25/2019

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25/2019(VIII)

Indigenous Development of Relevant Technologies for Plasma Assisted High Power sub-THz Source

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***Abstract*- Plasma assisted sub-THz devices are unique source for generation of high power radiation. This paper presents the status for development of relevant technologies for aforesaid devices. The relevant technologies have been developed for generation of high power (>10 W) and 0.1 THz radiation.**

I. Introduction

Terahertz (THz) radiation corresponds to a frequency range between 0.1 THz to 10 THz). Millimeter and microwave radiation lies at lower frequencies (below 100 GHz) while higher frequency radiations lie in the optical regime. Between these two worlds, there exists THz technology gap, where conventional solid-state optical and electronic technologies are struggling to provide good frequency coverage at high enough powers to underpin many emerging and exciting THz applications [1-4]. It is to be emphasized that until now very intense pulses of THz radiation are only available at large, expensive facilities based around particle accelerators or ultrafast pulse lasers. Unfortunately, the great benefits for the civil society that THz applications could provide are still precluded by the lack of required high power THz sources. Hence, there exists a scope for the development of low cost, compact and powerful plasma assisted sub-THz device technologies for various strategic and industrial application. The Plasma assisted slow wave oscillator uses a unique plasma-cathode electron (PCE) gun and plasma filled slow-wave structure (SWS) to produce efficient sub-THz radiation [5-8]. In such plasma filled sub-THz sources, the high current density electron beam provides better coupling with the rf circuit field which is responsible for efficient operation. In conventional vacuum tubes (without plasma) the beam space charge forces play a crucial role in the beam transport. Nevertheless, in plasma assisted microwave sources, it is largely compensated by the presence of ions on the envelop of the electron beam. The electron beam propagates in the ion-focusing regime (Bennett pinch) [9], so the requirement of external magnetic field gets eliminated or reduced. Due to elimination of external magnetic field, it makes device compact. Furthermore, it leads to efficiency enhancement. Also, since plasma formation is not closer to the accelerating anode, higher beam current operation can be achieved easily. In view of the certain proven advantages, the development of ~0.1 THz Plasma assisted Slow Wave Oscillator has been started with a targeted peak power of minimum 10W, with operating parameters as given in Table 1.

Parameters	Value
Frequency range	90-100 GHz
Operating Beam voltage	35kV-40 kV
Beam Current Density	>50 A/cm^2
Peak Power	>10 W

II. Development of Relevant Technologies

A. Miniaturized sheet electron beam source

As the frequency increases it becomes increasingly difficult using conventional electron beam sources to focus and form high current density, high quality sheet electron beams through the small size interaction region of the high frequencies vacuum electron devices (VEDs). The sheet-electron beams are quite useful in generating high power (i.e., due to high current density) and high frequency microwave signals due to thinness of the sheet-electron beams, which makes them able to permit good coupling to the RF waves in sub-mm slow-wave circuits. However, there occurs beam instability in the sheet-electron beam while propagating in the microwave interaction region. It is seen that the beam starts transverse movement causing ripples in the sheet-electron beam and often there is a breakage of the beam. This is because the sheet-electron beam exhibits disruptive diocotron instability due to E × B velocity shear effect during its propagation through a uniform axial magnetic field [9]. Therefore, it is our aim to investigate the PS discharge chamber to generate sub-mm sheet electron beam pulses of current density more than 50A/cm2, which can be propagated down the flat beam-wave interaction region of sub-THz sources. This will be the key technology for the successful development of the plasma based sub THz sources. The design parameters of plasma based sheet electron beam source have been optimized. The ratio of hollow cathode diameter to length of hollow cathode has been optimized and found to be ~1 for high current density sheet electron beam generation [10]. The detailed results will be presented in the conference.

