

## XV. SPONTANEOUS RADIOFREQUENCY EMISSION FROM HOT-ELECTRON PLASMAS\*

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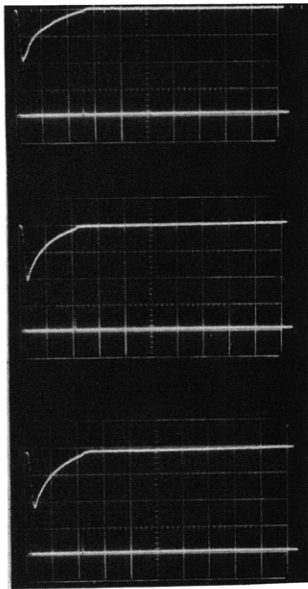
#### A. ENHANCED CYCLOTRON RADIATION FROM AN ELECTRON-CYCLOTRON RESONANCE DISCHARGE

Previously, we have reported preliminary observations of an instability occurring in the afterglow of a pulsed electron-cyclotron resonance discharge.<sup>1</sup> This instability was characterized by bursts of radiation at frequencies near that of the RF microwave field which generates the plasma. The bursts are normally observed, however, as occurring several hundred microseconds after the removal of this RF heating field. We have continued this investigation in order to gain sufficient information about the plasma so that an appropriate theoretical model might be formulated.

Above a background pressure of approximately  $2 \times 10^{-5}$  Torr  $H_2$ , the plasma is observed to be stable. Below this pressure, the plasma is unstable, in that the parameters of the plasma do not normally repeat themselves after each RF heating pulse. This critical pressure appears to be independent of the magnetic field over a wide range. It is in this low-pressure region that the intense bursts of microwave radiation are observed. The number of bursts, the most probable time of their occurrence, and their intensity are all complicated functions of the magnetic field strength or the background pressure. The radiation observed in a 30-Mc band near the RF heating frequency generally occurs later in the afterglow as the pressure is lowered. Just below the critical pressure, bursts are seen as early as 25  $\mu$ sec after the heating power is removed. At a pressure of  $5 \times 10^{-6}$  Torr and a central magnetic field of 880 Gauss, however, the most probable time for these bursts of radiation is more than 800  $\mu$ sec after the end of the heating pulse. Below approximately  $4 \times 10^{-6}$  Torr, it is impossible to form a discharge with the available microwave power. The dependence of the most probable time of occurrence on the magnetic field strength is extremely complicated. No typical trend is evident. Below a central field of approximately 690 Gauss, the bursts are absent. Increasing the field results in bursts whose amplitudes increase until the magnetic field reaches 830 Gauss. The amplitudes of these bursts are estimated to be of the order of 500 watts peak, with a duration of approximately 5  $\mu$ sec.

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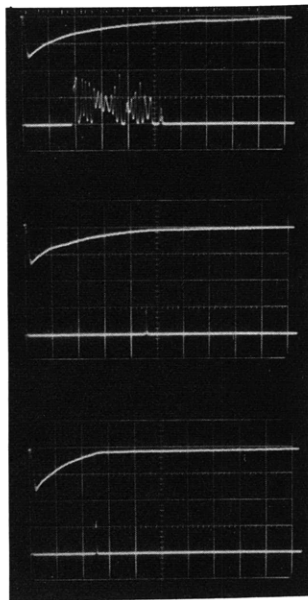
\*This work is supported by the United States Atomic Energy Commission under Contract AT(30-1)-3581.



← TIME

Fig. XV-1.

Afterglow behavior of the pulsed electron-cyclotron discharge under repeatable operating conditions. Top trace: radiated power near 2850 Mc. Bottom trace: decay of the stored plasma energy. Time scale: 50  $\mu$ sec/division. Conditions: pressure  $1.5 \times 10^{-5}$  Torr; magnetic field at mirror center, 1030 Gauss.



← TIME

Fig. XV-2.

Typical behavior under nonrepeatable operating conditions. Top trace: radiated power near 2850 Mc. Bottom trace: decay of the stored plasma energy. Time scale: 50  $\mu$ sec/division. Conditions: pressure  $1.5 \times 10^{-5}$  Torr; magnetic field at mirror center, 1050 Gauss.

## (XV. SPONTANEOUS RF EMISSION FROM HOT-ELECTRON PLASMAS)

Increasing the field strength results, first, in an appreciable decrease in burst amplitude, followed by a slight increase at even higher fields. The occurrence of multiple bursts does not appear to be limited to either extreme in pressure or magnetic field. Typical oscilloscope traces of these multiple bursts have been previously reported.<sup>1</sup>

The most encouraging result of this preliminary investigation is that there are several critical combinations of magnetic field and pressure for which the instability is repeatable. At a central magnetic field of 1030 Gauss and a pressure of  $1.5 \times 10^{-5}$  Torr, a single intense burst of radiation occurs consistently  $120 \pm 20$   $\mu$ sec after each RF heating pulse. Correlated in time with the burst is a sudden drop to zero of the measured energy density of the plasma. Figure XV-1 illustrates this behavior. Comparison of the energy radiated in the burst with the change in the stored energy in the plasma indicates that an appreciable fraction of the kinetic energy of the hot electrons is converted into coherent radiation by the instability. Figure XV-2 illustrates the more general behavior occurring at pressures and field strengths other than these special ones. Note that while the first shot is similar to the behavior illustrated in Fig. XV-1, the second shot does not indicate a change in stored energy when the burst occurs. The bottom shot exhibits a very intense period of microwave radiation which has no apparent effect on the stored energy. This behavior is still not understood. The behavior of the bursts at the critical values of fields and pressures, however, should make possible a thorough investigation of the repeatable operation.

Measurement of the frequencies radiated by the discharge has been complicated by the presence of the high-power heating pulses. In order to protect the detectors from these pulses, it has been necessary to use a narrow-band transmit/receive switch. Retuning this switch has indicated that under some operating conditions more than one band of frequencies is being radiated. These separate bands each have their own characteristic intensity and most probable time of occurrence. Although these bands are all near the frequency of the RF heating power, the narrow-band switch discriminates against part of the radiated energy, and thus makes time-resolved frequency measurements impossible. We plan to replace this transmit/receive switch in the near future with a wideband PIN diode switch. This will allow time-resolved spectra to be determined easily.

We shall continue the investigation of this intense instability. Experiments are to be directed toward a thorough study of the time-dependent plasma parameters both before and after the occurrence of the repeatable bursts.

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### References

1. C. E. Speck and A. Bers, "Observation of Enhanced Cyclotron Radiation from an Electron-Cyclotron Resonance Discharge," Quarterly Progress Report No. 82, Research Laboratory of Electronics, M. I. T., July 15, 1966, pp. 187-189.

