Analysis of the Performance of Trochoidal Collector for Space Applications

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***Abstract*— Trochoidal collector where the electrons follow a trochoidal path within the collector has been studied. The trochoidal collector is a crossed field multi-stage depressed collector where axial magnetic field is applied by means of a solenoidal magnet. The electrodes are in the form of half cylinders and hence increase the levels of depression and thereby improve the collector efficiency. The last electrode has a post which extends till the first electrode by which asymmetry in the electric field has been introduced within the collector which in turn decreases the back-streaming of the electrons back into the tube. Increased collector efficiency and reduced back-streaming makes this collector a promising choice for the space applications and hence its performance has been analyzed in this paper.**

***Keywords* — Traveling wave tube, Multi-stage depressed collector, Trochoidal collector, Space applications.**

I. Introduction

As space traveling wave tube has to be highly efficient, they require special highly efficient multi-stage depressed collector. A special collector where the electrons follows a trochoidal path due to the impact of magnetic field is called trochoidal collector. This cross-field collector has half cylinder electrodes, each at different levels of depression. As the result, more number of electrodes are available within the same length of collector and so better sorting of the electrons can be achieved with this collector.

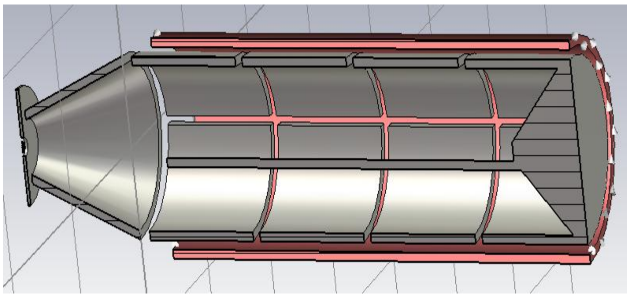


Fig.1: Geometry of the trocoidal collector showing the conical transition region, followed by electrodes. The outer solenoidal magnet can also be seen.

Further, the trochoidal collector has a post in the last electrode that extends till the first electrode. This introduces asymmetry in the electric field within the collector. Hence, this acts as a powerful mechanism in preventing the back-streaming of the secondary electrons produced within the collector.

Here, the authors have designed a trochoidal collector (as shown in fig.1) for Ka-band space TWT and have analyzed its performance. The major parameters to optimize are the potential at each collector stage and the magnetic field within the collector.

II. Performance Analysis

A. Electro-static Analysis

The potentials of the collector has been optimized for maximum RF efficiency. The table 1 summarizes the optimized potentials at each collector stage including the conical transition region.

TABLE I

Summary of Optimized Potentials

S. No.	Electrode	Optimized Potential (kV)
1	Body	5900
2	Transition region	1000
3	First upper	1750
4	First lower	1600
5	Second upper	1500
6	Second lower	1300
7	Third upper	1000
8	Third lower	750
9	Fourth	450

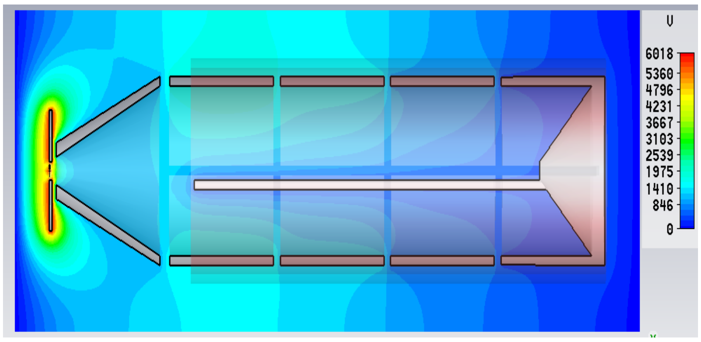


Fig.2: Equi-potntial line distribution within the collector showing the asymmetry in the electric field

The asymmetry in the electric field within the collector has been depicted in fig. 2 where each electrode holds its optimized potential.

B. *Magneto-static Analysis*

The magnetic field has been applied using a solenoidal magnet extending from the end of the conical transtition region to the end of the collector. The magnetic field within the collector plays a very important role in the sorting of the electrons and thereby critically affects the collector efficiency. The magnetic field within the collector is dependent on the current in the solenoidal coil and the number of turns in the solenoidal coil. The expression for peak magnetic field is given by [1],

$$(b - r_p) = \left(\frac{2V}{\eta B^2} \right)^{1/2}$$

where, b is the inner diameter of the half cylinders, r_p is the radius of the post, V is the beam voltage,   is the ratio of electronic charge to electronic mass and B is the peak magnetic field value.

