Desai and Newton[1] and Gribov and Pomeranchuk,[2] have been calculated for a square-well potential. For both repulsive and attractive potentials, the poles approaching $l=-\frac{1}{2}$ as $E\to 0^+$, $n>0$, are found to move towards infinity in the first quadrant as $E\to\infty$. The poles approaching $l=-\frac{1}{2}$ from the third quadrant as $E\to 0^+$, $n<0$, are found to move towards infinity as $E\to\infty$ in either the first or third quadrant. Curves are shown to illustrate this behavior. Some generalizations of these poles are presented.

[1] B. N. Desai and R. G. Newton, Phys. Rev. **129**, 1445 (1963).
[2] V. N. Gribov and I. Ya. Pomeranchuk, Phys. Rev. Letters **9**, 238 (1962).

FD11. Relativistic Regge Trajectories with Spins. MAX LUMING, *University of California, La Jolla.*—The relativistic N/D equation is applied to the calculation of Regge trajectories for the scattering of two equal-mass, spin $-1/2$ particles. It is shown explicitly that there is no fixed pole in the angular-momentum plane for both the singlet and triplet amplitudes. For the triplet amplitudes, the kinematical singularities in the energy-squared plane is examined in detail. A set of amplitudes is constructed that is free of kinematic singularities and satisfies simple unitarity condition. In an explicit example, the exact N/D solution is obtained and the trajectory and residue of Regge poles are calculated.

FD12. High-Energy Scattering in the Regge-Pole Plus Cut Model.* I. R. GATLAND (introduced by L. Gold) AND J. W. MOFFAT, *Research Institute for Advanced Studies.*—The unknown functions $\alpha(t)$, $f_i(t)$, and $h(t)$ in the pole plus cut theory of high-energy scattering,[1] which gives

$$d\sigma_i/dt=|f_i(t)[w^{-3/2}+\alpha(t)h(t)\exp\{(\alpha(t)-1)w\}|^2,$$

where $w=\ln(s/2M_1M_2)$, are written in terms of Omnes-type functions with only a right cut. Assuming in each case that the cut is dominated by a single pole, we obtain a fit to the experimental results on $\pi+p$, $K+p$, and $p+p$ scattering[3] and determine the ten free parameters.

* Work supported in part by the U. S. Air Force Office of Scientific Research.
[1] I. R. Gatland and J. W. Moffat, Phys. Rev. **132**, 442 (1963).
[2] R. Omnes, Nuovo Cimento **8**, 316 (1958).
[3] S. J. Lindenbaum, Intern. Conf. on Nucleon Structure, Stanford, 1963.

FD13. Singularity Structure of Asymptotic Quantum-Field Theory. J. C. STODDART (introduced by F. Rohrlich), *Syracuse University.*—It has been shown recently that the LSZ formulation of quantum-field theory can be extended to produce finite solutions for the S-matrix elements to all orders in perturbation theory.[1] In this paper, these solutions for the scattering of an arbitrary number of scalar bosons are examined in momentum space and their singularity structure found. It is shown that the fundamental integral equation proposed in Ref. 1 must be solved with the particle momenta off the mass shell and that the solution so obtained is the analytic continuation of the unitarity condition to unphysical off-mass shell regions. The analytic-mass shell amplitudes are constructed using the unitarity condition and this continuation. By an induction method, it is shown that the perturbation solutions in any order possess only the singularities that are required by unitarity, from which follows that the Mandelstam representation is valid for the special case of the four-line vertex.

[1] R. Pugh, Ann. Phys. **23**, 335 (1963).

FD14. Gravitational Scattering and Regge Poles. W. K. R. WATSON AND ED DALTON, *University of California, Riverside.*—The behavior of gravitational-scattering cross sections at high energy is examined from the viewpoint of Regge-pole theory. Comments are made on the applicability of recent theorems based on unitarity, and a possible Regge behavior of gravitational interactions is discussed.

FRIDAY MORNING, 24 JANUARY 1964 STATLER–HILTON GRAND BALLROOM AT 9:15

(P. EWALD presiding)

General-Interest Session II

G1. Some Experiments with Magnetically Suspended Rotors. J. W. BEAMS, *University of Virginia.* (45 min.)

