

Contents

1	General Introduction	1
1.1	Conventional Versus Plasma-Based Acceleration	1
1.2	Laser-Plasma Acceleration	3
1.3	About the Thesis	4
2	Laser-Plasma Accelerators	7
2.1	Introduction	7
2.2	Generation of Intense Laser Pulses	8
2.2.1	Chirped Pulse Amplification	8
2.2.2	TREX Laser System	9
2.3	Theory of Laser Propagation	10
2.3.1	Laser Diffraction	10
2.3.2	Laser Guiding in Plasma Channel	12
2.3.3	Relativistic Self-focusing	14
2.4	Plasma Waves	15
2.4.1	Plasma Wave Excitation	15
2.4.2	Electron Acceleration and Dephasing	21
2.4.3	Electron Beam Production	22
2.5	Limitations to Energy Gain	27
2.5.1	Acceleration Limits	27
2.5.2	Scaling Laws for Energy Gain	29
2.6	Summary and Conclusions	30
3	Staged Laser-Plasma Accelerator: Introduction	31
3.1	Introduction	31
3.2	Experimental Design	31
3.3	Experimental Configuration	32
3.4	Summary and Conclusions	36

4	Injection Module	39
4.1	Introduction	39
4.2	Experiments on Electron Beam Production at 40 TW	40
4.2.1	Experimental Configuration	40
4.2.2	Electron Beam Production via Self-trapping	41
4.2.3	Electron Beam Production via Ionization of N_2	42
4.2.4	Electron Beam Production with Tailored Plasma Density	44
4.3	Characterizations of Electron Beams	47
4.3.1	Slice Energy Spread Measurement	47
4.3.2	Emittance Measurement	50
4.4	Experiments on Electron Production at 25 TW	51
4.5	Implications for 1st Module	53
4.5.1	Emittance Preservation Between Stages	54
4.5.2	Electron Beam Capturing Conditions at 2nd Module	57
4.6	Summary and Conclusions	58
5	Plasma Mirror	61
5.1	Introduction	61
5.2	Theoretical Framework of Plasma Mirror	63
5.3	Experimental Configuration and Results	65
5.4	Electron Beam Interaction with Plasma Mirror	70
5.5	Summary and Conclusions	72
6	Acceleration Module	73
6.1	Introduction	73
6.2	Laser Profile Characterization	75
6.2.1	Wavefront Measurement	75
6.2.2	Characterization with Laguerre-Gaussian Pulses	76
6.2.3	Wakefield Excitation by Gaussian and Laguerre-Gaussian Pulses	77
6.3	Plasma Channel Characterization	81
6.3.1	Plasma Channel Formation	81
6.3.2	Laser Centroid Oscillation	82
6.3.3	Experimental Configuration	85
6.3.4	Experimental Results and Analysis	85
6.4	Wakefield Diagnostic Based on Laser Spectra	87
6.4.1	Background on Wakefield Diagnostics	87
6.4.2	Spectral Redshift as a Measure of Wake Excitation	88
6.4.3	Experimental Configuration	89
6.4.4	Simulations	91
6.4.5	Analysis of Optical Spectra	93
6.4.6	Summary of Spectral Analysis	99

6.5	Design Consideration for Staged LPA	100
6.5.1	Schemes for Multiple Laser Pulses	100
6.5.2	Group Velocity Dispersion	100
6.5.3	Self-Phase Modulation	101
6.5.4	Pulse Splitting in Staging Experiment	101
6.6	Experiment on Wake Excitation in 2nd Module	103
6.6.1	Experimental Configuration	103
6.6.2	Results and Analysis	105
6.7	Summary and Conclusions	107
7	Summary and Conclusions	111
	Curriculum Vitae	115
	References	117

Investigation of Staged Laser-Plasma Acceleration

Shiraishi, S.

2015, XVII, 121 p. 71 illus., 66 illus. in color., Hardcover

ISBN: 978-3-319-08568-5