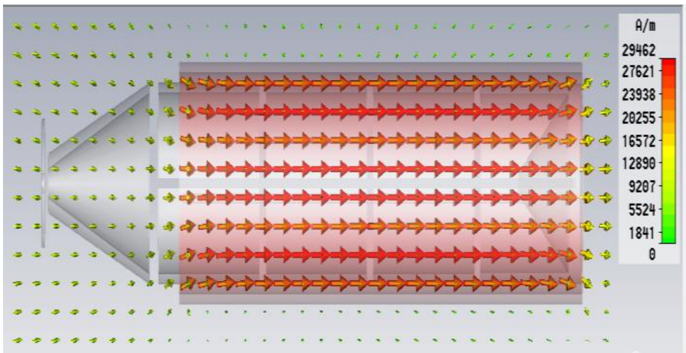


Fig.3: Magnetic field within the collector of the trochoidal collector

It has been observed that the axial magnetic field value has to be optimium to yield better performance. The effect of varying the solenoidal current and number of turns of the solenoid on the collector performance has been studied which has been summarized in table 2.

TABLE 2

VARIATION OF EFFICIENCY AND BACK-STREAMING CURRENT WITH SOLENOIDAL CURRENT AND NUMBER OF TURNS

S. No.	Current (A)	No. of Turns	Efficiency (%)	Back-streaming current (mA)
1	10	190	89.59	3.22
2	10	210	90.6	4.47
3	10	200	91.7	3.54

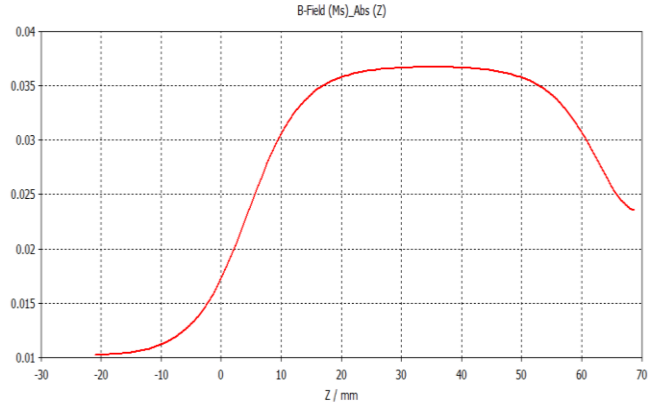
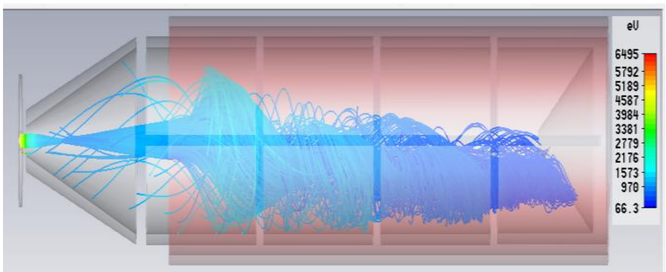


Fig.4: Optimized axial magnetic field profile at the centre of the trochoidal collector

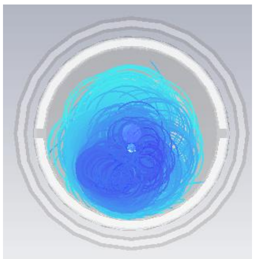
The optimized axial magnetic field profile at the centre of the collector is shown in fig. 4. The magnetic field within the conical transition region increases rapidly from 0.01T to 0.03T, whereas, the field from first to the fourth electrode are almost constant with a peak value of 0.0365T.

C. *Trajectory Analysis*

The trochoidal electron path due to the magnetic field can be seen in fig. 5. As the electrons travel along the collector, it loses its energy and gets slowed down as it moves towards the most depressed electrode. The orientation in the movement of the electrons towards the lower half cylinders can be observed and can be justified by the collection of electrons with low energy.



(a)



(b)

Fig.5: Electron trajectories within the trochoidal collector. (a) cross-sectional view; (b) end-view

III. CONCLUSIONS

The trochoidal multi-stage collector has been studied and its performance has been analyzed. The potentials applied to each electrode and the magnetic field profile within the collector has been optimized. It has been observed that this collector provides high collector efficiency and lower back-streaming and hence makes it a promising choice for space applications.

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