The Reflex-Diode HPM Source on Aurora

GEORGE A. HUTTLIN, MICHAEL S. BUSHELL, DAVID B. CONRAD, ASSOCIATE MEMBER, IEEE, DAVID P. DAVIS, KEVIN L. EBERSOLE, DANIEL C. JUDY, PEDRO A. LEZCANO, MARC S. LITZ, MEMBER, IEEE, NINO R. PEREIRA, BRIAN G. RUTH, MEMBER, IEEE, DOUGLAS M. WEIDENHEIMER, AND FORREST J. AGEE, MEMBER, IEEE

***Abstract*—This paper describes the most recent in a series of experiments to develop the reflex diode as a source of microwaves on the Aurora relativistic electron-beam pulser. We have achieved an overall output for radial extraction of ~400 J in microwave bursts from ~100 to 150 ns at frequencies below 1 GHz. The diagnostics for radial extraction have included directional couplers, card calorimeters, and free-field sensors. We have varied the anode/cathode spacing, downstream microwave reflector, and a second anode foil, but, within the range of variations, no strong trends have been noted.**

I. Introduction

AURORA is one of the largest pulsed, high-intensity electron-beam generators. The machine consists of four parallel Blumlein pulsers, each producing a 180-ns (FWHM) electron beam peaking at about 10 MeV and 250 kA with a ~35-Ω load. Although Aurora usually produces bremsstrahlung, it has been interesting to investigate alternative applications, one of which is microwaves. Because of the size of hardware compatible with the 1.22-m (diam) magnetically insulated transmission line (MITL), we have restricted our attention to the reflex diode, which is the simplest mechanism for microwave production. Despite the inefficiency of this mechanism, the magnitude of our power source still suggested we would produce substantial levels of microwave radiation.

With the generic reflex-diode oscillator [1] the beam is shot through a thin anode into an evacuated drift tube. A virtual cathode forms in the drift tube if the current exceeds the space-charge limit, as expected from simple theory [2] backed by particle-in-cell (PIC) simulations. The presence of a virtual cathode results in electron reflexing and microwave generation. The simulations also show that the virtual cathode itself can oscillate, giving another mechanism for microwave generation.

The initial experiment [3] on Aurora, conducted in August 1986, featured a 5-m-long axial wire calorimeter, which showed approximately 1 kJ of microwaves at the 20-GW power level. The high background in the axial calorimeter measurements prompted a second experiment [4] in which the axial calorimeter viewed microwaves reflected from a 45° screen in a 1.22-m diam "T" section, while the beam and debris were to have passed through the screen. Unfortunately, the axial calorimeter showed only ~50 J of microwave energy. We believe that the lack of a sufficient drift space beyond the reflection screen for the beam and debris was partially responsible for this low result. Each of these two experiments was supplemented by PIC calculations [5], which generally agreed with the measured diode impedance, microwave frequency, microwave turn-on, and the trend of microwave energy with the foil thickness.

We conducted a third experimental session [6] on Aurora in June 1988. Because of its difficulty we abandoned axial calorimetry in favor of more definitive measurements of the microwave energy that could be extracted by radial rectangular waveguides. The microwave power and energy per arm was seen to be independent of the number of arms up to the eight that were available. We tried using a carbonized-felt cathode coating and found no improvement in microwave output. We also tried different anode materials, of which we had the most success with 16-μm Al foil instead of the more common screens. We have subsequently found that a 16-μm foil can survive tens of shots without beam damage if we divert to a dummy load the energy from the trailing edge of the electrical pulse. This longevity of the anode foils has made it possible to keep vacuum cycling to a minimum and to shoot at a reasonably high rate.

The fourth experiment, conducted in March 1989, is the subject of this paper. Our goal in this experiment was to verify levels of radiated power and energy density and to study some of the effects of simple variations in geometry.

II. Experimental Description

The general layout of the most recent experiment as shown in Fig. 1 was similar to the previous Aurora high-power microwave (HPM) experiment [6]. We replaced one of the four bremsstrahlung diodes with a 45° elbow plus an additional 2 m of ~50-Ω MITL leading to the uncoated cathode tip. The elbow was necessary to align the MITL with the floor, and the 2-m section downstream of the elbow was assumed to be sufficiently long to isolate the beam from the asymmetries of the elbow. The 53-cm-

Manuscript received October 3, 1989; revised January 14, 1990. This work was supported by the Strategic Defense Initiative Office of Innovative Science and Technology and managed by the Harry Diamond Laboratories.

G. A. Huttlin, M. S. Bushell, D. B. Conrad, D. P. Davis, M. S. Litz, B. G. Ruth, and F. J. Agee are with the U. S. Army Laboratory Command, Harry Diamond Laboratories, Adelphi, MD 20783.

K. L. Ebersole, D. C. Judy, P. A. Lezcano, N. R. Pereira, and D. M. Weidenheimer are with Berkeley Research Associates, P. O. Box 852, Springfield, VA 22150.

IEEE Log Number 9035697.