G2. Early Days of Solid-State Theory. P. DEBYE, *Cornell University.* (45 min.)

G3. Some Unusual Properties of Microcrystals in Glass. S. D. STOOKEY, *Corning Glass Works.* (45 min.)

FRIDAY MORNING, 24 JANUARY 1964 STATLER–HILTON TERRACE ROOM AT 9:15

(R. HOFSTADTER presiding)

High-Energy Scattering and the Inferences Therefrom

GA1. High-Momentum-Transfer Proton–Proton Elastic Scattering at the Brookhaven Alternating-Gradient Synchrotron. JAY OREAR, *Cornell University.* (40 min.)

GA2. High-Energy Proton–Proton Scattering. ROBERT SERBER, *Columbia University.* (40 min.)

GA3. Structure of the Triton, the Helium^3 Nucleus, and the Neutron from Electron Scattering. L. I. SCHIFF, *Stanford University.* (40 min.)

FRIDAY MORNING, 24 JANUARY 1964 NEW YORKER GRAND BALLROOM AT 9:15

(C. G. B. GARRETT presiding)

Masers I

GB1. Optical-Maser Action up to 57.355 μ in Neon. C. K. N. PATEL, W. L. FAUST, R. A. MCFARLANE, AND C. G. B. GARRETT, *Bell Telephone Laboratories.*—We have obtained optical-maser action at 31.928, 34.679, 35.602, 37.231, 41.741, 53.486, 54.019, 54.116, and 57.355 μ in a discharge containing either pure neon or helium and neon. All of the maser wavelengths, except the 31.928-, 34.679-, and 41.741-μ lines belong to the $7p$–$6d$ group of transitions (Racah notation) of neon. The 31.928-, 34.679-, and 41.741-μ lines belong to the $6p$–$5d$ group, other transitions of which have already been reported in maser oscillation.[1] The strongest transition in the $7p$–$6d$ group is the 53.486-μ line and the output power is estimated to be of the order of a microwatt. The far-IR detectors used were a Golay cell and a low-temperature germanium bolometer. We describe the experimental technique and discuss the results and excitation mechanisms.

[1] W. L. Faust, R. A. McFarlane, C. K. N. Patel, and C. G. B. Garrett, Bull. Am. Phys. Soc. **8**, 299 (1963).

GB2. Line Shapes of the 1.15-μ Ne Transition.* A. SZÖKE,† *MIT.*—Subsequent to an earlier work,[1] the power output of a He–Ne^{22} optical maser oscillating at 1.15 μ has been measured as a function of its frequency, for various gas pressures between 0.5 and 1.5 mm Hg and two different He–Ne ratios, 10:1, 5:1. We find that pressure-broadening of the atomic spectral line is caused by collisions of excited Ne atoms with ground-state Ne and He atoms, each gas having approximately the same net effect at the operating pressures of the maser. Furthermore, we find that pressure introduces an asymmetry in the atomic line shape to the extent of 1/10th of the linewidth. Accompanying this asymmetry is a shift to higher frequencies, which is estimated indirectly to be of the same order of magnitude. Lamb's theory of the gas maser has been adapted to include asymmetric line shapes. The theory has been fitted to the experimental curves with the aid of a digital computer to obtain the above parameters characteristic of the line shape.

* Work supported by the National Aeronautics and Space Administration and done partly at the Computation Center, MIT.
† On leave from the Weizmann Institute, Israel.
[1] A. Szöke and A. Javan, Phys. Rev. Letters **10**, 521 (1963).

