Investigation of Millimeter Wave Extended Interaction Oscillation using Improved Pseudospark-sourced Electron Beams

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Abstract— **This article presents the investigation of millimeter wave extended interaction oscillation using both pencil and sheet-shaped pseudospark (PS)-sourced electron beams. A W-band (75-110 GHz) pencil beam extended interaction oscillator (EIO) was designed and constructed. In the first experiment the output power of 38 W was achieved from a four-gap PS discharge operating at 30.5 kV. PS-sourced beam generation was further improved by combining a single-gap PS structure with an integrated post-acceleration section in order to enhance the beam quality and increase the output power of the EIO to 200W. The study of a PS-sourced sheet beam EIO structure will also be presented.**

I. INTRODUCTION AND BACKGROUND

MILLIMETER wave sources in the frequency range from 0.1 to 1 THz have received increasing interest in recent years because of their many exciting applications such as in electron spin resonance spectroscopy, remote imaging, radar and 5G high speed mobile wireless communications. To date, vacuum electronic technology still remains the main method to achieve millimeter wave radiation of high power up to the kilowatt level, while conventional optical and electronic technologies are struggling to provide good frequency bandwidth at even rather moderate power levels. High quality intense electron beams have been crucial in vacuum electronic devices, thus the PS discharge has attracted a lot of attention recently as a promising source of high quality high intensity electron beam pulses with the beam current density up to 10^6Am^{-2} and brightness up to 10^{12}Am^{-2} rad^{-2} [1-3]. This is because a PS-sourced electron beam has the ability to self-focus due to the unique structure and the formation of an ion channel generated by the beam front. Simulations have shown that the PS-sourced electron beam can propagate within background plasma without any applied guiding magnetic field. This makes it an excellent electron beam source for desirable compact millimeter wave devices. Among various vacuum electronic devices, the EIO as a linear beam vacuum device has gained considerable attention as a promising millimeter wave oscillation source due to its high gain per unit length and compact configuration [4-7].

In this paper, we use a PS-sourced electron beam (PS-EB) instead of the conventional electron beam produced by a thermionic cathode to drive an EIO to achieve more compact devices. To achieve better beam quality, the PS-sourced electron beam is also investigated with post-acceleration to reduce its beam energy spread [8-10]. To achieve higher output power, a sheet beam EIO structure is further studied with a PS-sourced sheet beam [11].

II. EXPERIMENTS AND RESULTS

Fig.1 shows the first pencil beam EIO experimental setup with the four-gap PS discharge configuration. When the discharge was operating at 30.5 kV, an output power of 38 W was measured.

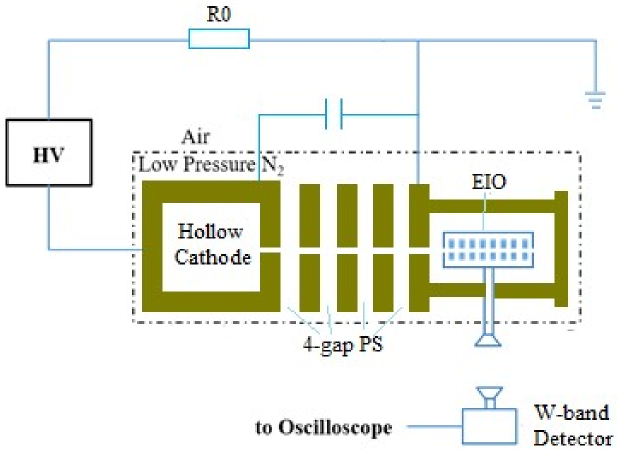

Fig. 1 Experimental setup of the pencil beam EIO driven by a PS-sourced electron beam

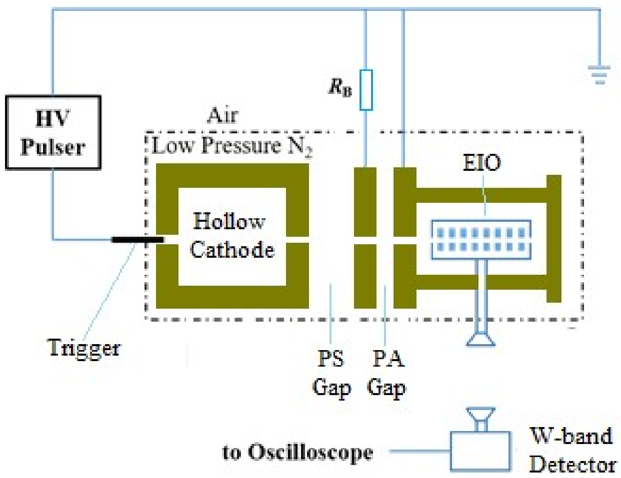

Fig. 2 Experimental setup of the pencil and sheet beam EIOs driven by a post-accelerated PS-sourced electron beam

Fig.2 shows the experimental setup of a one-gap PS discharge combining with an integrated post-acceleration section to drive the same pencil beam EIO structure. The post-acceleration section is used to improve the PS beam quality by reducing beam energy spread. Fig.3 shows some measurements of the beam voltage and current, the image of the beam cross section, and the beam intensity analysis. Fig.4 shows a typical time-correlated electron beam voltage, current pulse, the radiation pulse from the W-band EIO with this configuration, and an output power of up to 200 W was measured as compared with the configuration in [7] where the output power of only 38 W was achieved from a 4-gap PS discharge configuration.