0093-3813/90/0600-0618$01.00

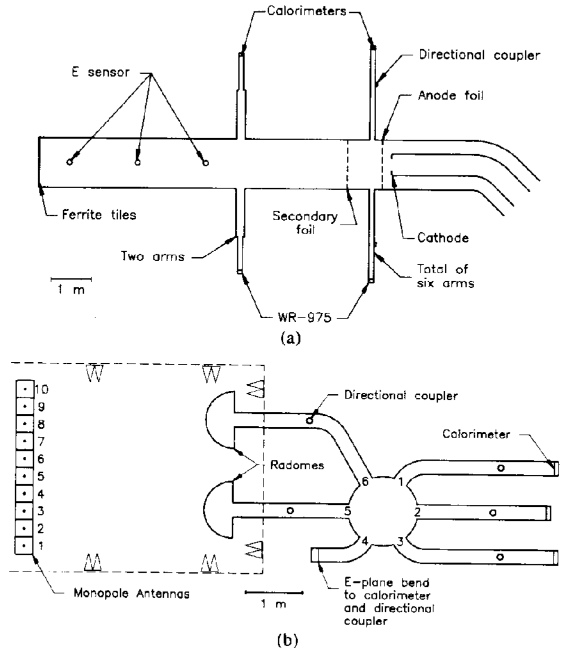


Fig. 1. Experimental configuration. (a) Plan view. (b) Axial view.

diam cathode with a 2.5-cm beveled tip and 30-cm-diam hole on axis was the same one used in the initial work. The anode foil covered the entire 1.22-m diam of the drift tube except along the edge where an array of semicircular pump holes were cut.

The anode/cathode gap was typically 23 cm. On occasion, we placed an additional foil at positions from 9 to 76-cm downstream from the anode. This foil was intended either as a mechanism to extend the reflexing path length [7], [8] or as a microwave reflector for resonance. The specific function of the secondary foil depended on the foil's position relative to the virtual cathode, assumed to be ~12 to 20-cm downstream from the anode foil as indicated by PIC simulations using the code MAGIC [9]. Otherwise, we permitted the microwaves to propagate axially for several meters.

For microwave extraction we surrounded the axial position 27-cm downstream from the anode with six WR-975 rectangular waveguides (605-MHz cutoff) oriented with $E_{TE_{10}}$ parallel to the z-axis of the drift chamber. Some of the six waveguides included 60° H-plane elbows, and one waveguide included a 90° E-plane bend. We also included an additional pair of diametrically opposed rectangular waveguides 3-m downstream from the anode, raising to eight the total number of waveguides loading the microwave source.

Except where the energy radiated through open-ended waveguides, resistive cards [10] absorbed the waveguide microwave energy. In our previous experiment [6] the cards had been parallel to and located at the ideal 850-MHz $\lambda/4$ distance from the end plate, but network analysis had shown rather high reflections S_{11} ranging from -8 to -10 dB between 0.7 and 1.0 GHz. For the present experiment, we empirically reduced S_{11} below -15 dB in the ~700- to 950-MHz range by moving the cards to the nominal $\lambda/8$ position. We attempted to sense the temperature change in each card through a pair of series thermistors connected to a Wheatstone bridge in the shield room. These cards were well-behaved when calibrated with tens of joules of microwaves at ~50 W and seem to have worked well for the previous experiment [6]. However, in the present experiment the calorimetry was sufficiently erratic so that it obscured trends in the data. The possibility of high-power breakdown initiated by the thermistors and their leads is a concern and might be more critical in the new position of the cards. Although we tried to keep the leads perpendicular to $E_{TE_{10}}$, it is possible that higher-order modes might have coupled directly to the thermistor circuit. We have begun work on a new calorimeter designed to rectify these problems. In general, the calorimeters did show energy levels within a factor of two of the levels obtained from the directional couplers and they did respond properly to being screened from microwaves.

Vestigial-loop directional couplers ~1-m upstream of each card termination detected microwaves flowing away from the source. Each of these couplers is a flattened loop recessed in a cylindrical cavity (below cutoff) in the center of the H-plane side of the waveguide. The loop was designed to have a response of equal magnitude to the electric and magnetic fields so that, at a given end of the loop, there would be no signal for a particular direction of propagation in the waveguide. Therefore the signal at one end of the loop would correspond to microwave propagation in one direction, while the signal at the other end would correspond to propagation in the other direction. The directivity was better than 15 dB for frequencies above 650 MHz, and better than 30 dB for frequencies above 750 MHz. For the most recent work we dummy-loaded the side of the loop corresponding to microwaves returning to the source. High-power reflection data from the cards used in the first two Aurora microwave experiments are commensurate with the range of reflections expected from the network analysis. Therefore we did not dedicate any data channels to measure reflected microwaves in the more recent experiments.

