

Contents

Preface	xvii	
1	Laser-Driven Plasmas: a Gateway to High Energy Density Physics and a Test-Bed for Nonlinear Science	
	<i>William L. Kruer</i>	
1	Introduction	1
2	High energy density physics	2
2.1	Definition and examples of high energy density physics	2
2.2	Enabling technology: high power lasers and other drivers	5
2.3	Enabling technology: diagnostics and integrated modeling	6
3	Laser plasma physics	8
3.1	Energy transfer between crossing laser beams	9
3.2	Laser beam deflection in nonlinearly generated plasma flow profiles	11
3.3	Kinetic effects on laser plasma instability evolution	14
4	Summary	16
2	An Experimentalist's Perspective on Plasma Accelerators	
	<i>Christopher E. Clayton</i>	
1	Introduction	19
2	Pursuing experimental goals	20
3	Plasma-accelerator laboratories	21
3.1	A laser wakefield acceleration experiment	23
3.2	The plasma wakefield acceleration experiment at SLAC	25
4	Diagnostics in theory and practice	27
5	Laser diagnostics	27
6	Plasma diagnostics	31
6.1	Thomson scattering	31
6.2	Refractive index description	37
7	Plasma wave diagnostics	40
7.1	Forward scattering at 0° incident angle	40
7.2	Forward scattering near 90° incident angle	43
7.3	Photon acceleration	46
7.4	Spectral interferometry	48

7.5	Frequency-domain holography	56		
8	Electron diagnostics	61	5 High Intensity Laser-Plasma Interaction Experiments	
8.1	Electron beam or bunch parameters	62	<i>Karl Krushelnick</i>	143
8.2	Basic measurements	65	1 Introduction	143
8.3	General properties of radiation from electrons	68	2 High harmonic emission	143
8.4	Radiation-based electron measurements	69	2.1 Basic experimental setup	144
9	Conclusions	73	2.2 Plasma diagnostics using harmonics	144
3	Waveguides for High-Intensity Laser Pulses	79	2.3 Magnetic field measurements	146
	<i>Simon Hooker</i>		3 Electron acceleration using high intensity lasers	151
1	Introduction	79	3.1 Self-modulated laser wakefield acceleration	151
2	Why are waveguides necessary?	79	3.2 Laser acceleration of electrons at intensities greater than 10^{20} W/cm ²	153
2.1	Diffraction	79	3.3 Mono-energetic beam production using ultra-short pulses	157
2.2	Refractive defocusing	81	4 Ion acceleration using short laser pulses	159
2.3	General properties of waveguides	82	4.1 Observations of ions from the “front” of laser solid interactions	160
3	Grazing-incidence waveguides	84	4.2 Ions and protons from the rear of laser interactions with thin foil targets	164
4	Plasma waveguides	86	4.3 Ions from laser interactions with underdense plasmas	168
4.1	Analysis of ideal parabolic channels	87	5 Conclusions	169
4.2	Techniques for generating plasma waveguides	89		
5	Summary	98	6 Computational Challenges in Laser-Plasma Interactions	
4	Harnessing Plasma Waves as Radiation Sources and Amplifiers	101	<i>Ricardo Fonseca</i>	173
	<i>D.A. Jaroszynski, Albert Reitsma and Bernhard Ersfeld</i>		1 Introduction	173
1	Introduction	101	2 Simulating plasmas	174
2	Laser-plasma interactions	102	3 Numerical models	175
3	The laser-driven plasma wakefield accelerator	104	4 Particle-in-Cell algorithm	176
4	Plasma-based acceleration	105	4.1 Particle pusher	177
5	Acceleration dynamics	110	4.2 Current deposition	178
6	Radiation source development	117	4.3 Field solver	179
6.1	Synchrotron sources and free-electron lasers	118	4.4 Normalization	181
6.2	Betatron radiation from plasma wakefield accelerator	128	5 Applications	182
7	Raman amplification	132	6 Conclusions	183
8	Three-wave interaction	132		
9	Dispersion of scattered wave	133	7 Particle Acceleration in Plasmas	
10	Slowly varying envelope approximation	134	<i>R. Bingham</i>	185
10.1	Low scattered amplitude	135	1 Introduction	185
10.2	Pump depletion	136	2 High energy plasma accelerators	186
10.3	Chirped pump, low scattered amplitude	137	3 Relativistic plasma wave acceleration	188
11	Summary	139	4 Plasma beat wave accelerator	189
			5 Laser wakefield accelerator	193
			6 Equations describing laser wakefield	194
			7 Self-modulated laser wakefield accelerator	196

8	Particle beam driven plasma wakefield accelerators (PWFA)	198
9	Photon acceleration	199
10	Relativistic self-focusing and optical guiding	200
11	Laser cluster/target interactions	201
12	Conclusions and outlook	203
8	Laboratory Astrophysics Using High Energy Density Photon and Electron Beams	
	<i>R. Bingham</i>	211
1	Introduction	211
2	Generating neutron star atmospheres	212
3	Cosmic ray acceleration at energetic shocks	213
4	Electron-positron plasmas	214
5	Physics of type II supernovae	215
9	Acceleration of Photons and Quasi-Particles	
	<i>J. T. Mendonça</i>	219
1	Abstract	219
2	Introduction	219
3	Motion of quasi-particles	220
4	Electrostatic waves	221
5	Wave kinetic equation	222
6	Resonant contributions	223
7	Beam instabilities	224
8	Quasi-particle trapping	225
9	Plasmons and driftons	226
10	Conclusions	228
10	Relativistic Phenomena in Plasma Solitons	
	<i>Francesco Pegoraro</i>	231
1	Introduction	231
2	Relativistic plasma solitons	232
2.1	1-D analytical results	233
2.2	Analytical models and numerical results for higher-dimension relativistic subcycle solitons	234
2.3	Subcycle soliton evolution	239
3	Experimental detection of relativistic solitons	242
3.1	Post-soliton detection by proton imaging techniques	242
4	Attosecond pulse generation	245
4.1	1-D Analytic results	246

