

CONTENTS

| | | |
|--|---|--------------|
| Chapter 1 | Introduction and Literature Review | 1-33 |
| 1.1 | Introduction | 2 |
| 1.2 | Classification of Microwave Tubes | 4 |
| 1.3 | Fast-Wave Gyro-Devices | 6 |
| 1.3.1 | Dispersion relation | 8 |
| <i>1.3.1a Beam-mode dispersion relation</i> | | 8 |
| <i>1.3.1b Waveguide-mode dispersion relation</i> | | 9 |
| 1.3.2 | Cyclotron resonance maser instability | 12 |
| <i>1.3.2a Phase bunching</i> | | 15 |
| 1.4 | Gyrotron Amplifier | 16 |
| 1.5 | Gyrokylystron Amplifier | 18 |
| 1.5.1 | Sub-assemblies | 19 |
| <i>1.5.1a Magnetron injection gun (MIG)</i> | | 19 |
| <i>1.5.1b RF interaction structure</i> | | 20 |
| <i>1.5.1c Collector</i> | | 21 |
| <i>1.5.1d RF window</i> | | 21 |
| <i>1.5.1e Output taper</i> | | 22 |
| 1.5.2 | Applications | 22 |
| <i>1.5.2a Millimeter wave radars</i> | | 23 |
| <i>1.5.2b Particle Accelerators</i> | | 23 |
| 1.5.3 | Types of gyrokylystron | 24 |
| <i>1.5.3a Cylindrical cavity gyrokylystron</i> | | 24 |
| <i>1.5.3b Coaxial cavity gyrokylystron</i> | | 25 |
| <i>1.5.3c Frequency multiplying gyrokylystron</i> | | 25 |
| <i>1.5.3d Clustered cavity gyrokylystron</i> | | 26 |
| <i>1.5.3e Photonic band gap (PBG) cavity gyrokylystron</i> | | 26 |
| <i>1.5.3f Multibeam gyrokylystron</i> | | 27 |
| 1.6 | Gyrokylystron — A Review | 27 |
| 1.7 | Motivation and Objective | 29 |
| 1.8 | Plan and Scope | 30 |
| 1.9 | Conclusion | 33 |
| Chapter 2 | Analysis of Gyrokylystron Amplifiers | 34-65 |
| 2.1 | Introduction | 35 |
| 2.2 | Nonlinear Analysis | 37 |
| 2.2.1 | Effect of velocity spread | 47 |
| 2.2.2 | Linear analysis | 48 |

| | | |
|------------------|---|---------------|
| 2.3 | Results and Discussion | 51 |
| 2.3.1 | Efficiency contours | 52 |
| 2.4 | Numerical Benchmarking | 56 |
| 2.4.1 | Two-cavity gyrokylystron amplifier | 58 |
| 2.4.2 | Four-cavity gyrokylystron Amplifier | 60 |
| 2.4.2a | <i>Sensitivity analysis</i> | 62 |
| 2.5 | Conclusion | 64 |
| Chapter 3 | PIC Simulation of Gyrokylystron Amplifiers | 66-92 |
| 3.1 | Introduction | 67 |
| 3.2 | PIC Simulation Code ‘MAGIC’ | 68 |
| 3.2.1 | Basics of MAGIC software | 69 |
| 3.2.2 | PIC simulation description | 71 |
| 3.3 | PIC Simulation of a Two-Cavity Gyrokylystron Amplifier | 74 |
| 3.3.1 | RF interaction structure modeling | 75 |
| 3.3.2 | Eigenmode and electromagnetic fields | 76 |
| 3.3.3 | Electron beam and RF wave interaction | 78 |
| 3.4 | PIC Simulation of a Four-Cavity Gyrokylystron Amplifier | 83 |
| 3.4.1 | RF interaction structure modeling | 83 |
| 3.4.2 | Eigenmode and electromagnetic fields | 84 |
| 3.4.3 | Electron beam and RF wave interaction | 86 |
| 3.5 | Conclusion | 91 |
| Chapter 4 | Design, Analysis and Performance Study of a Four-cavity 35 GHz Gyrokylystron Amplifier | 93-125 |
| 4.1 | Introduction | 94 |
| 4.2 | Design Methodology | 94 |
| 4.2.1 | Mode selection | 95 |
| 4.2.2 | Coupling coefficient | 96 |
| 4.2.3 | Wall loading | 98 |
| 4.2.4 | Start oscillation current | 101 |
| 4.2.5 | Space charge effects | 103 |
| 4.3 | Nonlinear Analysis | 108 |
| 4.4 | Device Simulation | 110 |
| 4.4.1 | Modeling of the RF interaction structure | 111 |
| 4.4.2 | RF cavity simulation (beam absent condition) — eigenmode study | 112 |
| 4.4.3 | PIC simulation of the RF interaction structure (beam present condition) — beam-wave interaction study | 115 |
| 4.5 | Device Design and Simulation Validation | 118 |
| 4.6 | Parametric Analysis | 119 |
| 4.7 | Misalignment Study | 122 |

| | | |
|-----------------------------|--|----------------|
| 4.8 | Conclusion | 124 |
| Chapter 5 | Performance Improvement of the Gyroklystron Amplifiers using Stagger-Tuning Technique | 126-145 |
| 5.1 | Introduction | 127 |
| 5.2 | Formalism | 129 |
| 5.3 | Stagger-Tuned Four-Cavity Gyroklystron Amplifier | 131 |
| 5.4 | Performance Improvement of the Gyroklystron Amplifier | 137 |
| 5.5 | Validation through PIC Simulation | 142 |
| 5.6 | Conclusion | 145 |
| Chapter 6 | Summary and Conclusion | 146-155 |
| 6.1 | Limitation of Present Work and Scope for Further Studies | 154 |
| References | | 156-162 |
| List of Publications | | 163-165 |