

Contents

1	Introduction	1
1.1	Review of Transverse Linear Optics	6
1.2	Beam Matrix	11
1.3	Review of Longitudinal Dynamics	12
1.4	Transverse and Longitudinal Equations of Motion	14
	Exercises	15
2	Transverse Optics Measurement and Correction	17
2.1	Betatron Tune	17
2.1.1	Introduction	17
2.1.2	Fast Fourier Transform (FFT) and Related Techniques	19
2.1.3	Swept-Frequency Excitation	25
2.1.4	Phase Locked Loop	26
2.1.5	Schottky Monitor	27
2.1.6	Multi-Bunch Spectrum	27
2.2	Betatron Phase	28
2.2.1	Harmonic Analysis of Orbit Oscillations	28
2.3	Beta Function	30
2.3.1	Tune Shift Induced by Quadrupole Excitation	30
2.3.2	Betatron Phase Advance	32
2.3.3	Orbit Change at a Steering Corrector	34
2.3.4	Global Orbit Distortions	35
2.3.5	β^* at Interaction or Symmetry Point	36
2.3.6	R Matrix from Trajectory Fit	37
2.4	Detection of Quadrupole Gradient Errors	40
2.4.1	First Turn Trajectories	41
2.4.2	Closed-Orbit Distortion	41
2.4.3	Phase Advance	42
2.4.4	π Bump Method	43
2.5	Multiknobs, Optics Tuning, and Monitoring	43
2.6	Model-Independent Diagnostics	46
2.7	Coherent Oscillations and Nonlinear Optics	48
2.7.1	Beam Response to a Kick Excitation	48

2.7.2	Coherent Damping	49
2.7.3	Detuning with Amplitude	50
2.7.4	Filamentation due to Nonlinear Detuning.....	52
2.7.5	Decoherence due to Chromaticity and Momentum Spread	53
2.7.6	Resonance Driving Terms.....	53
2.7.7	Tune Scans	54
2.8	Betatron Coupling	56
2.8.1	Driving Terms	56
2.8.2	First Turn Analysis	57
2.8.3	Beam Response after Kick	58
2.8.4	Closest Tune Approach.....	59
2.8.5	Compensating the Sum Resonance.....	60
2.8.6	Emittance near Difference Resonance	61
2.8.7	Emittance near Sum Resonance	62
2.8.8	Coupling Transfer Function	63
2.8.9	Excursion: Flat Versus Round Beams	63
	Exercises	64
3	Orbit Measurement and Correction.....	69
3.1	Beam-Based Alignment	71
3.1.1	Quadrupole Excitation	72
3.1.2	Quadrupole Gradient Modulation.....	75
3.1.3	Sextupole Excitation.....	76
3.1.4	Sextupole Movement	78
3.1.5	Structure Alignment Using Beam-Induced Signals ...	79
3.2	One-to-One Steering	80
3.3	Lattice Diagnostics and R Matrix Reconstruction	82
3.4	Global Beam-Based Steering	85
3.5	Singular Value Decomposition	87
3.6	‘Wake Field Bumps’	89
3.7	Dispersion-Free Steering	91
3.8	Errors.....	94
3.9	Orbit Feedback	95
3.10	Excursion – AC Dipole	96
	Exercises	97
4	Transverse Beam Emittance Measurement and Control ...	99
4.1	Beam Emittance Measurements	101
4.1.1	Single Wire Measurement	101
4.1.2	Multiple Wire Measurement	104
4.1.3	Graphics	106
4.1.4	Emittance Mismatch	111
4.2	Beta Matching in a Transport Line or Linac	116
4.3	Equilibrium Emittance	117