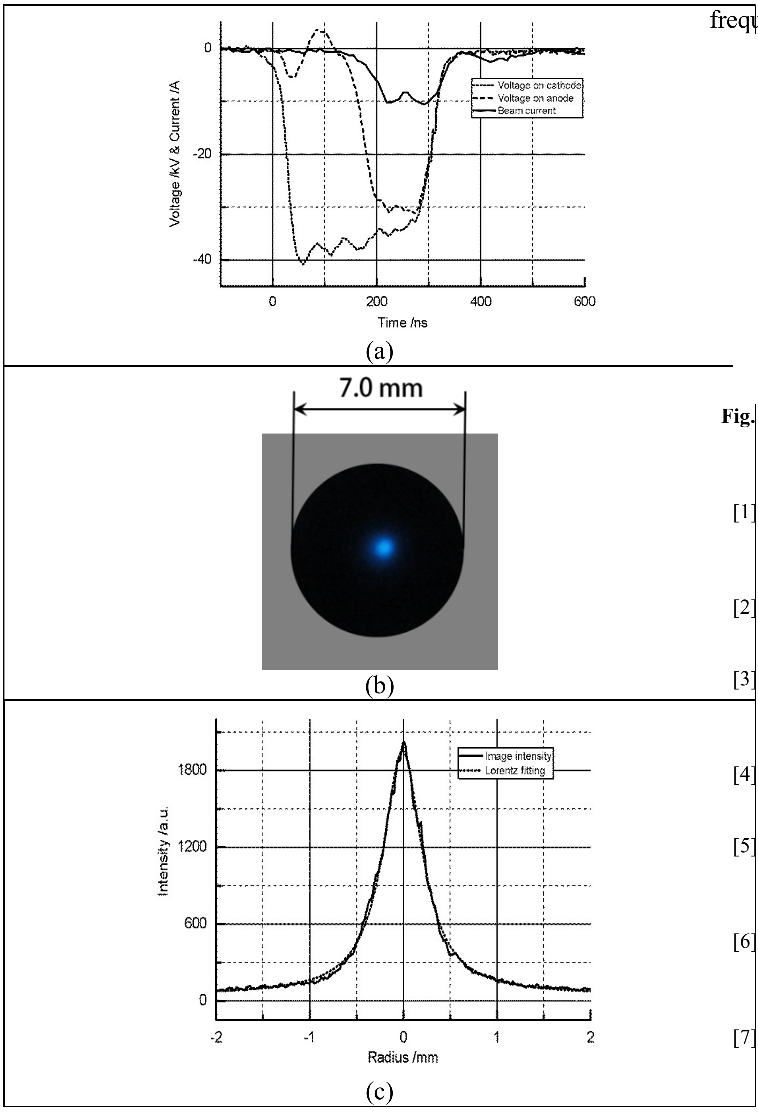

Fig.3 Typical waveforms of beam voltage and current (a), beam cross section image (b), and beam intensity along the radius of the beam(c)

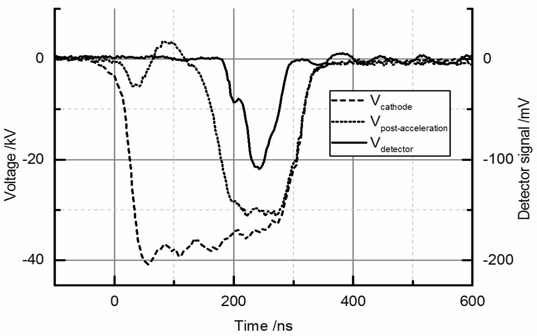

Fig.4 Typical time-correlated electron beam voltage, current pulse, the radiation pulse from the W-band EIO

With this improved configuration, further studies of a planar EIO with a PS sheet electron beam were conducted as shown in Fig.5. Preliminary experimental results have shown a much higher output power achieved from a W-band planar EIO. Further studies of a planar EIO with a PS sheet electron beam will be conducted using this improved configuration and a higher frequency 200GHz EIO structure in the near future.

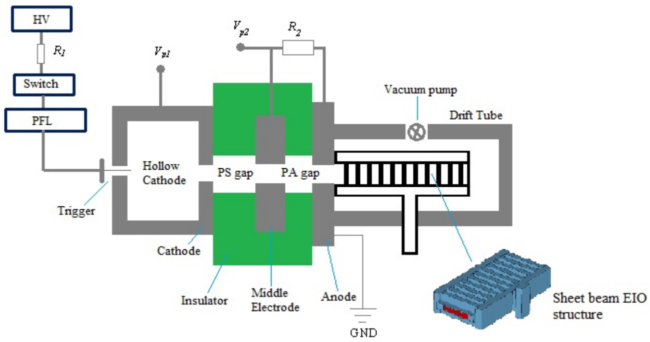

Fig. 5 Experimental setup of the EIO driven by a PS-sourced electron beam

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