The signals from the directional coupler propagated to the shield room through 120 ns of ~1-cm foam-insulated cable. To keep down the radiation effects, we shielded the cables with lead "chimneys" and steel-covered trenches. Also, 300-MHz high-pass filters eliminated low-frequency noise, and, in most cases, 1-GHz filters restricted the data to the TE_{10} mode in the WR-975 waveguide. We monitored the directional couplers with diode detectors and transient digitizers[1] on all shots, and, as other instrumentation needs permitted, we also used 1-GHz oscilloscopes.[2] We digitized the amplitudes of the

[1]Tektronix 7912.
[2]Tektronix 7104.

oscilloscope traces to verify the power and energy given by the diodes. We used 500-MHz low-pass filters on the diode outputs to eliminate the RF component. For on-line Fourier analysis we mixed the signals with a local oscillator at 600 MHz (just below the waveguide cutoff) and recorded these with transient digitizers.

We calibrated the directional couplers and their data channels with a vector network analyzer.[3] Since some stages of the analysis involved the measurement of 80- to 90-dB attenuations, we checked the network analyzer against comparable, well-calibrated broad-band attenuators and found that, at worst, the network analysis introduced an estimated error of ± 0.2 dB. The overall responses of the directional-coupler channels up to and through the oscilloscopes are shown in Fig. 2(a), while the responses up to the diodes are shown in Fig. 2(b). We measured these responses after the final shot of the test sequence using the complete lines with the devices as attached for the last shot. (Only couplers 1, 2, and 6 were routed to the1-GHz oscilloscopes during the experiment.) The dips in Fig. 2(a) at 1.1 GHz resulted from the connection of 1.5- and 1.0-GHz filters by the 6-dB splitters that routed the signals to the oscilloscopes. The deviation of the high-frequency trend of the coupler 2 curve from the others was caused by a difference in the WR-975 setup during the calibration. The high-frequency difference between the diode-channel calibration curve for coupler 4 and the others was caused by a different type of 1-GHz filter.

To measure the radiation from either one or two open-ended waveguides, we placed a line of 10 monopole antennas in a $3 \times 3 \times 6\text{-m}^3$ anechoic chamber as indicated in Fig. 1(b). The anechoic chamber was a temporary structure lined with conical absorbers. These absorbers were up to 60 cm in length, which is less than optimum. However, since our anechoic chamber was intended as an absorber of radiated energy and not as a simulation of unbounded space, we believe this compromise posed no serious problem.

Each monopole antenna consisted of an RG-141 center conductor protruding 1 mm above a $30 \times 30\text{-cm}^2$ metallic ground plane and oriented parallel to the electric field vector. We calibrated each antenna on-axis 3.66 m in front of an open-ended guide using the network analyzer in conjuction with a 50-W, 0.1- to 1.0-GHz amplifier. This distance, 3.66 m, was the same as used between the open-ended guides and the line of receiving antennas for the HPM experiments. This calibration made the antennas reasonably accurate sensors of radiated power and energy, even though the chamber was less than ideal. However, since the fields at the antennas depended on wall reflections and our antennas were not calibrated directly in terms of known fields, the usage of the antennas for field measurements was less accurate. For the power densities quoted in this paper we have assumed that the anechoic chamber was ideal. Frequency responses of two of the monopole antennas to total radiated power are shown in Fig. 3. The antenna signals were recorded directly on 1-GHz oscilloscopes.

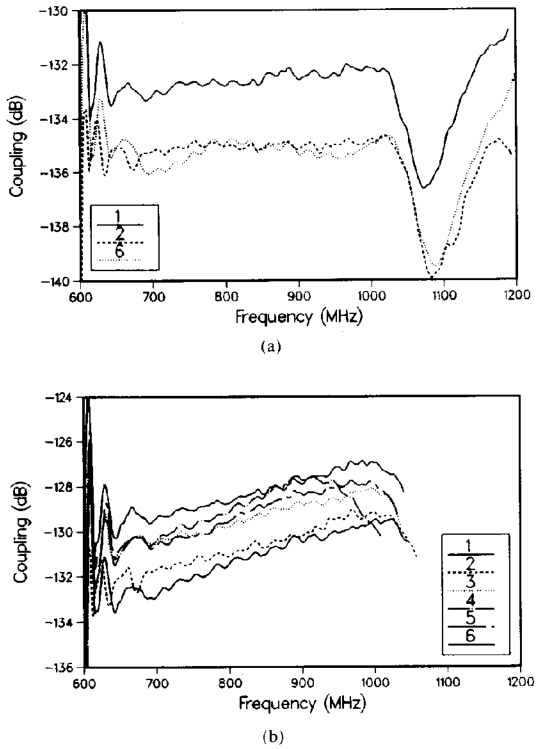


Fig. 2. Forward responses of vestigial-loop waveguide directional couplers: (a) oscilloscope channels (WR-975 to oscilloscope display); and (b) diode-detector channels (WR-975 to diodes).

Fig. 4 shows the electron-beam characteristics as measured with a self-integrating capacitive voltage divider and current-viewing resistor (CVR) just upstream of the elbow. We inferred the diode characteristics from these data using a transmission-line circuit analysis, which is a slight modification of the usual $L\dot{I}$ correction. The fast decay of the trailing edge of the voltage pulse resulted from the energy-diverting switch at the output of the pulse-forming network (PFN). The diode voltage peaked at -6.5 MV and the diode current peaked at -0.3 MA, implying a diode impedance of 22 Ω. We obtained the instrumentation trigger and fiducials from the CVR just upstream of the elbow.

