certain at present. The cylindrical wire probes indicated a Hall gradient $1/2\,(\vec{v}_d \times \vec{B})$, in agreement with theory,[5,6] from 0.1 to 1.0 ma discharge current, but this measured gradient dropped rapidly for higher currents.

In Fig. 2 is shown a comparison of density determinations with conventional wall probes and with the Hall effect. The agreement is not so satisfactory as that utilizing microwaves, and this result is most probably traceable to the difficulty of interpreting wall-probe data.

The experiments preliminarily reported herein indicate the usefulness of the Hall effect in the study of gaseous plasmas. Increase of the magnetic field strength leads to nonlinear responses which also contribute much to knowledge of fundamental processes in the plasma.[5] The Hall effect is applicable to study of afterglow plasmas and work of this nature has begun.

It is a pleasure to acknowledge the assistance of W. R. Reed, Jr., who assisted in assembly of the experimental apparatus and in the taking and reduction of data. I am thankful for conversations with members of the General Electric Research Laboratory and especially those with K. B. Persson, who originally suggested the Hall effect to the author as a possible experimental procedure in plasmas.

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MODULATION AND DIRECT DEMODULATION OF COHERENT AND INCOHERENT LIGHT AT A MICROWAVE FREQUENCY*

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We report the modulation and direct demodulation of optical radiation, using a cavity-type KDP Pockels cell and a microwave light detector (microwave phototube), together with both the coherent light from a pulsed ruby laser and the incoherent light from a mercury arc. To our knowledge, these are the first experiments with microwave-modulated light[1-3] in which detection has been accomplished directly, with the microwave modulation signal (2700 Mc) being directly available from the detector.

Figure 1 shows the experimental setup with a ruby laser source. The laser is of the elliptical type, using a 5.64-cm-long ruby rod with a threshold of 300 J when cooled by N_2 vapor; these experiments were performed with 380 J input. The Pockels cell light modulator uses the electro-optic effect in KH_2PO_4 (KDP).[1,2] The apparatus consists of a Nicol prism polarizer, a quarter-wave plate, a cylindrical microwave cavity (TM_{010} mode) containing an axially located bar of KDP 0.4 cm square by 3.4 cm long supported in Teflon, and a Nicol analyzer. The loaded cavity bandwidth is 5 Mc centered at 2700 Mc. Approximately 300 W of microwave power input produces 100% amplitude modulation of the transmitted light.

The detector is the recently developed Sylvania SY-4302A microwave phototube, comprising an S-1 photocathode and a helical slow-wave circuit.[4]

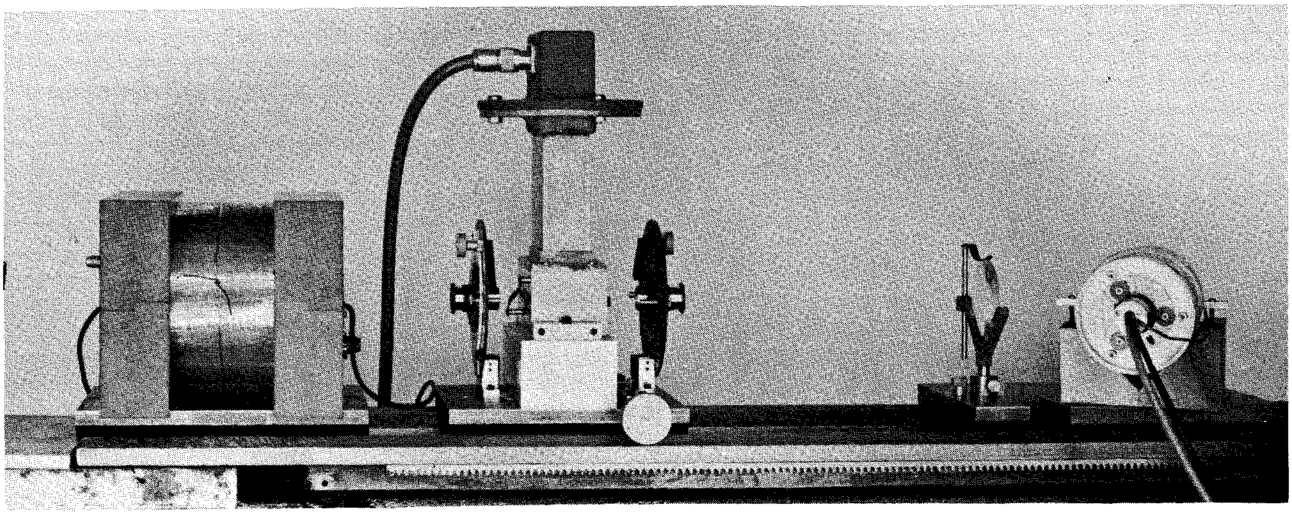

Fig. 1. Modulation-demodulation experiment with ruby laser.

Microwave-modulated incident light produces a microwave-modulated or pre-bunched electron beam from the photocathode; this beam modulation is amplified along the helix, and transferred to the output coaxial line. The tube responds to modulation frequencies from 1500 to 4500 Mc.

