Asymmetric Four-stage Depressed Collector with Half Cylinder Electrodes for Space Applications

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Abstract—**Multi-stage depressed collectors used for space applications have several stringent requirements, which mainly include high efficiency and low back-streaming. To accomplish these space requirements, authors have proposed a multi-stage depressed collector with half-cylinder electrodes and external ring shaped permanent magnet. The half-cylinder electrodes introduce asymmetry in the electric field and the external ring magnet produces radial magnetic field. The cross-field action of the electric and magnetic fields along with the asymmetry introduced, results in zero back-streaming and very high collector efficiency. After proper optimization of the electrode potentials and magnetic field values, maximum of 95.53% efficiency with zero back-streaming has been achieved, the results of which are presented.**

Keywords-multi-stage depressed collector; asymmetry; cross-field; space applications;

I. Introduction

Space requirements for the traveling wave tube are very stringent, which includes high efficiency, high linearity, less weight, small size and long life. To accomplish these space requirements, the multi-stage depressed collector has to be highly efficient with negligible back-streaming. Ideally, the multi-stage depressed collector should collect all the electrons at zero kinetic energy yielding 100% collector efficiency with no electron back-streaming into the interaction space.

Here, an attempt has been taken to achieve near ideal conditions. Multi-stage collector with electrodes as half cylinders and external ring shaped magnet has been proposed. With the half cylinder electrodes, the number of electrodes within a particular length has been increased, thereby enabling better velocity sorting of the spent beam electrons. Further, applying different potentials to the upper and lower electrodes will introduce axial asymmetry in the electric field.

The external ring shaped permanent magnet has been used to produce radial magnetic field within the collector. The cross-field action of the electric and magnetic field will cause the electrons to rotate and thereby prevent them from back-streaming back into the interaction space.

The optimization of the electric potentials and the magnetic field of the collector for maximum collector efficiency and minimum back-streaming current have been carried out and the results of which have been presented.

II. Modelling

The modelling of the proposed collector has been done in CST particle studio, as shown in Figure 1. Eight electrodes have been used with axial and radial distances of 1 mm between electrodes. The external magnetic field has been applied using a ring shaped permanent magnet.

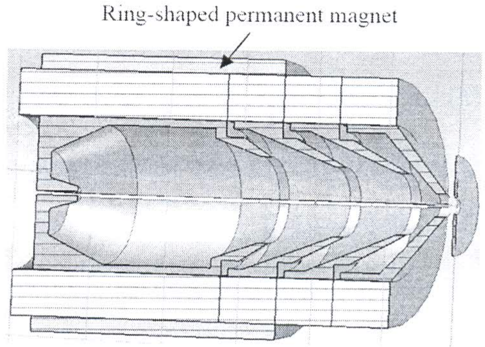


Figure 1. 3D cut-view of the proposed MDC

III. Results and Discussion

The simulation of the proposed collector has been done for Ka-band. The electric potentials have been optimized to maximize collector efficiency and to minimize the back-streaming current. The optimized potentials at the electrodes are (from right top) 1500V, 1100V, 750V and 450V.

The equipotential line distribution within the collector has been obtained for the optimized potentials. The asymmetry in the electric field can be seen by the axial asymmetry in the equipotential line distribution as seen in Figure 2.

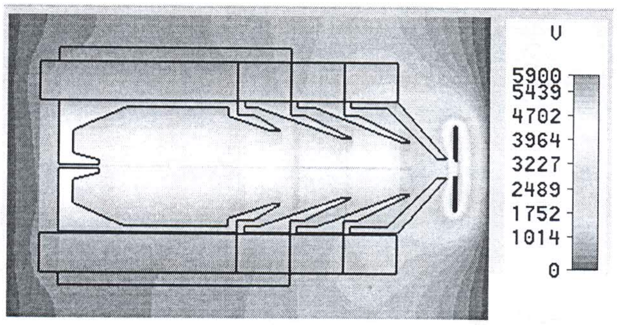


Figure 2. Equi-potential lines within the proposed MDC showing axial asymmetry

The remnant magnetic flux density of the permanent magnet has been optimized to get optimal axial magnetic field at the center of the collector. The variation of maximum axial magnetic field value with the remnant flux density of permanent magnet has been shown in Figure 3, which shows the linear relation.