Fig. 1(a) also shows a set of three electric-field sensors. However, as the data from these are suspect, we will replace the sensors with B-dot loops for future experiments. We terminated the axial drift region with ferrite tiles[4] to keep the axial microwave propagation unidirectional, which was to have facilitated the interpretation of the data from the electric-field sensors in terms of microwaves. However, we are concerned that these tiles might have saturated in the microwave flux.

[3]Hewlett-Packard Model 8510 A.

[4]Emerson & Cuming Eccosorb® NZ-31.

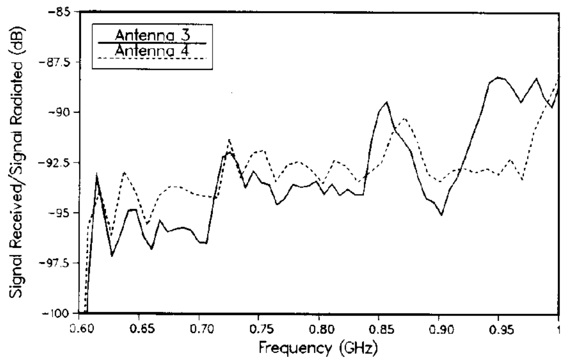


Fig. 3. Responses of free-field antennas 3 and 4.

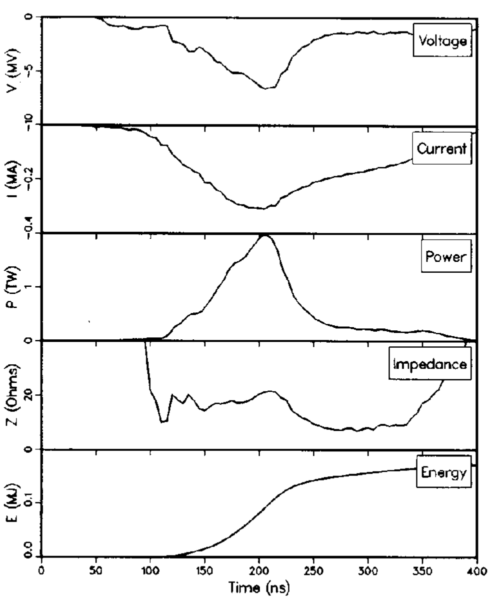


Fig. 4. Typical reflex-diode characteristics (shot 6842).

III. Results/Discussion

Our data from March 1989 comprise a total of 68 shots and include several independent measurements of the total power and energy extracted by the waveguides. The shots described below typify the data.

For shot 6840 we used only one foil, and, as for two other shots, only the lower (arm 5) of the two radiating arms was open to the anechoic chamber. Also, the signals were filtered below the 1.2-GHz cutoff of the TE_{01} and TE_{20} modes in the arm. Therefore, other than for an echo from the less-than-ideal "anechoic" walls, there was no possibility for a time-dependent distribution of power density in the chamber.

This simplicity of the radiated field made it possible to use one of the ten monopole antennas to infer the total radiated waveguide power and energy. Antenna 3 was almost directly aligned with the radiating waveguide and at the same distance from the waveguide as for its calibration. Therefore we feel confident that the data from antenna 3 are a reliable indicator of the total radiated power. Antenna 4 was 0.3-m out of alignment with the radiating arm. Therefore we made a small correction using the ideal free-space pattern for an open-end waveguide so that it too would give the total power radiated. The envelopes of the signals from antennas 3 and 4 are shown in Fig. 5(a). The frequency from the original signals was 750 $\pm$ 60 MHz. The two measurements of the waveguide power have a similar time-dependence and agree with an amplitude of ~ 1.0 GW. Any difference resulted from the rather strong frequency dependence of the antenna calibrations and our inability to determine the frequency with better accuracy.

For comparison, Fig. 5(b) shows the same power envelope measured with the directional coupler in the radiating arm. Both the shape and amplitude of power agree with the antennas. We had been concerned with the possibility of breakdown in the waveguide directional couplers at the circular apertures to the vestigal loops. These apertures are rounded, but include an insulating cover which might flash over in field components parallel to the surface. This breakdown might be a distinct possibility with high-frequency overmoding, which might also cause problems with an abnormally strong coupling to the loop and terminator. We are encouraged, however, by the agreement between the directional coupler in arm 5 and the free-field antennas and by the general agreement in the past between the couplers and calorimeters.

Fig. 5(c) shows the running integrals of the power from the two antennas and directional coupler. These different measurements agree with a final energy of about 60 J.

The data for each of the other arms on shot 6840 are shown in Fig. 6. In Fig. 6(a) the directional coupler data show somewhat differing power profiles. Since arm 6 (going to the upper open-ended waveguide) was screened off at its source end, its trace illustrates either the level of noise in the diagnostics or a baseline drift. No trace is given for coupler 3 because the transmission line from that coupler was malfunctioning on that shot. Fig. 6(b) shows the energy in the various arms from the directional couplers. The average energy per arm is seen to have been about 55 J; subtracting the background suggested by the trace for arm 6 gives the total energy extracted in the four recorded arms as being about 200 J.

