PREFACE

The Free electron lasers are a relatively new branch of engineering physics and engineering and technology that became a laser science over the last half of the 20^{th} century. The science of the free electron lasers draws heavily on many areas of classical physics and applied mathematics. Typically, not all of these subjects are well known to the wide variety of students (from physics, engineering physics, material science, biology, medicine, life science, electrical engineering, electronics engineering, mechanical engineering, nuclear engineering and other curriculums) who begin studies of the Free electron laser physics. The distinguishing feature of the free electron laser is that its properties are determined by the relativistic electron beam or a short pulse laser. The distinguishing feature of tunability for higher frequency ranges, their properties are determined by the relativistic electron beam or a short pulse laser. FELs are an extremely adaptable light source of radiation across very wide ranges of electromagnetic spectrum from microwaves to X-rays. It is based on radiation from “free” electrons or unbound electrons rather than electrons bound in atomic and molecular systems. FELs devices (i.e., Amplifier, Oscillator, SASE and Store Ring etc.) can be operated with multiple wavelengths and allow tuning of the wavelength continuously within some range, however, the major advantage of this device is that, it does not require a metallic structure for the beam-wave interaction to take place. Consequently, it has the potential to either radiation very high power with metallic walls or generation at sub millimetre wavelengths to X-ray, where there are no any other sources achieved.

The conventional sources of radiation offer very little in terahertz range. The microwave sources, for instance, operate below $60GHz$, while lasers operate above $30THz$ and gyrotrons are limited to $30-200GHz$ range. Free electron lasers can offer an alternative to fill the frequency gap. Since FELs are an extremely adaptable light source and a fascinating device that produces tunable coherent radiation over a wide frequency range from sub millimeter wavelengths to visible region with high efficiency and huge power levels using energetic electron beams. It comprises a high voltage $(>1MV)$ power supply (accelerator) and an electron gun, an interaction region with a strong wiggler magnetic field, beam pump, radiation coupler (mirror) and diagnostics, the device is tunable by tuning the beam voltage. The FELs has a magnetic field perpendicular to the beam velocity, i.e., the main components, hence, therefore, the electrons have an oscillatory motion in transverse direction, which is suitable for interaction with either TE mode or TEM mode (TWT is always interacting with the TM mode whereas in gyrotron always dominantly interact with the TE mode). As fast-wave device, gyrotron interacts with an electromagnetic wave (uniform or periodic magnetic field) with phase velocity equal or slightly larger to the light velocity, c, whereas, in FELs, the electron oscillation is in transverse direction while its bunching process is in longitudinal direction as similar to the TWT. Hence, the free electron lasers offer an alternative radiation source in the sub millimetre and above wavelengths.

An order of magnitude comparison of the peak brightness obtained or expected for the FELs, compared to other sources of EM radiation, pointing out again the interest for FELs in the soft to hard X-ray regions. In recent years, Vacuum Tube Devices (VTDs), free electron lasers (FELs) and Cerenkov free electron lasers (CFELs) have become very attractive devices at millimeter to infrared wavelengths and are capable of generating even much shorter wavelengths, up to x-rays. Strongly magnetized plasma in the inner region of a Free Electron Laser (FEL) also opens up the possibility of generating coherent radiation in the slow whistler mode using mildly relativistic electron beams. The frequency of emission, however, is limited to below the electron cyclotron frequency.

An operation of the FEL amplifiers (FELA) in the whistler mode restricts its frequency due to below the cyclotron frequency, however, with existing technologies, it is possible to achieve magnetic fields of the order of $10-15T$ and the operation frequency of the device can be enhanced up to $200-250GHz$. One may also have a DC magnetic fields tapering, whose amplitude and period change the scenario adiabatically along with the structure, the latter leads to adiabatic slowing down of the ponderomotive wave, therefore, the tapered electrons leading to improve the efficiency of the device. An earlier study on whistler pumped tapering of an FEL amplifiers paved the ground for the successful completion of this work.

These important aspects of DC magnetic fields tapering have motivated the author of the present thesis to take up the tapering analysis and simulation studies of the DC magnetic fields in the FEL amplifiers as research problem. The studies have been also made for the performance improvement of the FEL amplifiers in terms of gain and efficiency. The author, from time to time, has reported the present work part-wise at national and international conferences as well as in reputed journals, namely, Engineering Science and Technology: An International Journal (ESTIJ), International Journal of Engineering & Technology (IJET UAE), American Institute of Physics (AIP), Physics of Plasmas (POP), IEEE Transactions on Plasma Science, Journal of Fusion Energy, International Journal of Electronics, Taylor & Francis and PRAMANA-Journal of Physics (Indian Academic of Science and Soft Computing - Springer) etc.

The author will consider his modest effort a success, if it proves to be useful both in the understanding as well as the design and development of the potential HPM-Free Electron Laser Amplifiers (FELA).