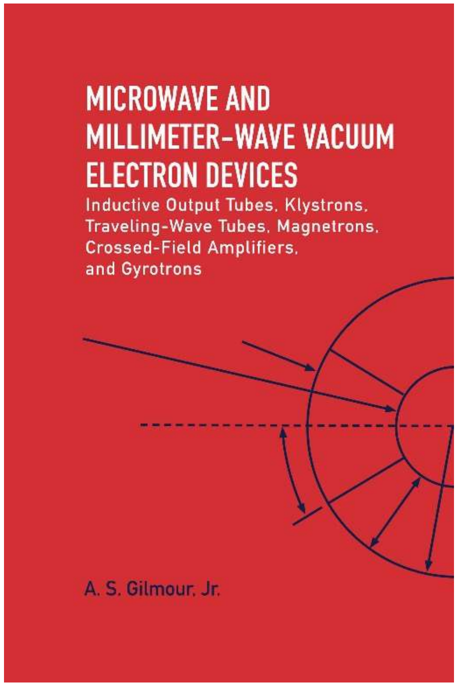

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Microwave and Millimeter-Wave Vacuum Electron Devices

A. S. Gilmour, Jr.

In recent years, there have been enormous advances in the operating capabilities of many vacuum electron devices (also known as microwave tubes). This book describes advances in devices that operate at frequencies from 300 MHz to 300 GHz. **THE EMPHASIS IS ON DESCRIBING HOW THE DEVICES WORK.**.

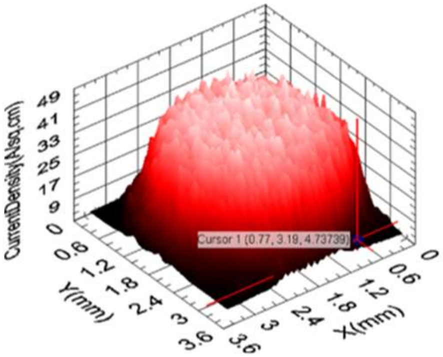
Presented in full color, over 1000 figures, like those shown in this brochure, are used to support and complement discussions of microwave tubes.

Overview of This Book

The types of tubes discussed in the book are previewed in the Introduction. Then, after a review of wave phenomena, the environment that exists in a tube if it is to work properly, is described.

The operating characteristics and theory of operation of modern M-type dispenser cathodes are described. The next step in the evolution of Pierce's ideal cathode (unlimited emission and life) may be the scandate cathode, with its extremely low work function. Recent progress on scandate cathodes is presented.

Scandate Cathode Emission Uniformity



Following the discussion of cathodes, electron guns and electron beams for linear beam devices are described.

Density modulation and velocity modulation are explained. Density modulation is used in devices operating at low microwave frequencies.

Velocity modulation is used throughout the entire microwave spectrum. The removal of a signal from a modulated beam by current induction is discussed.

An **IOT** uses a gridded electron gun to produce a density modulated electron beam. IOTs are efficient and reasonably linear because beam current is present only when needed and is as large as needed. IOTs dominate the TV transmitter market.

IOT for TV Broadcasting Service

A **klystron** uses a velocity modulated beam and can operate at powers from one W to at least one GW. Applications range from radar to particle accelerators. Efficiency is typically 50% although 90% is thought to be possible.

Efficiency varies inversely with perveance so, for high power, high voltage is needed. High Efficiency at high powers can be realized with **multibeam klystrons (MBKs).**