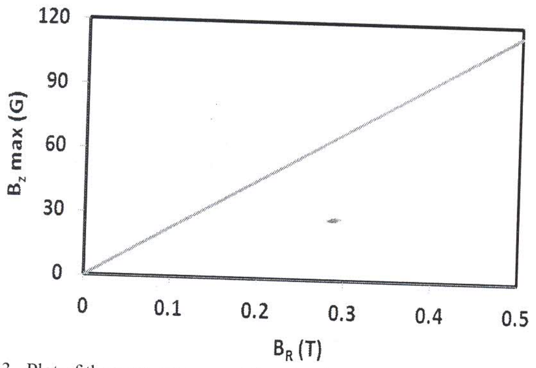


Figure 3. Plot of the remnant magnet flux density of the permanent versus the maximum axial magnetic field at the center showing linear relation

The variation of the collector efficiency with change in the remnant flux density of the permanent magnet has been studied for optimization. It has been found that for a B_R of 0.11T, a maximum collector efficiency of 95.53% has been obtained, as seen in Figure 4. The axial magnetic field profile at the center of the collector is shown in Figure 5.

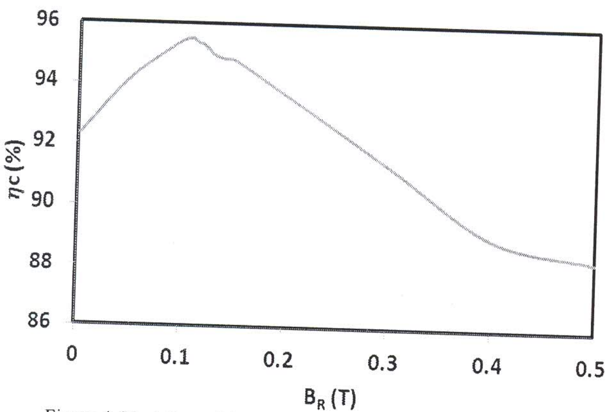


Figure 4. Variation of the collector efficiency with B_R of permanent magnet

The electron trajectories within the collector, both with and without the effect of secondary electrons have been shown in Figure 6 (a) and (b) respectively. The performance for both the cases has also been summarized in the table 1. It has been observed that collector efficiency of 95.53% has been obtained with zero back-streaming current, without taking the effect of secondaries into account and a collector efficiency of 92.18% with zero back-streaming including the effect of secondaries. Hence, as the proposed collector has obtained high collector efficiency and zero back-streaming, it can be a suitable candidate for space applications.

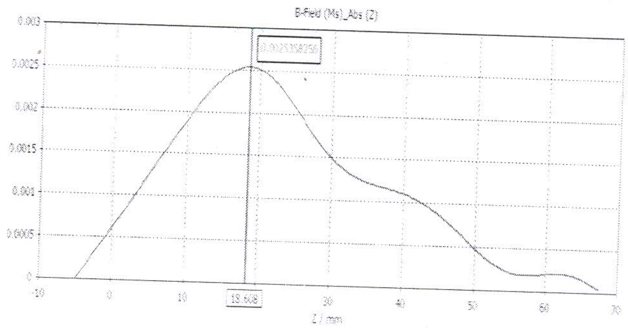
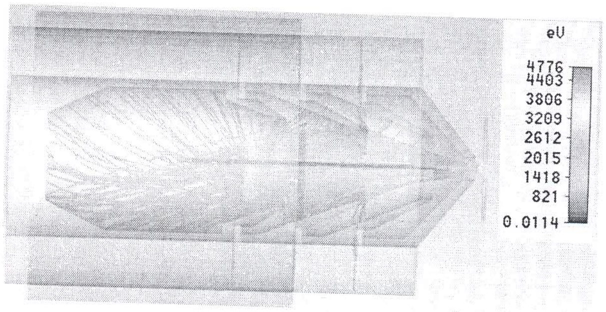
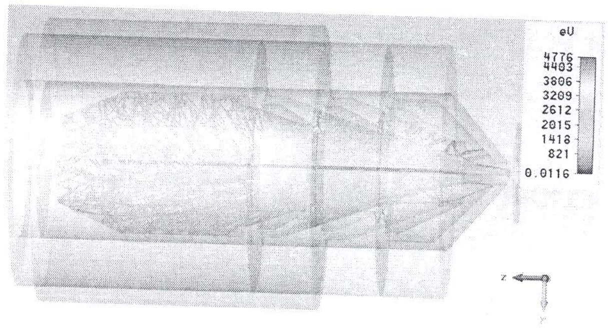


Figure 5. Axial magnetic field at the center due to the external ring magnet



(a)



(b)

Figure 6. (a) Primary electron trajectories and (b) Electron trajectories, including both primary and secondary, within the proposed MDC

TABLE I. SUMMARY OF THE PERFORMANCE OF THE PROPOSED MDC WITH AND WITHOUT THE EFFECT OF SECONDARY ELECTRONS

Parameter	Without secondaries	With secondaries
Collector Efficiency	95.53%	92.18%
Back-streaming current	0.00 mA	0.00 mA
Body Current	0.00 mA	0.19 mA

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