

# Design of a 0.22-THz 100W Microfabricated Planar Travelling-Wave Tube

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**Abstract**—In-house developed analytical design tools were used to design a vacuum micro fabricated planar TWT with rectangular sheet beam of centre frequency 0.22-THz, output power 100W, gain 30dB, and bandwidth more than 20GHz. Staggered double-vane loaded rectangular waveguide slow-wave structure was used in planar TWT which was designed with cold bandwidth more than 50GHz from 195GHz to 245GHz for its operation with sheet electron beam of voltage 20kV and current 50mA. The structure was matched at the input and the output ends with the WR-3 waveguide (432 $\mu$ m x 864 $\mu$ m). Large-signal analysis code (SUNRAY-THz) was used for design of a complete SWS with input/output couplers, sever in-between circuit, and velocity taper. Very good agreements were achieved for the output power and the gain of a 0.22-THz TWT over the operating band between SUNRAY code with 3D e.m. field simulator (CST-PS).

**Keywords**- THz TWT; THz amplifier; THz oscillator, Vacuum Microelectronic Devices.

## I. INTRODUCTION

Compact vacuum microelectronic devices (VMDs) are being investigated for efficient high power generation and amplification of terahertz (THz) frequencies (0.1THz - 10THz) for many new and emerging applications including ultra high data rate communication, remote sensing, security, medical imaging, spectroscopy and high resolution radars [1-2]. The operation of these devices is based on the efficient interaction of the electron beam with the radiofrequency (RF) circuit field in such a manner that maximum energy from the electron beam can be transferred to the RF circuit field. Among various vacuum devices, travelling wave tubes (TWTs) are preferred for communication and radar as high power amplifiers because of their wide instantaneous bandwidth, high gain and high linearity. At THz frequencies, TWTs are very difficult to fabricate because the dimensions of the RF slow-wave structure (SWS) are just hundreds of microns. Also, because of the small size of the electron beam tunnel, the beam current density requirement is much more than 100A/cm<sup>2</sup>. The planar SWS is preferred for a high power THz TWT because it is easier to fabricate with high precision and surface finish. MEMS technology like the UV-LIGA process is used to fabricate planar SWS within tolerance of  $\pm 5\mu$ m and surface roughness less than 10nm. The Nano-CNC technique is also being used to fabricate such structures. A rectangular/elliptical shape sheet beam is chosen for a THz TWT because it has a very low space charge field (at least 100 times less) compared

to that of the equivalent cylindrical beam of the same current, voltage and charge density. The sheet beam has therefore, a high current carrying capacity providing large gain per unit length and has the requirement of a low magnetic field for focusing the electron beam.

## II. DESIGN OF SWS FOR A 0.22-THz TWT

High efficiency, high gain 0.22-THz planar TWT, as shown in Fig.1, of output power 100W, gain 30dB and bandwidth more than 20GHz is designed using in-house developed design tools. Critical components of a planar TWT are:

- (i) The electron gun assembly with flat cathode for generation of a rectangular/elliptical sheet beam;
- (ii) The RF slow-wave structure (SWS) of high impedance, low loss and planar geometry for supporting and amplifying THz waves extracting kinetic energy from the sheet beam;
- (iii) The input and the output couplers to feed THz signal into the circuit and coupled out amplified signal from the circuit;
- (iv) The magnetic focusing circuit for confined flow of the sheet beam through the structure;
- (v) The collector for collection of the spent beam efficiently with zero back streaming.

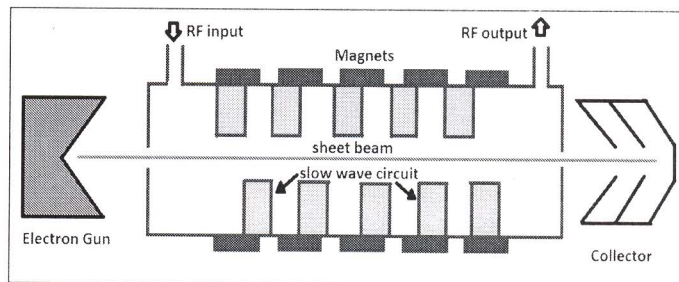


Fig.1. Schematic of a THz TWT with a planar RF SWS and a sheet beam.

Among various types of SWS as being investigated for a 0.22-THz TWT, staggered double-vane loaded rectangular waveguide slow-wave structure (SDV-SWS) [3], as shown in Fig.2, is selected for a high power planar THz TWT. It has comparatively higher impedance, broader bandwidth, less circuit loss and less higher modes. Also, SDVSWS is easier to fabricate compared to folded-wave SWS (FW-SWS) [4] for a 0.22-THz TWT with other significant advantages are:

- (i) It is easier to match SDVSWS with WR-3 waveguide (425 $\mu$ m x 850 $\mu$ m) at the input and the output ends;