The total energy as given by the free-field antennas and directional couplers was a little higher than given by our previous data [6]. This might have resulted from the longer duration of the microwaves, which more recently approached the nominal width of the voltage and current. One improvement in preparation for the most recent experiment had been rectangular-waveguide apertures smoothed to ~ 2-mm radii. Assuming the static field configuration, this corresponds to a field enhancement factor of ~ 7. Previously, the apertures had been rather sharp, with larger and uncertain enhancements. The improved apertures still had a large enhancement; however, the decreased enhancement might account for the longer duration of the radially extracted microwaves.

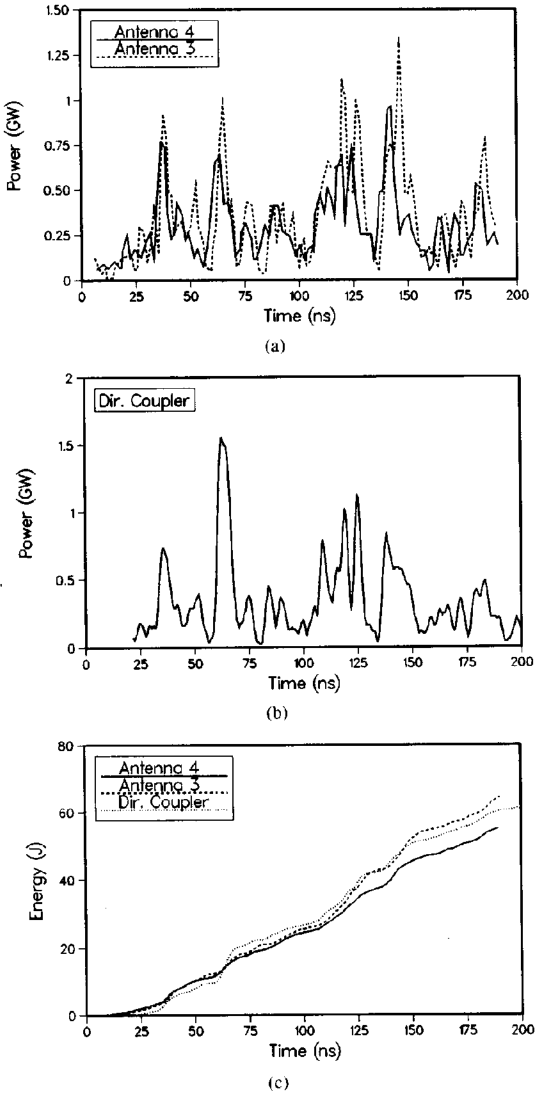


Fig. 5. Comparison of antenna and directional-coupler measurements (Shot 6840). (a) Radiated power sensed by each of the two antennas most closely aligned with the single radiating arm. (b) Directional-coupler measurement of radiated power. (c) Energy radiated from each of the antennas and directional coupler.

The 0.13-MJ diode energy (as summed up to the time the PFN output was diverted) indicates that the four waveguide arms illustrated in Fig. 5 had a total efficiency of 0.15%. If we assume that the arms not monitored by directional couplers had similar energies, then we can quote an efficiency approaching 0.3%. Note that this efficiency only includes radially extracted microwaves between 0.6 and 1.0 GHz and assumes that our traces include the entire microwave signals.

While the field map with only one radiating arm was relatively stable as expected, such was not the case with two arms. The power densities recorded by the two adjacent antennas 3 and 4 on shot 6838 (Fig. 7) show a time-

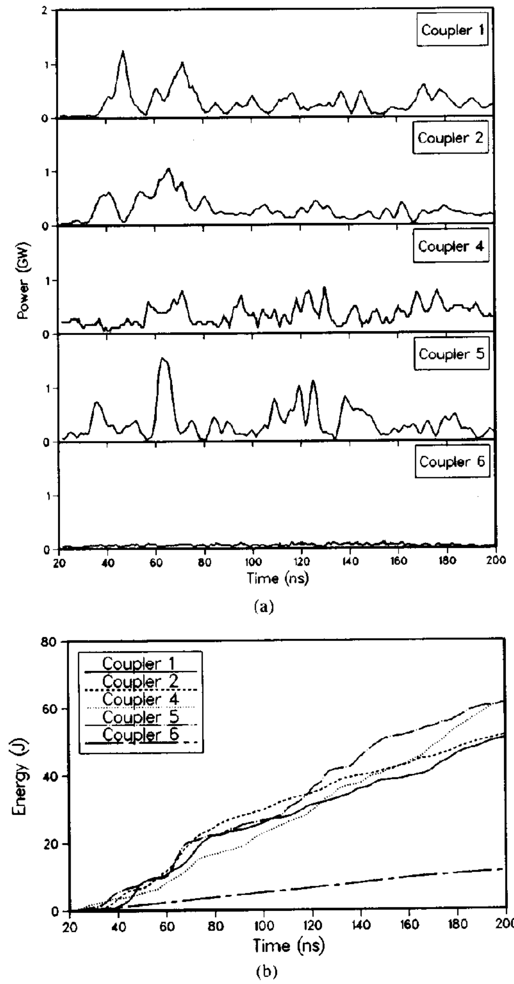


Fig. 6. Comparison of directional-coupler measurements (shot 6840): (a) forward power; and (b) energy.

