Tuesday Morning, 22 May 1990
8:30 am -- Regency Ballroom

"Physics and Applications of
Advanced Pulsed Power
Accelerators and Particle Beams"

Dr. Pace VanDevender
Sandia National Laboratory

Tuesday Morning, 22 May 1990
9:40 am -- Regency Ballroom G&H

Oral Session 3A
Intense Beam Microwave Sources - I
Chairman: S.H. Gold

3A-1&2 INVITED

Characteristics of a High Efficiency, High Power X Band TWT Amplifier.

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ABSTRACT

We present a description of results obtained on the performance of several X band TWT amplifiers. The amplifiers operate in a TM_{01} mode in a cylindrically symmetric rippled wall configuration. In some cases the amplifier is severed to ensure that the system does not oscillate due to positive feedback. Peak output powers of several hundred megawatts have been achieved at efficiencies of up to 45% and energy efficiencies of greater than 35%. The performance of the amplifiers will be compared with expectations based on theoretical analysis and simulation results.

This work was supported in part by the Air Force Office of Scientific Research, by the Department of Energy, and by the Strategic Defense Initiative Office of Innovative Science and Technology, and administered by Harry Diamond Laboratories.

3A-3

Experimental Studies of High Power Plasma Filled Backward Wave Oscillators*

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Recently, it has been demonstrated that a plasma loaded backward wave oscillator (BWO) powered by a relativistic electron beam can generate hundreds of megawatts of microwave radiation at high efficiency (about 40%). In this paper, the results of an experimental study of an 8.4 GHz BWO filled with an externally controlled background plasma is reported. It was found that the enhanced efficiency can be maintained even for large electron beam currents approaching to the vacuum space charge limiting current and we anticipate that this might hold even beyond the space charge limiting current. A small frequency up-shift (few percent) was detected for the plasma loaded BWO. A hydrogen flashover plasma gun was used and its characteristics, including plasma density, drift velocity and temperature, were investigated. Detailed studies of beam propagation in vacuum as well as in plasma loaded structures will be presented. It appears that a slightly over-moded device will be needed for peak power handling capability of 5-10 GW.

*Work sponsored by AFWL and administered by NRL.

3A-4

Absolute Instability for Enhanced Radiation from a High-Power Plasma Filled Backward Wave Oscillator

K. Minami, M. M. Ali, K. Ogura, T. Hosokawa, H. Kazama, T. Ozawa (Niigata University, Japan), T. Watanabe (Institute for Fusion Science, Japan), V. L. Granatstein, W. W. Destler, R. A. Kehs, Y. Carmel, W. R. Lou, and D. Abe (University of Maryland, USA)

The linear theory of electromagnetic radiation from a high-power backward wave oscillator (BWO) with a plasma filled, sinusoidally corrugated waveguide driven by a relativistic electron beam has been derived and analyzed numerically. It is shown that our experimental results [1] of enhanced radiation from plasma BWO's can be explained by the linear theory developed here. Among previous works on the study of BWO's, we describe what seems to be the first thorough analysis as an absolute instability classified generally by Briggs.

We consider an infinitely long axisymmetric slow wave structure in which a uniform, cold, collisionless and strongly magnetized plasma is filled. A solid beam with a longitudinal velocity is passing through it. We obtain an accurate linear dispersion relation, $D = 0$.

The parameters corresponding to our experimental conditions are used in the numerical computations. The procedure is as follows: the solution of complex wavenumber k for a given complex frequency, f, can be found at the center of contour circles of $|D|$ on the complex k plane. There are many roots of $D = 0$ on the complex k plane for a real f. We have to sort out the spatially growing waves from evanescent waves; if Im(k) has different signs when Im(f) takes a large positive value and 0, then the wave is convectively unstable, otherwise it is evanescent. If two roots of k merge for Im(f) > 0, the saddle point, then the wave is an absolute instability which corresponds to BWO's. It is found that the location of the saddle point goes down in the lower half k plane as the plasma density increases. The spatial growth rate and resultant radiation are enhanced by the presence of a plasma. The enhanced radiation can be attributed to a decrease in the group velocity of the backward wave by the plasma, resulting in an increased interaction between the wave and the beam. The saddle point, however, moves into Im(f) < 0 region, when the density is exceedingly large; the absolute instability is suppressed suddenly and only the convective instabilities remain. They correspond to plasma TWT and cannot cause radiation unless a feedback mechanism exists in the slow wave structure.

The present analysis of the absolute instability enables us, for the first time, a practical design proposed here for high-power, coherent and enhanced plasma BWO's.

[1] K. Minami et al., Appl. Phys. Lett. 53, 559 (1988); Y. Carmel et al., Phys. Rev. Lett. 62, 2389 (1989).

3A-5

The Emission of Plasma Cyclotron Waves In Plasma-Filled Backward Wave Oscillators

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Abstract

It is found through computer simulations of plasma-filled backward wave oscillators that within a certain range of magnetic field the growth rate of beam-plasma cyclotron interaction is significantly larger than the conventional backward wave oscillation. This slow plasma cyclotron wave is emitted from plasmas only if it also satisfies the dispersion relation of a ripple wall waveguide which couples the slow wave to fast wave. This observation may be employed to interpret previous experiments which displayed a strong dependence of output power on the magnetic field.

3A-6&7 INVITED

Progress in Relativistic Klystron Research

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Experimental work by collaborators at SLAC, LLNL, and LBL is continuing towards the development of a relativistic Klystron capable of supplying RF power to a "next generation" high gradient Linear Collider. With the latest modifications to our Relativistic Klystron we have been able to obtain over 300MW pulsed RF power (in pulse widths of 30-40 ns.) at 11.4 GHz. This power has been used to accelerate electrons in a short length of high gradient accelerator section. Efforts are now underway to investigate RF breakdown limitations in multiple high gradient accelerator sections using this power. A description of progress with these programs will be presented. A discussion of some of the obstacles which have been overcome will also be described.

Work supported by the Department of Energy, contract DE-AC03-76SF00515.

3A-8

Nonlinear Beam Loading and Dynamical Limiting Currents in a High Power Microwave Gap*

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ABSTRACT

The successful operation of the relativistic klystron amplifier (RKA) at a power level of 3 GW[1] raised the question of whether higher power can be generated or if a saturation mechanism is limiting the output power. The answer to this question depends on the degree of beam loading and the maximum amount of current modulation which can be transmitted across an rf gap.

Using a simple model, we show that the intense space charge of a high current beam may increase the gap capacitance by a factor of two to three over the vacuum value. This increase in capacitance due to beam loading would (a) provide additional shunts of the current to the load, leading to saturation of efficiency; (b) cause detuning of cavities, and (c) result in longer build-up time of the current modulation. Some of these features were observed in recent RKA experiments and simulations. The limiting current under an AC gap voltage is computed and compared with the steady state value. The implications of these findings on operation efficiency and frequency stability in other high power microwave devices are discussed.

1. M. Friedman et al., Rev. Sci. Instrum. (Jan 1990 issue); also in IEEE Trans. Plasma Sci., (Special Issue on HPM, Jun 1990 issue).

* Supported by SDIO/IST and managed by the Harry Diamond Laboratory.