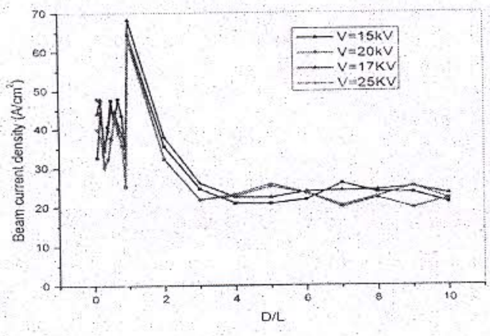

Figure 1. Variation of beam current density for different D/L ratio at different applied voltages (t=60ns) [10]

B. *Planar beam-wave interaction structure*

The design of interaction region will mainly depend on the axial and transversal component of the sheet-electron-beam during its propagation inside the interaction region. Initially, there will be plasma formation on the envelop of the sheet-electron beam through beam impact ionization. The presence of plasma will shift the space charge electric field towards the RF structure. Therefore, the plasma density plays a crucial role and contribution in efficient coupling between the electron beam slow space charge waves and RF waves. Accordingly, the dimension of interaction region has been optimized using simulation. The interaction region would be a planar interaction region which is easier to fabricate than the conventional cylindrical structure even at higher frequencies. The planar interaction structure has been designed and developed using micro-machining technique. The developed planar interaction

Figure 2. Developed planar interaction structure suitable for W-band

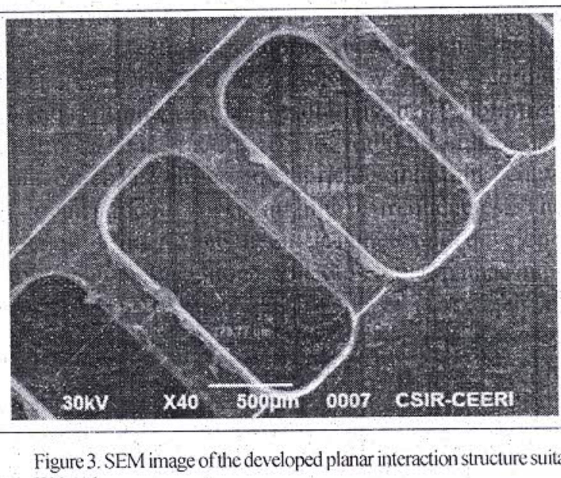

Figure 3. SEM image of the developed planar interaction structure suitable for W-band

C. *Integrated lab prototype of interaction structure*

Finally, plasma based sheet electron beam source and the interaction structure would be integrated with rectangular horn antenna to launch the sub-THz wave and it will also act as spent beam collector. The length and angle of spent beam collector has been optimized for the operating beam voltage ranging between 30 kV-40kV and beam current varying between 0.1 A-10 A. The simulation has been carried out for beam profile trajectories at aforesaid operating condition to eliminate the collision of spent beam electrons with the window. The detailed results will be presented in the conference. The 2-D schematic view of this source is presented in figure 4.

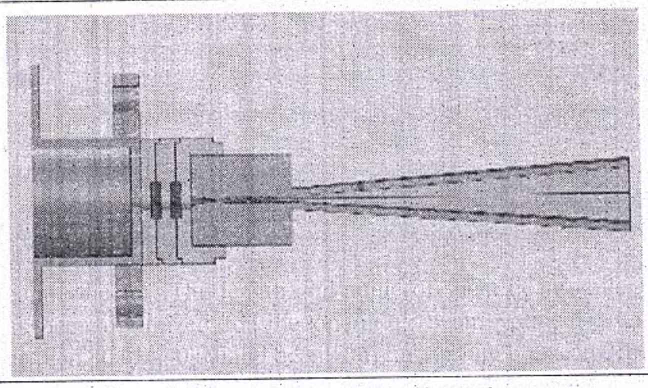

Figure 4. Integrated lab prototype of interaction structure

III. Conclusion

The developed lab prototype of plasma assisted slow wave oscillator has three major components: sheet beam source, planar interaction structure and spent beam collector. The developed sheet electron beam source is capable for delivering the high current density (>50A/cm2) and focused beam which would eliminate requirement of external magnetic field in sub-THz sources. The planar interaction structure has been developed with less than 10-micron dimensional tolerance using micro-machining technique. The advancement in these relevant technologies have paved the way for development of indigenous high power plasma assisted sub-THz source.

Acknowledgment

The work has been carried out with the financial support from CSIR (MLP 0114). Authors would also like to acknowledge the other team members of microwave devices area for useful discussions.

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