## LIST OF FIGURES

Fig. 1.1	Comparison of average power versus frequency for various types of devices [Parker <i>et al.</i> (2002)]	4
Fig. 1.2	Dispersion diagrams for the gyrotron oscillator and gyroklystron amplifier (a) fundamental resonance, and (b) harmonic resonance	12
Fig. 1.3	$TE_{0n}$ mode RF electric field in a waveguide with electron beamlets	13
Fig. 1.4	Illustrations of phase bunching phenomenon in an annular electron beam (a) random distribution, and (b) phase bunched electrons in their cyclotron orbits	14
Fig. 1.5	Side view of the annular electron beam (a) electrons in random phase, and (b) electrons in bunched phase	15
Fig. 1.6	Cross-sectional view of the single orbit before electron bunching	15
Fig. 1.7	Interaction structures of different gyro-amplifiers (a) gyroklystron, (b) gyro-TWT, and (c) gyro-twystron	17
Fig. 1.8	Schematic arrangement of a gyroklystron amplifier with axial output	17
Fig. 2.1	Arrangement of gyrating electrons in their Larmor radius in the cylindrical cavity with cartesian and cylindrical coordinate systems	41
Fig. 2.2	Contour plot of orbital efficiency as a function of normalized field amplitude and normalized length	52
Fig. 2.3	Normalized momentum as a function of normalized interaction length for optimum bunching condition	54
Fig. 2.4	Electrons phase bunching along the normalized distance	54
Fig. 2.5	Normalized field amplitude and transverse efficiency as a function of normalized distance	55
Fig. 2.6	Normalized momentum versus normalized distance plots for a set of gyroklystron parameters (a) over bunching condition, and (b) variation in detuning parameter from optimal bunching	55
Fig. 2.7	Contour plot of orbital efficiency as a function of normalized beam current and normalized length	56
Fig. 2.8	Flow chart for the performance estimation of a gyroklystron amplifier	57
Fig. 2.9	Efficiency as a function of frequency	58
Fig. 2.10	RF output power and gain as a function of input power	58
Fig. 2.11	Electronic efficiency variation in each cavity as a function of length	60
Fig. 2.12	RF output power as a function of frequency	61
Fig. 2.13	Output power and gain as function of input power	61
Fig. 2.14	Output power and efficiency variation with beam current	61
Fig. 2.15	Output power and efficiency variation with quality factor	63

Fig. 2.16	Output power variation with electron beam pitch factor ( $\alpha$ ) for different velocity spreads	63
Fig. 3.1	Spatial discretization of simulation space and full grid and half grid assignments of "Yee" cell [Magic User's Manual 2007]	69
Fig. 3.2	Scheme of update for E and B fields, space coordinates, momentum and current in simulation [Magic User's Manual 2007]	70
Fig. 3.3	Various fields association in full grid and half grid cell [Magic User's Manual 2007]	71
Fig. 3.4	Flow chart illustrating the order in which the simulation is created [Magic User's Manual 2007]	73
Fig. 3.5	Cross-section of a two cavity gyroklystron interaction structure	75
Fig. 3.6	Electric field (a) vector plot, and (b) contour plot for input cavity of gyroklystron	77
Fig. 3.7	Quality factor for input cavity of gyroklystron	77
Fig. 3.8	Phase space of electron beamlets (a) before interaction, and (b) after interaction	79
Fig. 3.9	Temporal field magnitude recorded using probe at the output cavity	80
Fig. 3.10	Observed frequency spectrum of the electric field at the output cavity	80
Fig. 3.11	Evolution of particles energy along axes	80
Fig. 3.12	Axial variation of electron positive power	81
Fig. 3.13	RF output power	81
Fig. 3.14	Output power and gain as a function of the input power	81
Fig. 3.15	Output power as a function of drive frequency	82
Fig. 3.16	Cross-section of a four cavity gyroklystron interaction structure	84
Fig. 3.17	Electric field (a) vector plot, and (b) contour plot for input cavity of four-cavity gyroklystron	85
Fig. 3.18	Variation of electric field magnitude along axial direction of input cavity	85
Fig. 3.19	Quality factor for input cavity of four-cavity gyroklystron	85
Fig. 3.20	Energy distribution of all the electrons along the interaction length	87
Fig. 3.21	Variation in electron positive power along the axis of interaction structure	87
Fig. 3.22	Growth of the electric field amplitude with respect to time at the output cavity	88
Fig. 3.23	Temporal growth of RF output power	88
Fig. 3.24	Frequency and power growth with respect to time	88
Fig. 3.25	Frequency spectrum of the output cavity	90
Fig. 3.26	RF output power as a function of drive frequency	90
Fig. 3.27	Output power and gain as a function of the input power	91
Fig. 4.1	Coupling coefficient $C_{mn}$ as a function of ratio of beam to	97

