Technological Development for X-band Plasma Assisted Slow Wave Oscillator (PASOTRON)

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Abstract: *Plasma assisted microwave devices are unique source for microwave radiation. This paper presents the status for development of X-band Plasma Assisted Slow Wave Oscillator (PASOTRON) of peak power 0.5MW.*

Keywords: PASOTRON, BWO, Microwave Oscillator, Rippled Waveguide, Plasma, SWS, PCE gun.

Introduction

The Plasma assisted BWO uses a unique plasma-cathode electron (PCE) gun and plasma filled slow-wave structure (SWS) to produce efficient microwave radiation [1-3]. In such plasma filled microwave sources, the high current density electron beam provides better coupling with the rf circuit field which is responsible for efficient operation. In conventional tubes (without plasma) the beam space charge forces play a destructive role in the beam transport. Nevertheless, in plasma assisted microwave sources, it is largely compensated by the presence of ions in plasma. The electron beam propagates in the ion-focusing regime (Bennett pinch) [4], so the requirement of external magnetic field is eliminated. 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. These devices are capable of producing coherent radiation in the centimeter and millimeter wavelength regimes at a higher power level than their vacuum counter parts. In view of the certain proven advantages, the development of X-band Plasma assisted Slow Wave Oscillator 'PASOTRON' has been started with a targeted peak power of minimum 500 kW, with operating parameters as given in Table 1.

Table 1: Operating parameters

Frequency range	8.5-9.7 GHz
Operating voltage	35-40kV
Beam current density	200A/cm^2
External magnetic field	0.0 Tesla
Output power (peak)	0.5 MW
Microwave pulse duration	~200ns

Technological development of the device related to PCE-Gun and SWS for X-band to launch the microwave signal is presented in this paper.

Development of PCE-Gun

PCE-gun is capable of producing beam of high current density which is an essential requirement for developing plasma assisted microwave source. In conventional high power microwave tubes the explosive electron emission cathodes are generally used for electron beam emission because these cathodes “turn-on” at relatively low electric fields (~100s kV) and deliver very high current densities (~100s A/cm^2) that allow microwave tubes to generate extremely high power [2-4]. Also, the conventional thermionic cathodes can provide long pulse electron beam operation but limited current density which is not adequate for high power microwave sources. We have developed a self-breakdown based single gap plasma cathode electron (PCE) gun (5-20kV/50-160A) in Argon gas atmosphere (60-100 mTorr) [5-6]. The developed PCE-Gun is shown in figure 1.

Figure 1: Image of developed PCE-Gun.

In the PCE-Gun, the pseudospark discharge is a viable possibility due to the emitted linear beam’s characteristic properties, such as, high current density and high brightness as well as self-focusing during its propagation. We have observed that the electron beam is focused and has propagated more than 250mm in the drift space region. A typical waveform for discharge current, beam current (measured at z=60mm) and applied voltage is shown in figure 2. The current density in the developed PCE-Gun is more than 200 A/cm^2.

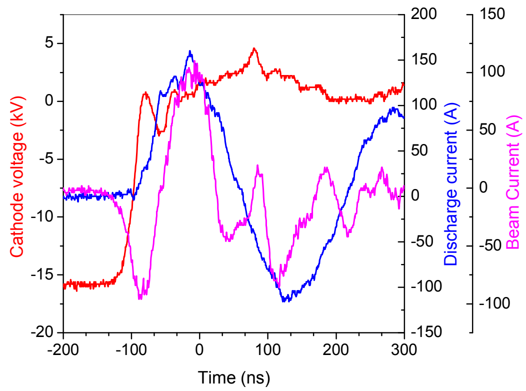

Figure 2: Experimental waveforms for discharge current, beam current and cathode voltage with time.

To design the slow wave structure (SWS) for microwave sources, the current density evaluation of the electron beam is an important parameter which provides an insightful measurement. We have found that the current density of electron beam is maximum at the centre of electron beam i.e. at r=0 (see figure 3(a)) for different beam current which is good for microwave application. The radial current density at three different axial location for 14kV has been measured which is presented in figure 3(b).At each location in the centre most position current density is maximum which confirms the focused beam. The self-focusing of electron beam due to presence of plasma and higher current density eliminates requirement of external magnetic field which leads to develop a compact device. The analysis has been done for different axial and radial location under different applied voltages.

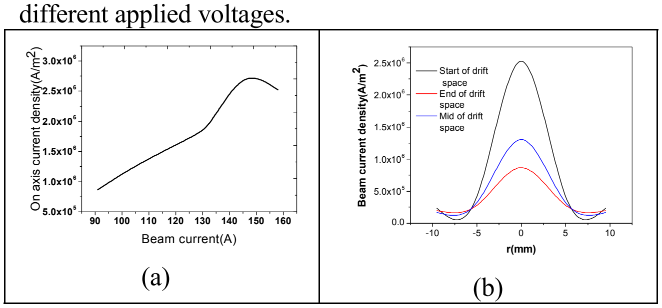

Figure 3: (a) Experimental on axis(r=0 mm) current density vs total beam current and (b) radial current density for three different axial location at 15kV.

Development of rippled SWS

For our work, we have developed rippled SWS. This has been taken as a cylindrical waveguide with ripples and having radial profile given by R (z) = R_0 $+h$ cos (k_0z), where R_0 is the mean radius, h is the rippled height and $Z_0 = 2*pi/k_0$ is the spatial periodicity. For designing the oscillators beam should be near to the walls of SWS. Therefore, beam radius (R_b) and mean radius (R_0) is chosen in such a way to keep fill factor as 73%. The actual developed X-band rippled wall SWS and corresponding simulated and cold test dispersion relation with 40kV load line are shown in figure 4 (a,b). The simulation has been done using CST while cold test has been performed using resonant method with 4 periodic structures. A good correlation has been obtained between simulated and experimental results. The optimization has been carried out for rippled waveguide structure by varying different structural parameters. The achieved SWS designed parameters are: R_b= 0.5cm, R_0=1.20cm; h=0.5cm; *pitch=1.0cm.*

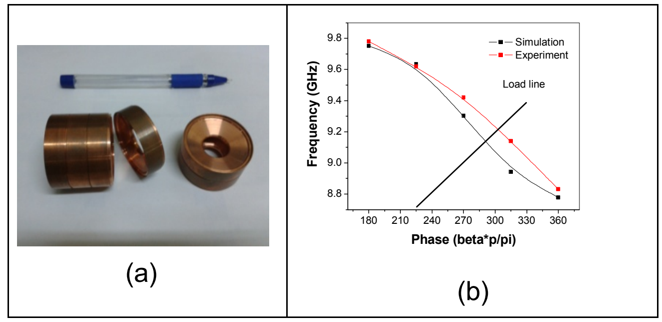

Figure 4: (a) Image of developed rippled-wall SWS and (b) dispersion characteristic of the SWS.

Conclusion

The developed PCE-Gun is capable for delivering the high current density (>200A/cm^2) and focused beam which would eliminate requirement of external magnetic field in microwave sources. In the planned PASOTRON the beam will be injected from PCE-Gun which will generate plasma inside the developed X-band SWS. However, the role of plasma inside the plasma filled SWS is not yet well explained, so the research work related to plasma assisted devices at CSIR-CEERI, Pilani would lead to a new direction in microwave tube technology.

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