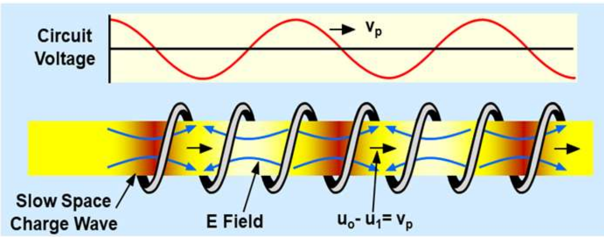
VKL-8301

VKL-8301B

10 MW MBK

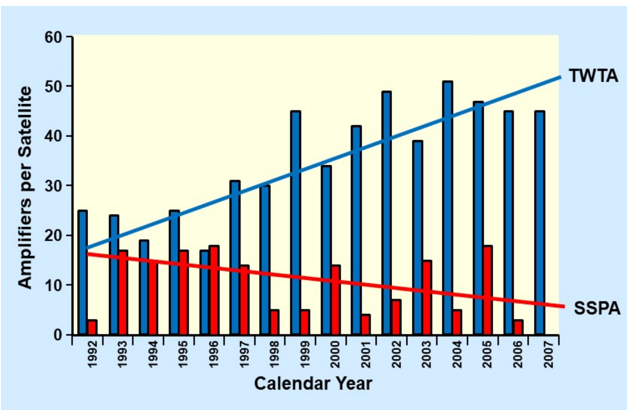
Extended interaction klystrons operating at 94 GHz were developed for atmospheric studies. A 263 GHz device is used for nuclear magnetic resonance signal enhancement.

Traveling wave Tubes (TWTs) are amazing devices. Their operation depends on the coupling of the circuit (helix shown here) and the slow space charge wave in the electron beam. With the proper circuit, they can have a bandwidth of over two octaves.



Slow space-charge wave

Helix TWTs are the amplifiers of choice for satellite applications. Efficiencies at saturation can be over 75%. Life expectancies exceed 15 years.

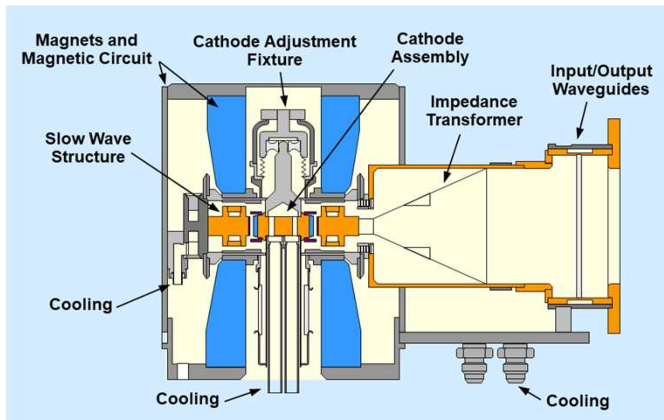


TWTA and SSPA usage on satellites

Magnetrons and crossed-field amplifiers (CFAs) are compact powerful devices. They have cylindrical formats. Current flow is radial from the cathode to the anode. A primary use for magnetrons is radar. Huge numbers are used in ovens.

CFAs are important for many military applications. CFAs are at the heart of Navy's Aegis system with literally dozens of tubes used in each system.

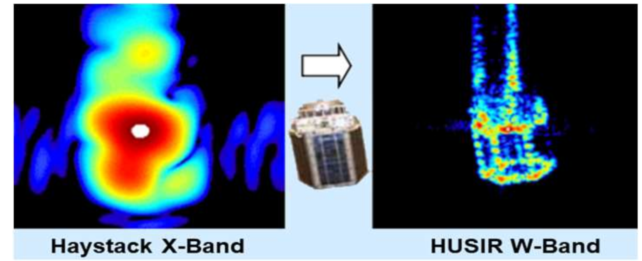
CFAs made it possible for the world to hear Neil Armstrong say: "That's one small step for man, one giant leap for mankind."



Cross section of a CFA

Gyrotrons are relative newcomers to the microwave field. The electron beam is a hollow cylinder rotating with a rotational velocity that is greater than the axial velocity. Their rotational energy is coupled to the circular electric field in a cavity. Operation is at the cyclotron frequency. Power outputs of megawatts at frequencies of 100-200 GHZ are possible. Gyrotrons were developed that can produce the pulse energy at 170 GHz necessary to initiate a fusion reaction. 2018 was named "year of the gyrotron."

Improvement in resolution using 100GHz



1 MW, 170 GHz gyrotron

Broadband Windows that provide an interface between the vacuum environment of the microwave tube and the outside world present a significant problem at MW CW power levels. A solution is the use of cvd diamond windows brazed into circular waveguide at the Brewster angle