4.3.1	Circumference Change	120
4.3.2	RF Frequency Change	121
4.3.3	Wigglers	122
4.4	Linac Emittance Control	125
4.4.1	Introduction	125
4.4.2	BNS Damping	126
4.4.3	Trajectory Oscillations	128
4.4.4	Dispersion-Free Steering	129
	Exercises	130
5	Beam Manipulations in Photoinjectors	133
5.1	RF Photoinjector	133
5.2	Space-Charge Compensation	134
5.3	Flat-Beam Transformation	137
	Exercises	139
6	Collimation	141
6.1	Linear Collider	141
6.2	Storage Rings	143
	Exercises	147
7	Longitudinal Optics Measurement and Correction	149
7.1	Synchronous Phase and Synchrotron Frequency	150
7.2	Dispersion and Dispersion Matching	152
7.2.1	RF Frequency Shift	153
7.2.2	RF Modulation	154
7.2.3	RF Amplitude or Phase Jump	155
7.2.4	Resonant Correction of Residual Dispersion	155
7.2.5	Higher-Order Dispersion in a Transport Line or Linac	156
7.3	Momentum Compaction Factor	159
7.3.1	Synchrotron Tune	159
7.3.2	Bunch Length	160
7.3.3	Lifetime	161
7.3.4	Path Length vs. Energy	162
7.3.5	Beam Energy via Resonant Depolarization	163
7.3.6	Change in Field Strength for Unbunched Proton Beam	164
7.4	Chromaticity	164
7.4.1	RF Frequency Shift	165
7.4.2	Head-Tail Phase Shift	165
7.4.3	Alternative Chromaticity Measurements	167
7.4.4	Natural Chromaticity	167
7.4.5	Local Chromaticity: $d\beta/d\delta$	168
7.4.6	Chromaticity Control in Superconducting Proton Rings	168

7.4.7	Application: Measuring the Central Frequency	170
	Exercises	171
8	Longitudinal Phase Space Manipulation	175
8.1	Bunch Length Compression	175
8.2	Bunch Length Precompression	178
8.3	Bunch Coalescing	180
8.4	Bunch Splitting	182
8.5	Harmonic Cavities	186
8.6	Energy Spread	190
8.7	Energy Compression	197
8.8	Beam Loading and Long-Range Wake Fields	197
8.9	Multi-Bunch Energy Compensation	202
8.10	Damping Partition Number Change via RF Frequency Shift	203
	Exercises	208
9	Injection and Extraction	211
9.1	Transverse Single-Turn Injection	211
9.2	Multi-Turn Injection	214
9.2.1	Transverse Multi-Turn Injection	214
9.2.2	Longitudinal and Transverse Multi-Turn Injection	216
9.2.3	Longitudinal Multiturn Injection	217
9.2.4	Phase-Space Painting	218
9.3	H^- Charge Exchange Injection	219
9.4	Resonant Injection	220
9.5	Continuous Injection	221
9.6	Injection Envelope Matching	221
9.7	Fast Extraction	224
9.8	Kickers	226
9.9	Septa	229
9.10	Slow Extraction	230
9.11	Extraction via Resonance Islands	232
9.12	Beam Separation	234
9.13	Crystal Extraction	236
	Exercises	238
10	Polarization Issues	239
10.1	Equation of Spin Motion	239
10.2	Thomas-BMT Equation	240
10.3	Beam Polarization	241
10.4	Spinor Algebra Using $SU(2)$	241
10.5	Equation of Spin Motion	242
10.6	Periodic Solution to the Equation of Spin Motion	243
10.7	Depolarizing Resonances	244
10.8	Polarization Preservation in Storage Rings	246

10.8.1	Harmonic Correction	247
10.8.2	Adiabatic Spin Flip	249
10.8.3	Tune Jump	250
10.9	Siberian Snakes	250
10.10	Partial Siberian Snakes	255
10.11	RF Dipole	257
10.12	Single Resonance Model	257
	Exercises	261
11	Cooling	263
11.1	Damping Rates and Fokker–Planck Equation	263
11.2	Electron Cooling	266
11.2.1	Basic Description	266
11.2.2	Estimate of the Cooling Rate	268
11.2.3	Optical Functions at the Electron Cooler	271
11.2.4	Outlook	273
11.3	Stochastic Cooling	274
11.3.1	Basic Description	274
11.3.2	Application: Emittance Growth from a Transverse Damper	276
11.4	Laser Cooling	277
11.4.1	Ion Beams	277
11.4.2	Electron Beams	279
11.5	Thermal Noise and Crystalline Beams	282
11.6	Beam Echoes	285
11.6.1	Illustration	285
11.6.2	Calculation of Transverse Echo	286
11.6.3	Measurements of Longitudinal Echoes	290
11.6.4	Measurements of Transverse Echoes	292
11.7	Ionization Cooling	295
11.8	Comparison of Cooling Techniques	297
	Exercises	298
12	Solutions to Exercises	301
	References	328
	Index	361

<http://www.springer.com/978-3-540-44187-8>

Measurement and Control of Charged Particle Beams

Minty, M.G.; Zimmermann, F.

2003, XX, 364 p., Hardcover

ISBN: 978-3-540-44187-8