Cusp electron gun with modulation electrode for a THz gyro-amplifier

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***Abstract*—A terahertz gyrotron traveling wave amplifier (gyro-TWA) centered at 370GHz is under development for the electron paramagnetic resonance (EPR) imaging application. This paper reports the investigation of a triode-type cusp electron gun for the terahertz gyro-TWA. The simulation results showed that at the beam alpha (the ratio of transverse to axial velocity) center of 1.07, an optimal alpha spread of ~10% was achieved, when it was operated at a beam voltage of 50 kV and a beam current of 0.35 A.**

I. Introduction

Electron paramagnetic resonance (EPR) imaging has important applications in many areas that include biochemistry, life sciences, and solid-state materials. High field EPR requires high-frequency millimeter wave excitation, for example, millimeter wave sources at 372 GHz are required at 13.3T. One of the important developments of the EPR technology is pulsed excitation, which allows time domain analysis to study the dynamics of 'in vivo' biochemistry. EPR involves interaction with the unpaired electrons. To achieve a high signal-to-noise ratio in the pulsed excitation, a high excitation power is required. High power terahertz amplifiers are therefore required for the EPR application. A broadband high power gyrotron traveling wave amplifier operating at the center frequency of 372 GHz is under development for this highly demanding application.

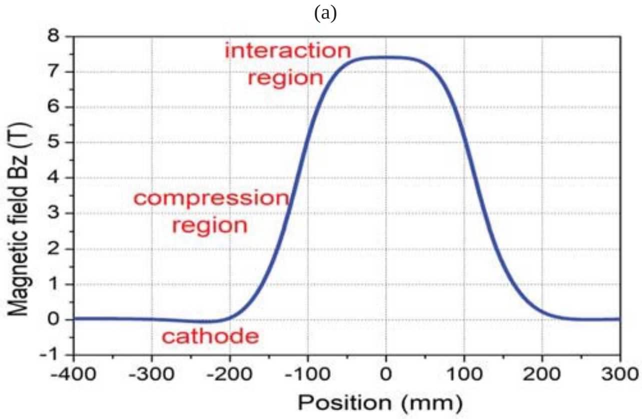
Switching on and off the beam current by applying voltages to a grid located in front of the cathode is an effective way to modulate the output of the gyro-TWA, besides switching on and off the input seed signal and the high voltage power supply. In this paper, the feasibility of employing such a grid structure in a terahertz gyro-amplifier is investigated.

II. Design of the Gridded Cusp Gun

In the gyro-TWA, a helically corrugated waveguide [1, 2] is used as the interaction region, and a cusp electron gun [3] is used to generate a large orbit axis-encircling electron beam. The design of this cusp electron gun for the high-frequency gyro-TWA has been based on the previous experience of two guns for two W-band gyro-devices, a gyrotron backward wave oscillator (gyro-BWO) [4] and a gyro-TWA [5, 6], as well as a triode-type cusp electron gun designed for a W-band gyro-TWA [7, 8].

The parameters of the cusp electron gun were derived from the requirements of the gyro-TWA. The beam voltage is 50 kV in order to achieve the required bandwidth of 10%. The beam current is 0.35 A, and the magnetic field strength at the interaction region is 7.4 T. The magnetic field is generated by a superconducting magnet. It contains 6 coils, including the main coil and 2 'shim' coils, and 3 reverse coils to provide two free degrees to fine tune the magnetic field at the cathode region. The superconducting magnet and its magnetic profile are shown in Fig. 1.

(a)



(b)

Fig. 1. (a) The superconducting magnet and (b) the magnetic field profile.

III. Simulation Results

The cusp electron gun employed a triode-type configuration [7]. The schematic drawing is shown in Fig. 2. A bias voltage of 1 kV was applied to the modulation electrode to allow fast switching of the electron beam. The values of parameters L, s are carefully chosen to minimize the effort of the modulation electrode. The geometry was fully parameterized and an optimization routine was used to search for the optimal set of geometry parameters, as well as the optimal position of the superconducting magnet. There were two optimization goal functions. One was to minimize the electron beam alpha spread, and the other is the center of the alpha to be close to the desired value.

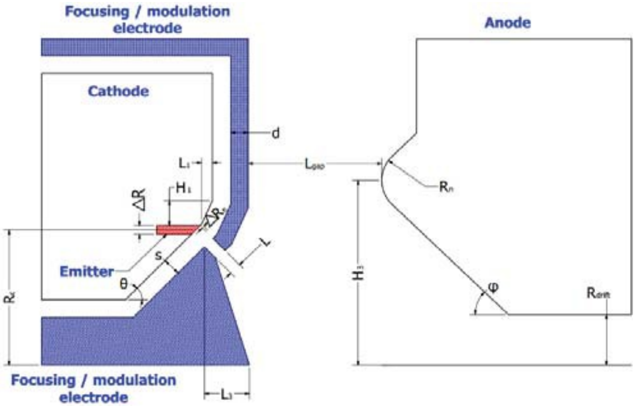


Fig. 2. The geometric model of the triode-type cusp electron gun.

Fig. 3 shows the simulated beam trajectory and the beam alpha values of the optimized triode-type cusp electron gun.

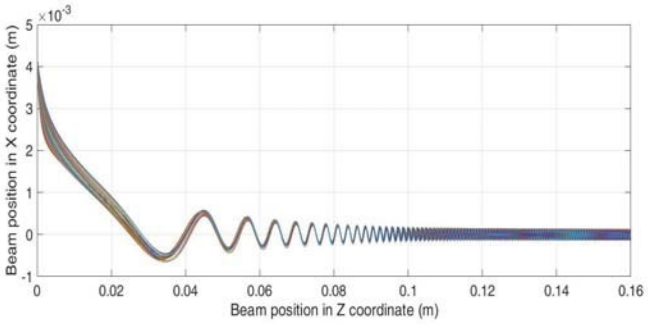


Fig. 3. The simulated beam trajectory as a function of the axial position.

The beam alpha at the entrance of the beam wave interaction region was also simulated to obtain the alpha spread. The result is shown in Fig. 4. The maximum and minimum alpha values in the simulation are 1.26 and 0.92, respectively. The alpha spread in terms of its full width at half maximum (FWHM) is 10%.

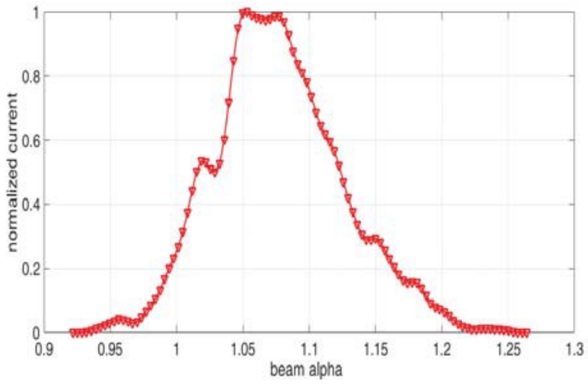


Fig. 4. The alpha spread of the designed electron gun.

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