PREFACE

Nuclear Magnetic Resonance (NMR) spectroscopy emerges as an eminent spectroscopy approach to provide the solution in many areas like Physics, Chemistry, medical science, protein, drugs/medicine, and most recently to detect the cancer tissue of the body. The NMR spectroscopy approach has an advantage over the veteran X-ray spectroscopy approach because X-ray spectroscopy required a highly ordered crystalline environment to record diffraction patterns. But NMR spectroscopy has a major drawback as low signal sensitivity/intensity in the NMR experiment due to the low gyromagnetic ratio of the nucleus. The intensity of the signal can be enhanced by using a technique called Dynamic Nuclear Polarization (DNP) in which the polarization of electrons is transferred to the nucleus. Transfer of electron spin polarization occurs only when the microwave signal is irradiated at the electron Larmor frequency. Therefore, to match the frequency of the microwave signal to the electron Larmor frequency, the DNP technique requires a frequency tunable source that can produce a few tens of watts of CW power in the millimeter-wave and submillimeter-wave regimes. Among all available microwave tubes, the gyrotron oscillator is the only device that can generate a CW power in the millimeter-wave regime and the submillimeter-wave regime for a long period.

In the present thesis, an analytical approach has been implemented to investigate the RF behavior and beam-wave interaction mechanism of gyrotrons. This is validated through the PIC simulation code and experimentally published results. Thermal analysis is performed to investigate the effect of deformation of the RF interaction cavity on the operation of the gyrotron. The authors are fascinated to increase the frequency tunable bandwidth of gyrotron for DNP / NMR spectroscopy applications. In the present work, the magnetic tuning and thermal tuning scheme are used to achieve the frequency tuneable bandwidth of the three-section (conventional) cavity-based gyrotron.

The authors have presented the utilization of photonic bandgap (PBG) as an RF interaction circuit in place of a straight section of the three-section cavity. The photonic band characteristics are examined using the ADI-FDTD method. Due to its mode/frequency selective property, it provides a higher frequency tuneable bandwidth than conventional gyrotron using the magnetic tuning scheme alone. The PBG cavity has larger transverse dimensions, so the PBG gyrotron can provide a more stable operation than the conventional gyrotron. The frequency tunable bandwidth can be further enhancing by modifying the three-section cavity into a multi-section slightly tapered cavity. Because the multi-section slightly tapered cavity can maintain the diffractive Q factor even when operating in the higher-order axial mode. In addition, a submillimeter-wave gyrotron is designed to operate in a second-harmonic that helps achieve high resolution in DNP / NMR spectroscopy applications.

The author has reported the present work in various national/international conferences and reputed journals like IEEE Transaction of Electron Devices and IEEE Transaction on Plasma Science. The author will consider his modest effort as a success if it would be useful to the community of microwave tube designers and researchers for DNP/NMR applications.