency in Mc/sec Calculated	Observed
7→8	97 301.19	97 301.19±0.20
9→10	121 624.67	121 624.63±0.25
11→12	145 946.82	145 946.79±0.30
13→14	170 267.52	170 267.49±0.35
15→16	194 586.49	194 586.66±0.40
17→18	218 903.47	218 903.41±0.45

Construction details of the new multiplier and detector will be given elsewhere. The principal improvement over the previous ones appears to result from a reduction of the physical size of the crystals used for multiplication and detection. The crystals were cut and shaped in our own shop by Mr. W. B. Francis. The tungsten "cat whisker" was also made, and the point was etched electro-chemically in our own laboratory. It is possible that a sharper contact point has been obtained than that of commercially available crystals. The results shown were obtained with K band klystrons. Millimeter wave tubes have also been used, but because of their lower powers they give less harmonic power at the higher frequencies.

The present developments seem not only to have made spectroscopy in the "no man's land" between optical and radio waves a practical reality but at the same time to have improved by an order of magnitude the performance in the previously worked 2- to 5-mm region. The components of the system are so broad-banded that one can obtain fourth or fifth harmonic power from the full tuning range of a K band klystron without retuning either the multiplier or detector. This reduces to insignificance the previously difficult task of "finding" fourth or fifth harmonic power.

* The research reported in this paper has been sponsored by the Geophysics Research Directorate of the Air Force Cambridge Research Center, Air Research and Development Command.

[1] The present work does not represent the first generation and detection of radiation in the region of one to two millimeters. As early as 1923 [Phys. Rev. 21, 378 (1923); 21, 587 (1923)], E. F. Nichols and J. D. Tear closed the gap between optical and radio waves in the sense that energy was generated and detected.

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Unstable Particles from Penetrating Showers*

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In the course of an experiment on penetrating showers[1] in carbon, cloud-chamber pictures of 500 showers originating in carbon plates inside of the cloud chamber were obtained. Among these pictures only two examples of decays of neutral V particles were found. Thus only about one shower per two hundred and fifty gives rise to a V^0 decay. This may be compared to the rate obtained by Fretter *et al.*[2] with a similar apparatus of about one V^0 decay per 18 penetrating showers. This comparison is perhaps not quite correct, as Fretter pictures were on the average of higher quality than those obtained with this apparatus. On the other hand, the lack of cascade development in the carbon plates should have made the search efficiency relatively higher than in Fretter's experiment. It is assumed that the search efficiency is high only if the V^0 is emitted into a less populous part of the shower, that is, at an angle greater than the median angle for the shower. This means an efficiency of about 50 percent. This assumption gives about one V^0 decay per 125 showers in carbon. This is still more than a factor five lower than the rate obtained by Fretter. Since two cases were found when about 14 were expected, it seems unlikely that this results from a statistical fluctuation.

The major difference between the two experiments seems to be that these showers were generated in carbon while those of Fretter occurred in lead. It is possible also that the median energy of the primaries triggering this apparatus was somewhat higher than those triggering Fretter's apparatus because of a more complex triggering arrangement.

It seems possible that V_1^0's (i.e., the majority of the V^0's[3]) are formed primarily in interactions of lower energy than those selected here ($\bar{E}\sim 20$ Bev). If this were the case, showers in a heavy nucleus where secondary multiplication occurs would give rise to more V_1^0's than showers from a light nucleus such as carbon. In particular, it might be that π-meson nucleon collisions are the only sources of V_1^0 particles.

Of the 1000 shower particles observed traversing an average distance of 15 cm, one was found to decay in flight. This may be compared with the Manchester result[4] of 14 $V^{\pm}$ decays in 8000 tracks traversing 15 cm each.

The secondary particle from the decay undergoes a large angle scattering (30°) in traversing a lead plate. It seems very probable that this is a nuclear scattering and that the secondary particle is a π-meson.

A search was made for close pairs of penetrating particles coming from interactions in carbon. Such pairs might be interpreted as being the product of the decay of a short-lived, low Q, neutral particle. Twenty-two pairs of penetrating particles with angles of separation of the order of 5° or less were found in 100 showers in carbon. The probability of a chance coincidence was calculated from the average angular distribution of shower particles in the showers and the angle between the shower particles in question. The result of the calculations indicated that fewer pairs were observed than were expected by chance. An angular correlation has been observed by photographic plate workers.[5] From our data it appears that less than $\frac{1}{2}$ percent of the penetrating secondaries arise from the decay of a ζ^0 (if such exist).