4.2	2-D Particle-in-Cell simulation results	246
11	Interference Stabilization of Atoms in a Strong Laser Field	
	<i>M. V. Fedorov</i>	251
1	Introduction	251
2	Definitions of stabilization	251
3	Rydberg atoms	254
4	Quasiclassical dipole matrix elements	255
5	Qualitative explanation of the IS physics	256
6	Two-level model	257
7	Quasienergies	259
8	Multilevel system of Rydberg levels	261
9	Degeneracy of Rydberg levels	263
10	A fully quasiclassical approach	266
11	Experiment	268
12	Two-color interference stabilization	269
13	Conclusion	273
12	Entanglement and Wave Packet Structures in Photoionization and Other Decay Processes of Bipartite Systems	
	<i>M. V. Fedorov</i>	275
1	Introduction	275
2	General consideration	277
2.1	Definitions: entanglement, coincidence and single-particle measurements, conditional and unconditional probabilities	277
2.2	Double-Gaussian bipartite wave function	278
2.3	Double-Gaussian conditional and unconditional wave packet widths	279
2.4	The Schmidt number	280
2.5	Double-Gaussian wave packets in the momentum representation	281
2.6	Identity, reciprocity, and uncertainty relations	281
3	Photoionization of atoms and photodissociation of molecules	282
4	Spontaneous emission of a photon by an atom	286
5	Parametric down-conversion (PDC)	287
6	Multiphoton pair production	291
7	Conclusion	294
13	Intense Field Quantum Electrodynamics	
	<i>Nikolay Narozhny</i>	297
1	Introduction	297
1.1	What is “strong field” in QED?	297

1.2	How far we are from the QED “strong field”?	300	5	Acknowledgements	360
2	Quantum processes in a plane wave field	301	16	Progress in Fast Ignition	
2.1	Furry picture	301	<i>Peter A. Norreys</i>		361
2.2	Volkov solutions for Dirac equation for an electron in a laser field	302	1	Introduction	361
3	Simplest processes (theory and experiment)	305	1.1	Background	361
3.1	Nonlinear Compton scattering	305	1.2	Inertial confinement fusion	362
3.2	Photoproduction of a e^-e^+ -pairs	308	1.3	The fast ignition concept	363
4	A short focused laser pulse	311	1.4	The cone-guided and cone-focused concepts	364
5	Ponderomotive effect	315	2	Fast electron energy transport	365
5.1	Nonrelativistic analysis	315	2.1	Background	365
5.2	Equations of average motion of a relativistic electron	316	2.2	Absorption processes	366
5.3	Ponderomotive scattering of electrons by a focused laser pulse of relativistic intensity	318	2.3	Alfvén-Lawson current limit	367
6	Pair creation by a focused laser pulse in vacuum	320	2.4	Weibel instability	367
7	Conclusions	323	2.5	Two-stream and filamentation instabilities	369
14	Fundamentals of ICF Hohlraums		2.6	Filament coalescence and stochastic electron motion	370
	<i>Mordecai (“Mordy”) D. Rosen</i>	325	2.7	A two-step process for ion heating in fast ignition	370
1	Basic physics	325	2.8	Collimation, beam hollowing and annular transport	371
1.1	History of hohlraums	326	3	Computational modelling	373
1.2	Radiation transport	329	4	Conclusions	373
1.3	Solving the diffusion equation	331	17	Fusion Targets	
1.4	Solving for the Albedo	335	<i>Damian C. Swift</i>		377
1.5	Solving for the hohlraum temperature	338	1	Introduction	377
2	Hohlraum optimization	341	2	Ablator material and microstructures	378
2.1	Cocktails	341	3	Continuum mechanics and shock physics	381
2.2	Foam-walled hohlraums	343	4	Properties of the ablator material	385
2.3	Hohlraums with axial shine shields	345	4.1	Equation of state and phase diagram of beryllium	385
3	Applications of hohlraums to ICF	348	4.2	Plasticity of beryllium	393
3.1	Gain calculation: conventional and fast ignitor	348	5	Instability seeding from the microstructure	396
3.2	Pulse shaping	349	5.1	Experiments resolving microstructural response	396
4	Conclusions	350	5.2	Simulations of microstructural effects	397
15	Dense Plasma Physics – the Micro Physics of Laser-Produced Plasmas		5.3	Experiments measuring instability growth	399
	<i>S. J. Rose</i>	353	6	Conclusions	405
1	Introduction	353	18	Direct-Drive Inertial Fusion: Basic Concepts and Ignition Target Designing	
2	Non-equilibrium microphysics	353	<i>Valeri N. Goncharov</i>		409
3	Equilibrium microphysics	357	1	Introduction	409
4	Conclusion	360	2	Basic concepts	410
			3	Direct-drive ignition target design	412

4	Stability	416
5	Acknowledgements	417
19	Ablative Richtmyer-Meshkov Instability: Theory and Experimental Results	
	<i>Valeri N. Goncharov</i>	419
1	Introduction	419
2	One-dimensional flow	420
3	Perturbation evolution: theory	421
3.1	Classical case without ablation	421
3.2	Effects of mass ablation	424
4	Perturbation evolution: experiment	426
5	Acknowledgements	427
Index		429