	waveguide radii $(r_b/r_w)$ for the different modes	
<b>Fig. 4.2</b>	Cavity mode indices versus ohmic power loss density with output power as a parameter for (a) input cavity. (b) second and third	100
	cavities, and (c) output cavity	
Fig. 4.3	Start oscillation current versus operating DC magnetic field for the different nearby competiting modes	102
Fig. 4.4	Start oscillation current versus operating DC magnetic field for $TE_{01}$ mode for different values of beam pitch factor ( $\alpha$ )	102
Fig. 4.5	Voltage depression versus beam voltage for different values of beam current	104
Fig. 4.6	Voltage depression and limiting current versus the ratio of waveguide to beam radii $(r_w/r_b)$	105
<b>Fig. 4.7</b>	Flow chart describing the gyroklystron design procedure	105
Fig. 4.8	Electrons phase distribution at different positions in phase space (a) inlet of the input cavity (b) inlet of the second cavity (c) inlet of the penultimate cavity (d) inlet of the output cavity (e) middle of the output cavity, and (f) outlet of the output cavity	107
Fig. 4.9	Normalized field distribution and electronic efficiency in the output cavity	109
Fig. 4.10	Output power variation with electron beam pitch factor ( $\alpha$ ) for different velocity spreads	110
Fig. 4.11	Cross-sectional view of the four-cavity gyroklystron RF interaction structure	111
Fig. 4.12	Vector plot of the electric field profile at the top cross-sectional view	112
Fig. 4.13	Contour plot of the electric field profile at the top cross-sectional view	113
Fig. 4.14	Contour plot of the electric field profile at the side cross-sectional view	113
Fig. 4.15	Radial variation of the electric field in the input cavity	113
Fig. 4.16	Cross section of electron beam (a) before interaction and (b) after interaction (inset shows a zoomed beamlet)	114
Fig. 4.17	Loaded quality factor of the input cavity	114
Fig. 4.18	Cross-section of electron beam (a) before interaction and (b) after interaction (inset shows a zoomed beamlet)	115
Fig. 4.19	Observed frequency spectrum of electric field at the output cavity	116
Fig. 4.20	Variation of electric field along the axial length of the RF interaction structure	116
Fig. 4.21	Evolution of particles energy along the RF interaction length	116
Fig. 4.22	Temporal growth of RF output power at the output cavity	117
Fig. 4.23	Dependence of RF output power and gain on driver power	118
Fig. 4.24	Dependence of RF output power on frequency	118
Fig. 4.25	RF output power and efficiency variation with magnetic field	120

Fig. 4.26	RF output power and efficiency variation with beam current	120
Fig. 4.27	RF output power and efficiency variation with beam voltage	121
Fig. 4.28	RFoutput power and efficiency variation with quality factor of output cavity	121
Fig. <b>4.29</b>	RF output power and frequency variations with cavities axis misalignment w.r.t. electron beam axis	122
Fig. <b>4.30</b>	RF output power variation with driver frequency for different values of cavities axis misalignment	123
Fig. 4.31	RF output power and frequency variations with drift tubes axis misalignment w.r.t. electron beam axis	123
Fig. 4.32	RF output power variation with driver frequency for different values of drift tubes axis misalignment	123
Fig. 4.33	RF output power and frequency variations with RF interaction structure axis misalignment w.r.t. electron beam axis	124
Fig. 5.1	Flow chart illustrating the steps involved in the calculation of the bandwidth of a stagger-tuned gyroklystron amplifier	133
Fig. 5.2	Variable part of gain as the function normalized frequency detuning ( $\delta$ ) for $\overline{Q} = 0.2$ and (a) $\xi^2 = 18$ and different values of $\xi^2$	134
	detuning (b) for $\mathcal{Q} = 0.2$ and (a) $\mathcal{Q}_2 = 10$ and different values of $\mathcal{Q}_1$	
	, (b) $\zeta_1^{-} = 100$ and different values of $\zeta_2^{-}$	
Fig. 5.3	Gain degradation as a function of stagger-tuning parameter $\xi_1$ for $\overline{Q} = 0.2$ and $\xi_2^2 = 0.2\xi_1^2$	135
Fig. 5.4	Normalized bandwidth as a function of stagger-tuning parameter $\xi_1$	135
-	for $\overline{Q} = 0.2$ and $\xi_2^2 = 0.2\xi_1^2$	
Fig. 5.5	Normalized gain-bandwidth product as a function of stagger- tuning parameter $\xi_1$ for $\overline{Q} = 0.2$ and $\xi_2^2 = 0.2\xi_1^2$	136
Fig. 5.6	Gain degradation as a function of stagger-tuning parameter $\xi_1$ for different values of $\xi_2$	138
Fig. 5.7	Normalized bandwidth as a function of stagger-tuning parameter $\xi_1$ for different values of $\xi_2$	139
Fig. 5.8	Normalized gain-bandwidth product as a function of stagger- tuning parameter $\xi_1$ for different values of $\xi_2$ and $G_0$ =45 dB	139
Fig. 5.9	Variable part of gain as the function normalized frequency detuning ( $\delta$ ) for different values of stagger-tuning parameter ( $\xi_1 = \xi_2 = \zeta$ )	140
Fig. 5.10	Normalized bandwidth, gain degradation, and gain-bandwidth product as a function of stagger-tuning parameter( $\xi_1 = \xi_2 = \xi$ ) for the designed four-cavity gyroklystron amplifier	140
Fig. 5.11	Temporal growth of RF output power for different values of stagger-tuning parameter $\xi$	142
Fig. 5.12	RF output power as a function of frequency for different values of stagger-tuning parameter $\xi$	143

<b>Fig. 5.13</b>	Gain degradation as a function of stagger-tuning parameter $\xi$	143
<b>Fig. 5.14</b>	Normalized bandwidth as a function of stagger-tuning parameter $\boldsymbol{\xi}$	144