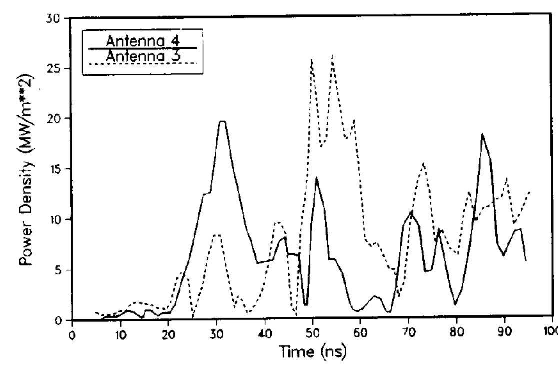


Fig. 7. Power density as recorded by two adjacent receiving antennas in the field of two radiating arms (shot 6838).

dependent radiation pattern. The temporal discrepancy of the data from the two antennas is evidence of the changing phase difference between the two radiating arms. We would have expected this phase difference to change from

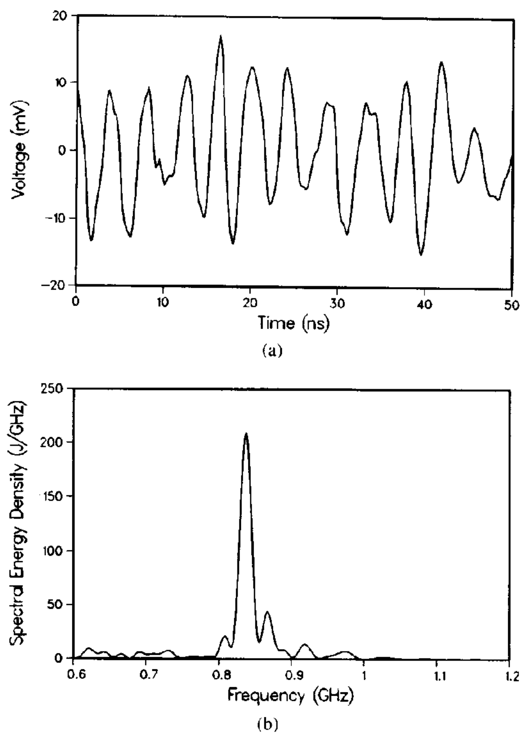


Fig. 8. Sample frequency determination on arm 2 for shot 6872: (a) Heterodyned signal as seen on digitizer; and (b) resulting spectral energy density (normalized to give the energy detected by diode).

the lack of correspondence between the different profiles of the arms in Fig. 6(a) and from the arm-to-arm phase difference changes seen in our past work [6]. The energy densities recorded at antennas 3 and 4 were 0.67 and 0.54 (± 0.15) J-m^{-2}, respectively.

Shot 6872 produced one of our cleanest spectra, obtained from the heterodyned signal shown in Fig. 8(a) recorded on the transient digitizers sweeping at 5 ns/div. Because of this sweep speed, unfortunately, the complete intermediate-frequency signal could not be recorded. This signal resulted in the spectrum shown in Fig. 8(b). Since we had no calibration information for the mixers, we weighted the square of the Fourier transform so that its integral agreed with the integrated power from the diode detector.

Prompted by previous work at the Lawrence Livermore National Laboratory [7], this shot included a secondary foil 9-cm downstream from the anode. Assuming that the virtual cathode would otherwise have formed at its usual position, 12–20 cm from the anode, the secondary foil would then have been between the anode and virtual cathode and in a position to extend the reflexing path length. The data for the other 13 shots with such an arrangement, with foil-to-foil spacings from 9 to 18 cm, do not show as clean or consistent spectra, however. Consequently, the effect of the second anode on the reflexing frequency is not clear in the data.

In this experiment we also varied the anode/cathode gap from 16 through 23 cm, and we varied the anode/secondary-foil separation from 46 to 76 cm. At this spacing the secondary foil and anode would have formed a resonant cavity. The results have not demonstrated a strong microwave extraction dependence on foil positioning, which might be related to the severe overmoding in the source region.

A strong virtual cathode forms only when the diode current is much greater than the space-charge-limiting current $I_{\mathrm{SCL}} \simeq 17 \times (\gamma^{2/3} - 1)^{3/2}/G(\mathrm{kA})$, where $G \sim 1$ – 2 is a correction factor which might include two-dimensional and foil-scattering effects. Aurora's current of 300 kA only exceeded the space-charge limit by a factor of 2–4. The downstream current is an estimate of the space-charge limit. We have estimated the charge deposition downstream by measuring the dose deposited in thermoluminescent detectors by the electron beam which penetrated the aluminum drift tube wall. These measurements [11], which suggest that the average current downstream was on the order of 60 kA, agree with previous CVR measurements and will be compared to ongoing PIC computations in future work.

