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Abstract: There is increasing realization that the region of electromagnetic spectrum between 100 GHz-1 THz has a myriad of potential applications that could directly impact society. These include security applications like non-invasive detection of concealed weapons, explosives and contraband items; imaging of thermonuclear fusion plasmas, medical imaging or detection of cancer, industrial quality control, and future ultra-wide band/high data rate communication systems. For the quest for high frequency and high power sources required to realize these applications and close the so-called THz gap, microwave vacuum integrated technology is an extremely attractive choice for their ability to handle high power in a relatively compact volume. However, the beam-wave interaction physics imposes constraints on the fabrication tolerances and surface roughness that an RF structure can possess. This directly impacts the cold (RF transmission only) and hot (beam and RF interaction) characteristics/performance of the tube. Thus, as we proceed to frequencies in the THz region, conventional machining is unable to handle the required structure fidelity and surface quality.

In this paper, our efforts involving the design, fabrication and RF measurements of an 0.22 *THz* ultra wide band sheet beam travelling wave tube amplifier are described. Eigen mode dispersion curve analysis and particle-in-cell analysis of the UC Davis designed TWT demonstrated wide band width (> 50 *GHz*; i.e., ~ 30% instantaneous BW). The output power was calculated to be > 50 *W* in the pass band for an input drive of 1 *W*. A PPM based sheet beam transport focusing structure employing SmCo6 magnets and an existing sheet electron gun developed by CPI [1]for use in a proof-of-principle experiment is also described that showed a beam transmission of 80 % that corresponds to a transmitted current of ~ 207 *mA* for a 20 *kV* electron beam.

We also describe MEMS fabrication technology to make micro-metallic structures/waveguides possessing the requisite high dimensional definition and low surface roughness (< skin depth). Our efforts in MEMS precision fabrication have primarily focused on the following areas: (a) LIGA technique for high aspect ratio structures in a single process employing KMPR[2, 3] and SU-8[2, 3]; (b) Si-DRIE process[4]; and (C) Nano-machining / nano-CNC milling[5]. We were successful in fabricating completely metalized 0.22 *THz* TWTA circuits within 3-5 μm tolerance and a surface roughness ranging from 30-80 *nm*. An extensive SEM and 3D microscope analysis was also conducted and described in detail. A scalar network analyzer system was configured for RF measurements employing a BWO in the frequency range 180-265 GHz^2. Both KMPR LIGA and nano- machined circuits showed an excellent agreement with the simulations with S21 ~ -5 *dB*

in the passband and also matching well the predicted 1 *dB* bandwidth of ~ 65 *GHz* predicted from 3D FDTD and FEM electromagnetic solvers. S11 remained a little high for the case of LIGA circuits as compared to the simulated value of ~ -10 *dB*, but for the nano machined circuits S11 gave an excellent agreement with the simulation.

We also describe in this paper our idea/preparation for an exploratory proof-of-principle hot test employing MEMS fabricated TWTA circuits. The PIC analysis for MEMS fabricated circuits placed in a holder assembly that connects an existing sheet beam electron gun, PPM structure, vacuum ports and input/output couplers suggested an output power of ~ 70 *W* for an input drive of ~ 1 *W* at 0.22 *THz*.

It is hoped that MEMS fabricated micro-scale vacuum electron devices will pave the way for the elimination of the so-called “THz gap” by scaling for high frequency operation. This is also important for many applications in the THz region that demands compact and mobile device with reasonable power and bandwidth.

Keywords: MEMS Fabrication, Vacuum Electron Devices, THz Gap, LIGA Fabrication, Nano-Milling/Machining, Vacuum integrated Power Amplifiers, mm-wave/THz technology