GB3. Hanle Effect in the He–He Laser.* W. CULSHAW AND J. KANNELAUD, *Lockheed Research Laboratories.*—Zeeman investigations on the 1.153-μ line of a planar He–Ne laser show that the usual polarizations, such as circular for an axial magnetic field, are obtained provided the eigenstates do not overlap within their natural linewidths. At lower values of magnetic fields, departures from such specific polarizations occur due to the additional coherence imparted by the overlapping states. The effect is discussed, using time-dependent perturbation theory, and a solution valid for a small initial perturbation is obtained. This shows that when the cavity resonance is centered on the Doppler distribution the radiation is linearly polarized for values of magnetic field such that $geH/mc<1/\tau$, and that the electric vector rotates with increasing magnetic field. For an asymmetrical position of the resonance, elliptical polarization is predicted. When the decay constant of the lower level is assumed zero, the results are analogous to the classical expressions for the depolarization of resonance radiation. Some experimental verification is provided by polarization studies on the beats between axial modes of the laser and by investigations on low-frequency beat phenomena.

* Research supported by the Independent Research Program of Lockheed Missiles & Space Company.

GB4. Hanle Effect of the 1470-Å Xe Resonance Line. D. ANDERSON AND W. LICHTEN, *The University of Chicago.*—The zero-field level crossing (Hanle Effect) was measured by a resonance-fluorescence technique with a natural mixture of Xe isotopes. Light from a Xe resonance lamp entered an absorption cell equipped with LiF windows. The fluorescence was observed in a direction perpendicular to the incoming light beam, with the absorption cell located in a uniform magnetic field perpendicular to the plane containing the incoming and outgoing beams. Coherence-narrowing of the Lorentz line was observed. An extrapolation to zero pressure gave a full half-width of 40 ± 4 G. Use of the optical value[1] $g_J=1.204$ gave a lifetime of $3.0\pm1.0\times10^{-9}$ sec for the $5p^56s\,{}^3P_1$ state of Xe, or an oscillator strength of $0.32_{-0.08}{}^{+0.17}$. Use of the formulas giving the oscillator strengths for the p^5s configuration[2] gave the ratio of ${}^1f/{}^3f=0.9$, or $0.61_{-0.15}{}^{+0.30}$ for the total oscillator strength of the transition to the $5p^56s$ configuration from the ground state. The main uncertainty in the lifetime is from the effect of hyperfine structure of the odd isotopes.

[1] J. B. Green, E. H. Hurlburt, and D. W. Bowman. Phys. Rev. **59**, 72 (1941).
[2] R. Knox. Phys. Rev. **110**, 375 (1958).

GB5. Microwave Oscillation Locked to O–O Hyperfine Transition, Using a Rubidium 87 Maser Amplifier. M. ARDITI, *ITT Federal Laboratories,* AND T. R. CARVER, *Princeton University.*—Maser amplification in an optically pumped rubidium 87 gas cell has been previously described,[1] but self-sustained oscillations have not been reported. With such a rubidium maser amplifier we report self-sustained oscillations, at microwave frequency, using some additional gain introduced by a parametric amplifier to overcome insertion and coupling losses. The gas cell is enclosed in a microwave-transmission cavity connected to a low-noise parametric amplifier at 6834 Mc/sec. The gain of the parametric amplifier is adjusted in such a manner that a gain greater than unity, from input of cavity to output of parametric amplifier, is obtained only when optical pumping is produced. When the output of the parametric amplifier is connected, in proper phase, to the input of the transmission cavity, it is possible to obtain a microwave oscillation that is locked to the relatively stable frequency of the O–O hyperfine transition. A continuous microwave oscillation has been obtained when using a continuous-pumping light. The use of pulsed light, for optical pumping, permits the study of the oscillation buildup under various experimental conditions.

[1] N. Knable, Bull. Am. Phys. Soc. **6**, 68 (1961).

GB6. High-Power Ultraviolet Gas Laser. HARRY G. HEARD, *Energy Systems, Inc.*—Observation of laser action in the ultraviolet spectrum is reported. Coherent light results from transitions $C^3\pi\to B^3\pi$ in nitrogen. The peak-power output summed over all the lines in the second positive group of this band system is of the order of 10 W. The specific gain is approximately 60 dB/m at 4 Torr. Band-spectra emission is observed over the frequency spectrum extending from 3000 to 4000 Å; the highest observed intensity is at 3371.3 Å, corresponding to the band head for $\Delta v=0$. Each band contains a

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