IV. Conclusions

We have demonstrated the extraction of ~50 J per shot of microwave radiation in the 0.6- to 1.0-GHz range into each of eight radial arms. The average energy per arm agrees reasonably with the observations of the previous Aurora microwave experiments [3]–[6]. With eight arms, we have the capability for radiating 400 J from single-moded rectangular waveguides.

The original work on the Aurora reflex diode produced ~1 kJ of microwaves as seen by an axial calorimeter, unfortunately obscured by a large background. To avoid this background problem we have investigated more recently the energy which could be extracted radially in rectangular waveguides. This approach has yielded reasonably good data on the energy per pulse, at least regarding in-band energy content. Up to a total of eight radial arms, the energy per radial arm has not diminished with an increasing number of arms, which suggests that we can extract more energy by simply adding arms. We are preparing for an experiment to extract energy into 18 radial arms, which might push the total energy extracted radially toward 1 kJ, in the absence of source saturation. With eight arms our extraction efficiency is much lower than experiments with axial extraction [12].

Acknowledgment

The authors would like to acknowledge the resources and motivation supplied by H. E. Brandt, the tireless effort of the Aurora operations group, and helpful discussions with J. Golden.

References

[1] L. E. Thode, "Virtual-cathode microwave device research: Experiment and simulation," in *High Power Microwave Sources*, V. L. Granatstein and I. Alexeff, Eds. Boston: Artech, 1987, chap. 14.

[2] D. J. Sullivan, J. E. Walsh, and E. A. Coutsias, "Virtual cathode oscillator (Vircator) theory," in *High Power Microwave Sources*, V. L. Granatstein and I. Alexeff, Eds. Boston: Artech, 1987, chap. 13.

[3] A. Bromborsky *et al.*, "Preliminary results from a reflex diode experiment on the Aurora intense pulsed relativistic electron beam generator," in *1987 IEEE Int. Conf. on Plasma Sci., Conf. Rec.--Abstracts* (Arlington, VA), June 1-3, 1987, p. 39.

[4] A. Bromborsky *et al.*, "On the path to a terawatt: High power microwave experiments at Aurora," in *Microwave and Particle Beam Sources and Propagation* (Proc. SPIE 873). Bellingham, WA: SPIE, 1988, pp. 51-61.

[5] L. E. Thode, "Aurora reflex diode simulation and experiment, final report," Mission Res. Corp., Albuquerque, NM, Rep. MRC/ABQ-R-1050, Feb. 1988.

[6] G. A. Huttlin *et al.*, "Generating high-power microwaves with the Aurora pulser," in *Microwave and Particle Beam Sources and Directed Energy Concepts* (Proc. SPIE 1061) H. E. Brandt, Ed. Bellingham, WA: SPIE, 1989, pp. 24-33.

[7] P. Poulsen, Lawrence Livermore Nat. Lab., private communication.

[8] D. E. Voss, Voss Scientific, Albuquerque, NM, private communication.

[9] B. Goplen, L. Ludeking, J. McDonald, G. Warren, and R. Worl, "MAGIC user's manual," Mission Res. Corp., Newington, VA, Rep. MRC/WDC-R-184, Sept. 1988 (unpublished).

[10] L. Smutek, W. M. Bollen, and J. Pasour, "HDL quarter wavelength calorimeter," Mission Res. Corp., Newington, VA, Rep. MRC/WDC-R-171, 1988 (unpublished).

[11] G. A. Huttlin *et al.*, "Reflex-diode high-power microwave source on Aurora," in *Intense Microwave and Particle Beams* (Proc. SPIE 1226), H. E. Brandt, Ed. Bellingham, WA: SPIE, 1990.

[12] R. Platt *et al.*, "Low frequency multigigawatt microwave pulses generated by a virtual cathode oscillator," *Appl. Phys. Lett.*, vol. 54, no. 13, pp. 1215-1216, 1989.

*

George A. Huttlin, a native of Philadelphia, PA, was born on March 19, 1947. He received the B.A. degree (1969) in physics from La Salle College, Philadelphia, and the M.S. (1972) and Ph.D. (1975) degrees in 1975 from the University of Notre Dame, South Bend, IN, where he studied polarization effects in low-energy nuclear physics.

In 1975 he began work at the Harry Diamond Laboratories Aurora Facility, where he has been involved with pulsed-power machine design, modeling, and diagnostics. More recently, he has studied high-voltage vacuum/fluid flashover and the applications of photoconductivity to pulsed-power switching and to microwave reflection. He began his work in HPM by participating in the BWO experiments on the Dragon machine at the University of Maryland, which extended to work on the Aurora HPM experiments, for which he assumed responsibility in 1988.

*

Michael S. Bushell was born in Sweetwater, TX, on July 21, 1948. He received the B.S. degree in physics from Texas Tech University, Lubbock, in 1969, and the M.S. degree in physics in 1972.

