SUBMILLIMETER BACKWARD WAVE OSCILLATORS

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Received August 3, 1987

Abstract

NASA Lewis Research Center is engaged in a program to develop a series of backward wave oscillators (BWO's) for the frequency range 500 to 2000 GHz. Generically BWO's are electron beam traveling wave tubes operating in a dispersive regime in which the group velocity and the phase velocity of the induced electromagnetic wave are in opposite directions. The oscillation frequency of a BWO is controlled by the electron beam velocity (anode voltage).

Such tubes because of their frequency tunability, phase locking capability, and large bandwidth are ideal local oscillators for heterodyne receiver/spectrometers.

The design of the BWO's will be discussed with emphasis on the etched slow wave structure, zero compression electron beam, long life cathode, and moderate operating voltages.

Introduction

Submillimeter wavelengths are coincident with the rotational spectra of many molecules which are present in planetary atmospheres and in interstellar dust clouds. Radio astronomers and spectroscopists therefore have a natural interest in these wavelengths. However, the earth's atmosphere is opaque to submillimeter radiation
and it is necessary to project a space based astronomical observatory. Hence the NASA interest.

In developing tubes for use in space there are design constraints that must be addressed. Passive cooling, lifetime, moderate voltages, and permanent magnet focusing are important considerations.

Working devices at submillimeter wavelengths have characteristic dimensions of a fraction of a wavelength. This presents a fabrication problem. Although slow wave structures have been machined for frequencies about 1 THz, there is little hope of machining structures for use at 2 THz. It was decided early in this development effort that a microfabrication technique such as ion-beam assisted etching would be used.

Heat is generated in a tube by the interception of electrons on the slow wave structure and by the ohmic losses of the RF wave on the circuit. For the submillimeter wave BWO the minute dimensions result in high energy densities and temperatures which compound the problem because ohmic losses increase with temperature. To alleviate this problem the circuit is etched onto a metallized diamond (type IIA) substrate for heatsink purposes. Type IIA diamonds are gem quality stones that have a thermal conductivity as much as five times greater than copper.

Existing BWO's have lifetimes of only a few hundred hours primarily because of cathode failure. The submillimeter BWO's will be equipped with either a long-lived reservoir type or a lanthanum hexaboride cathode (LaB6). A grant was given to the University of Oregon Graduate Center for the study of the LaB6 cathodes. These cathodes are capable of surface current densities greater than 30 A/cm$^2$ and have tolerable evaporation rates at their operating temperatures. The evaporation of emitter material from the cathode surface is the limiting factor which determines cathode lifetime. Lifetime testing of the reservoir cathode will be started soon at the USAF Rome RADC cathode facility. Either of the two types of cathodes will extend the BWO lifetime to thousands of hours.

Other considerations in the development of space beam tubes are the required operating voltages and magnetic focusing fields. Because the BWO circuit is fabricated by etching, it is possible to construct an interdigital line or a meander line. Both of these circuits are high impedance backward-wave fundamental