* Supported in part by a grant from the Research Corporation.
† Now at Physics Department, University of Rochester, Rochester, New York.
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The Short-Lived Radioisotopes P^{28} and Cl^{32}†

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The series of radioactive isotopes B^8, N^{12}, Na^{20}, and Al^{24} has been reported by Alvarez[1] and by Birge.[2] These isotopes all decay by positron emission, at least some of the branches of which lead to excited states that decay by alpha-particle emission.

We have observed two new activities which result from the bombardment of silicon and sulfur by 20-Mev protons from the UCLA cyclotron. From threshold and energy considerations, we ascribe these activities to P^{28} and Cl^{32}, additional members of the above series. The method of detection involved the use of a scintillation gamma-ray spectrometer with a NaI crystal.

The half-life of the Cl^{32} activity is 0.306 ± 0.004 second, and in addition to positrons it emits gamma-radiation of energy 4.8 ± 0.2 Mev. The half-life of the P^{28} was found to be 0.280 ± 0.010 second. It emits positrons and gamma-radiation up to an energy of 7 Mev.

The thresholds for the excitation of these activities has been measured relative to the threshold for $Mg^{24}(p,n)Al^{24}$ at 15.4 ± 0.3 Mev.[2] In the case of $Si^{28}(p,n)P^{28}$ the threshold is 15.6 ± 0.5 Mev, and for $S^{32}(p,n)Cl^{32}$ the threshold is 14.3 ± 0.5 Mev.

From these threshold values one calculates a mass for the P^{28} of 28.0012 ± 0.0007 amu, and for the Cl^{32} a mass of 31.9963 ± 0.0007 amu, using the values of Li[3] for the masses of Si^{28} and S^{32}. These nuclei are apparently just barely stable to proton emission.

We have searched for alpha-particles from these activities, using a ZnS screen and photomultiplier, but without positive results. The sensitivity of our arrangement can be indicated by the following statement: Either (a) the alpha-particles have energy less than 1 Mev or (b) the transition which results in their emission has a probability less than 10 percent of those transitions which result in gamma-ray emission.

We have also obtained some results on Al^{24} from the reaction $Mg^{24}(p,n)Al^{24}$. We observe gamma-radiations of energy 7.1 ± 0.2 Mev, 5.3 ± 0.2 Mev, 4.3 ± 0.2 Mev, and 2.9 ± 0.2 Mev. Our value for the half-life is 2.10 ± 0.04 seconds which agrees within experimental error with the value obtained by Birge.[2]

† Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
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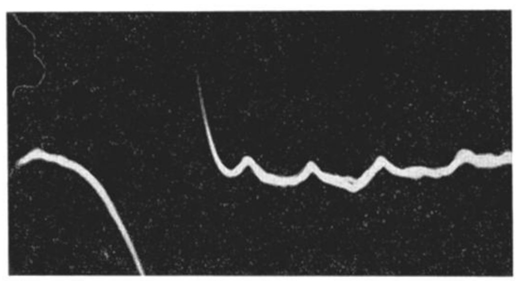
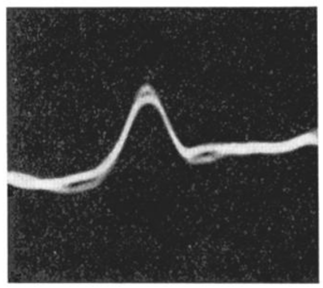


Fig. 1. Simultaneous display of the 8th, 10th, 12th, 14th, and 16th rotational lines of OCS at frequencies of 97, 121, 146, 170, and 194 kMc/sec from left to right, respectively.



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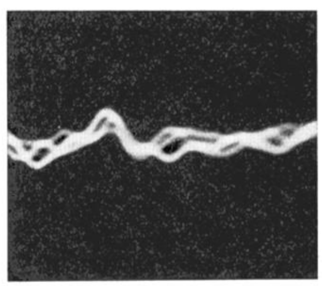

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FIG. 2. The upper curve is the 16th rotational line of OCS at 1.54 mm (195 kMc/sec); the lower is the 18th rotational line of OCS at 1.37 mm wavelength (219 kMc/sec).