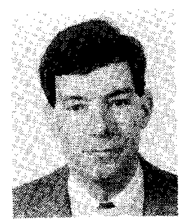
His primary field of endeavor has been in the areas of source region EMP effects and electromagnetic coupling phenomena. He is presently on the staff of the Aurora Facility at Harry Diamond Laboratories in Adelphi, MD.

*

David B. Conrad (A'87) was born on August 19, 1952. He studied electrical engineering at the University of Maryland, College Park.

He joined the U.S. Army Adelphi Laboratory Center, Harry Diamond Laboratories in December, 1985, where he has worked for the Nuclear Survivability Laboratory as an Electronics Technician involved in high power microwave research and development, experimentation, and device response applications. In February 1989 his activities expanded with his involvement in high power microwave generation research at the Laboratory's Aurora Facility, where he has been broadly employed in dosimetry and recent upgrades and modifications to machine and data acquisition/diagnostics areas and capabilities.

*



David P. Davis received the B.S. degree in physics in 1975 from Drexel University, Philadelphia.

He has been with Harry Diamond Laboratories since 1972, where he is currently involved in high power microwave production and testing and in nuclear radiation effects testing. Other areas of work in the past have included pulsed power development and EMP testing and analysis.

*

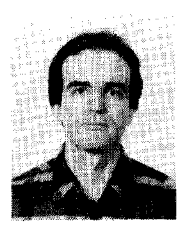
Kevin L. Ebersole was born on February 21, 1968, in Reading, PA. He received the A.A. degree in electrical engineering technology from Pennsylvania State University, State College. He has been with Berkeley Research Associates, Springfield, VA, since October 1988.

*

Daniel C. Judy was born in September 1961 in Riverdale, MD. He earned the B.S. degree in electrical engineering (1989) from the University of Maryland, College Park.

He joined the U.S. Air Force in 1979, serving four years in active duty as a Radar Technician. He joined the Harry Diamond Laboratories in 1987 as a Coop Student and assisted in data acquisition and analysis on HPM experiments. He is currently working on megavolt gas-switch jitter reduction.

*



Pedro A. Lezcano was born on November 20, 1958 in Cuba. He worked for nine years as a Field Service Technician before joining Berkeley Research Associates, Springfield, VA, in September 1988.

*

Marc S. Litz (S'86-M'89) was born in Philadelphia, PA, in February 1956. He received the B.S. degree (1981) from Drexel University, Philadelphia, and the M.S. degree (1987) from Catholic University, Washington, DC. For his M.S. degree he investigated photoconductive switches for high power microwave applications.

He joined the Harry Diamond Laboratories Aurora Facility in 1981, developing data acquisition and signal-processing software systems. His research interests at this time involve high current relativistic electron-beam device physics, upon which he is basing his Ph.D. degree research.

Nino R. Pereira was born on March 11, 1945 in Amsterdam, The Netherlands. He obtained the M.S. degree in physics from the University of Amsterdam in 1970, after which he taught physics in Paraguay for two years. He obtained the Ph.D. degree from Cornell University, Ithaca, NY, in 1976.

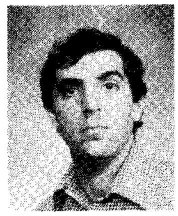
He has investigated nonlinear waves in plasmas and fluids, lasers, and, since 1981, pulse power. He joined Berkeley Research Associates, Springfield, VA, in 1984. His present work is centered around the development of flash X-ray sources, including the plasma radiation source and the Aurora gamma-ray simulator.

*

Brian G. Ruth (M'89) was born in Souderton, PA, in 1960. He received the B.S. degree in physics from Drexel University, Philadelphia, PA, in 1983.

He joined the Harry Diamond Laboratories in 1983, where he is currently working on the application of mode conversion techniques to electron-beam-driven high-power microwave sources.

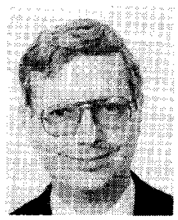
Mr. Ruth is a member of Sigma Pi Sigma.



Douglas M. Weidenheimer received the Associate in Engineering degree from the Pennsylvania State University, Berks Campus, in 1983.

He was employed with the Sandia National Laboratories from 1983–1985, working on high-density plasma-source experiments. From 1985–1987 he worked on large excimer laser experiments at the Western Research Corporation. He joined Berkeley Research Associates, Springfield, VA, in July 1987 as an Engineer assigned to the Aurora Facility, and has been working on upgrading the data acquisition and pulsed-power capabilities of the Facility.

*



Forrest J. Agee (M'82) was born in El Paso, TX, on August 11, 1941. He received the B.S. degree in physics from Clemson University, Clemson, SC, in 1963, and the M.S. and Ph.D. degrees in physics from the University of Virginia, Charlottesville, in 1965 and 1967, respectively, where he studied the superfluidity of liquid helium.

He has done work in cryogenics, superconductivity, and electromagnetic pulse effects. His current research interests include high-power microwave sources, electron accelerators, and pulsed radiation sources. He is the Director of the Aurora Radiation Test Facility at the U.S. Army Harry Diamond Laboratories. His recent work has been in expanding the applications of the Aurora 12 MV, 1.2 MA, 14 TW electron accelerator and several smaller machines.