With the ruby laser, the microwave output of the SY-4302A contains, besides the detected modulation signal, spikes of microwave output at other frequencies (1480 Mc, 2960 Mc, 4440 Mc) corresponding to photobeats between simultaneous axial mode oscillations in the laser.[4] Figure 2 is a typical result. The lower trace is the "d-c envelope" of the photocurrent from the phototube cathode, as monitored by means of a 10-kΩ series resistance in the cathode lead of the SY-4302A. The upper trace is the video output of a superheterodyne microwave receiver connected to the SY-4302A and tuned to the modulation frequency. The laser is oscillating quasi-continuously during the entire trace, while the modulator is driven with 15-μsec pulses at 10 kc repetition rate, giving the two large pulses of microwave output apparent in the upper trace. The small spike midway between is very probably a strong photobeat at 2960 Mc coming through on the skirt of the receiver's response. With one watt of microwave power to the modulator, corresponding to 14% amplitude modulation, the microwave power level in the detected modulation pulses from the SY-4302A is −45 dbm. We easily detect much lower power levels as well, for example, power outputs near −75 dbm with 1 mw of power to the modulator.

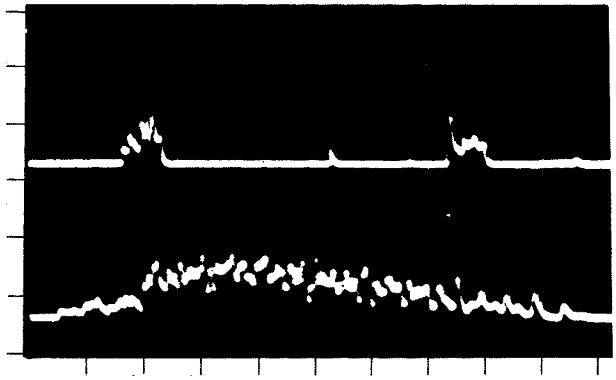

Fig. 2. Photocurrent from the phototube cathode (lower trace) and detected microwave output from the helix (upper trace). Time scale is 20 μsec per major division; photocurrent scale is 100 μA per major division.

For c-w experiments, the ruby laser is replaced by a mercury arc lamp. With one watt of c-w power to the modulator and a light transmission through the system sufficient to give a dc photocurrent of 0.1 μA in the SY-4302A, microwave output at the modulation frequency is readily observed at −71 dbm with a signal/noise ratio of at least 10. It may be noted that the temperature rise of the KDP crystal with 1 watt of c-w input causes a shift of 30 Mc in the cavity resonant frequency.

Those familiar with conventional traveling-wave tubes (TWT's) may find it surprising that efficient beam-circuit coupling can be obtained with so little beam current (much less than the Kompfner-dip current). The significant difference between the microwave phototube and the TWT amplifier is that the beam is initially current-modulated in the phototube, and a current-modulated electron beam will produce significant beam-circuit interaction even at low currents. The distinction can be made clear by an examination of the coupled-mode equations for traveling-wave interactions in the two cases.

When the coupled-mode equations for the phototube are solved using the assumptions of small current and synchronous operation, the predicted microwave power output is $P \cong (mI_0/fL)^2\, K/V_0 \cdot 10^{-8}$ watts, where m is the modulation index (per cent modulation $\times\, 10^{-2}$), I_0 is the photocurrent in μA, f is the modulation frequency in Gc, L is the helix length in inches, K is the longitudinal interaction impedance in ohms, and V_0 is the helix voltage in volts. This neglects any beam transformation occuring in the gun region. With the mercury arc the predicted power output is about −75 dbm, in good agreement with the observed value of −71 dbm. For the ruby laser the predicted value of −15 dbm is considerably larger than the observed value of −45 dbm; the discrepancy is probably due to the fact that the modulation frequency, the cavity resonance frequency, and the receiver LO frequency were not properly aligned. The narrow bandwidths involved, combined with frequency drifts, made exact adjustments difficult in a pulsed experiment.

The experiments reported here verify a number of predictions[4] concerning the use of microwave phototubes for demodulating coherent or incoherent microwave-modulated light signals. The observed power levels appear to be in reasonable agreement with theory. More complete studies are in progress and will be reported later. We thank Mr. Benjamin Yoshizumi for much assistance in performing the experiments; Mr. Leonard Dague for skilled construction of equipment; and the Sylvania Microwave Device Division for the loan of the phototube, which was developed by Messrs. J. Gaenzle and R. T. McKenzie.

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COEFFICIENTS FOR THE DIFFUSION OF LEAD, TIN, AND COPPER INTO SINGLE CRYSTALS OF GOLD IN BOILING 2*M* HCl

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It has recently been reported[1] that intermetallic compounds of tin can be prepared electrochemically by polarizing gold and palladium electrodes to the corrosion potential of tin in boiling 2*M* HCl containing dissolved tin. The general nature of this electrochemical synthesis is now recognized for a considerable number of systems in which intermetallic compounds exist. The purpose of this letter