CHAPTER 5

SUMMARY, CONCLUSION AND FUTURE SCOPE

5.1 Introduction

Due to its extensive and newly emerging applications in defence (i.e. Radar, EMP Gun etc.), plasma physics, industry, thermo-nuclear fusion, the heating industry and other fields, high power microwaves (HPM) have piqued the interest of system designers and engineers. The HPM devices, also known as microwave-electron beam devices or microwave tubes, are based on microwaves. In the microwave, millimetre wave, and THz wave bands of the electromagnetic spectrum are used as sources and amplifiers. HPM devices are also used in Directed Energy Weapons (DEW). High-power microwaves cannot be generated using conventional microwave tubes or semiconductor-based sources and amplifiers. Various electron beam technologies are being developed for HPMs to enhance the power level and frequency range. In recent years, the development of HPM devices has emerged as a novel technology that has pushed conventional microwave device physics on a new path. High voltages are employed to generate the relativistic electron beam in these devices, and the electron energies are comparable to or more than 510 keV (the rest energy of an electron). MILO is an HPM source that can produce a self-azimuthal magnetic field. The operational mechanism of a compact MILO device is robust, with a frequency range from P-Band to K-Band. MILO is primarily used in the defence and telecommunications industries. MILO is one of the most successful, widely used devices of the HPM sources family. Nonetheless, several research-related challenging concerns must be addressed to increase device performance. The MILO's performance characteristics still have a lot of improvement. Mode control, power improvement, efficiency enhancement, and pulse shortening are all aspects of MILO that need to be improved. These factors drew the author of this thesis to investigate the RF interaction structure. The author also investigated the effect of dielectric on MILO by the use of the Field Matching approach and compared the results between simulation analysis and analytical analysis. The research work has been organized into five chapters. This chapter summarises the research conducted in the current thesis. The work's conclusions and findings are explained and discussed here.

5.2 Summary and Conclusion

5.2.1 Chapter 1

The first chapter, 'Introduction,' provides an overview of the study topic. In this chapter, the author discusses HPM system fundamentals, schematic diagrams, brief working principles, and applications. MILO's historical growth is described in detail, as well as its chronological progression. Several groups are engaged in theoretical and experimental work on MILO. The current research is focused on the effect of dielectric on various parameters of MILO. Chapter 1 also includes a brief discussion of MILO subassemblies. In summary, Chapter 1 of the thesis presents a birds-eye perspective of the history, application, basic principles, numerous components, and worldwide scenario of the standard as well as various versions of MILO.

5.2.2 Chapter 2

In this chapter, as a MILO interaction structure, the partly dielectric-filled axially periodic disk-loaded co-axial SWS was investigated. In the absence of an electron beam, the field matching technique was used to compute its dispersion relationship and interaction impedance (i.e., cold analysis). The dispersion characteristics and interaction impedance are important, for any beam–wave interaction structure because they assist determine the operating frequency and the design parameters of the device where efficient beam–wave interaction occurs. The influence of the material's dielectric constant on dispersion characteristics and phase velocity was investigated. In addition, the influence of various structural parameters on dispersion characteristics and interaction impedance was determined. The numerically calculated dispersion characteristics were compared to the dispersion characteristics acquired using the CST Studio Suite for validation. In this chapter, electromagnetic analysis was performed on a partially dielectric filled cavity structure by the use of a field matching approach and also investigated the effect of dielectric on various structural parameters. The purpose of this study was to improve knowledge of structural dependency on dispersion characteristics, which may be useful to design engineers working on HPM devices MILO.

5.2.3 Chapter 3

In this chapter, the electromagnetic (or RF) behaviour of the axially periodic disc loaded coaxial structure is investigated in the presence of an electron beam (hot analysis) with the help of a field matching approach. The linearized maxwell's fluid equation (i.e., Vlasvo-Maxwell's equation) has been used to analyze the region in which the electron beam was present (i.e. Region I). The beam-wave interaction analysis of the device mainly focuses on determining the dispersion relation (in presence of an electron beam) and temporal growth rate. The dispersion curve, temporal growth rate and other parameters are obtained through analytical and simulation analysis, considering all the harmonics generated in the structure. The effect of dielectric material on device parameters has been already investigated in the beam absent analysis. The purpose of this study was to improve the theoretical knowledge of the partially dielectric filled MILO in the presence of an electron beam, which may be helpful to design engineers working on HPM devices like MILO.

5.2.4 Chapter 4

In this chapter, the S-band dielectric filled tapered MILO was studied in detail through analysis and using commercial PIC simulation code 'CST Particle Studio'. The equivalent capacitance, equivalent inductance, and coupling capacitance of the dielectric filled interaction structure were determined using equivalent circuit analysis. Both analysis and simulation were used to verify the tapered MILO designed value. The performance of devices was determined using typically used beam parameters. In addition, investigations on the influence of cathode misalignment on MILO produced RF output power were reported. Without dielectric loading, the device generates an average power of 2.4 GW with an electronic efficiency of 13.71 per cent. Furthermore, with dielectric loading, the device generates an average power of 3.38 GW at a frequency of 2.56 GHz, with a 19.3 per cent overall efficiency. In the nut cells, this research implies that by employing this strategy, any HPM system's overall efficiency may be enhanced.

5.3 Limitation of Present Work and Scope for Further Studies

Peak power, efficiency, pulse width or energy per pulse are the most important operating characteristics of a MILO. Maximizing device RF power output and efficiency have been an active area of research, taking into consideration various beam and structure parameters. One of the shortcomings of MILO is marginal conversion efficiency. The load current in the MILO device is formed by a considerable portion of the DC input current. The load current produces the azimuthal magnetic field required to steer the initially radial beam into an axial flow. However, it has no contribution to RF power. Thus, to increase the RF output power, stored power in the SWS cavities is increased by using a dielectric. The effective capacitance of the SWS cavity of the structure increases when it is filled with the dielectric material, thereby improving RF power as well as stored power. The Proper resonance between the extractor gap and the interaction structure should occur to optimize power conversion efficiency. As a result, maximum RF coupling occurs between the extractor gap and the coaxial transmission line, resulting in appropriate RF radiation. The Stub design is modified to extract maximum RF power. The Cathode structure should be enhanced to improve pulse shortening and shot-to-shot.

Dielectric loaded MILO gives an additional controlling tool for the dispersion curve, increased RF output, improves the RF spectrum of the structure, gives the frequency tunability of the structure etc. Despite these benefits, thermal analysis of the dielectric filled MILO is missing. It should be analyzed properly for the effective use of dielectric materials in MILO structures. The effect of a dielectric is also analyzed for bi- frequency MILO. The Field matching approach is used here to analyse the DFMILO, it should be explored further for the thermal behaviour of the DFMILO.