

Contents

1	The Soft X-ray Free-Electron Laser FLASH at DESY	1
	E. Plönjes and K. Tiedtke	
1.1	Introduction	1
1.2	FLASH Machine.	2
1.3	Layout of the Facility	3
1.3.1	Layout of the Optical System	5
1.3.2	Characterization of the Optical System.	9
1.4	Characterization of the FEL Pulses	10
1.4.1	Monitoring of the Intensity and Beam Position	11
1.4.2	Monitoring of the Spectral Distribution	11
1.4.3	Monitoring of the Temporal Properties.	13
1.5	Manipulation of the Photon Beam.	14
1.5.1	Reduction of Photon Pulse Energy	14
1.5.2	Suppression of FEL Harmonics.	14
1.5.3	Single Pulse Selection	15
1.5.4	Split and Delay Units	15
1.6	Additional Light Sources for Advanced Multi-colour Experiments	17
1.6.1	Optical Laser System.	17
1.6.2	THz Beamline for Pump-Probe Experiments.	18
1.7	Near Future Perspectives	18
	References.	20
2	The Soft X-ray Free-Electron Laser FERMI@Elettra.	23
	Marco Zangrando, Nicola Mahne, Lorenzo Raimondi and Cristian Svetina	
2.1	Introduction	23
2.2	Diagnostics	26
2.2.1	Beam Position Monitor	26
2.2.2	Intensity Monitors.	27
2.2.3	Energy Spectrometer	27

2.2.4	Transverse Distribution	29
2.2.5	Transverse Coherence	32
2.3	Manipulation	32
2.3.1	Beam Defining Apertures.	33
2.3.2	Gas Absorber	34
2.3.3	Split and Delay Line	35
2.3.4	Focusing Mirrors.	36
2.4	Conclusions	39
	References.	39
3	Overview on Attosecond Sources	41
	Francesca Calegari, Giuseppe Sansone and Mauro Nisoli	
3.1	Introduction	41
3.2	Ultrafast Laser Technologies for the Generation of Attosecond Pulses	42
3.2.1	Pulse Compression Techniques	42
3.2.2	Optical Parametric Amplification.	43
3.2.3	Carrier-Envelope Phase Stabilization	45
3.3	High-Order Harmonic Generation	47
3.3.1	Semiclassical Model	47
3.3.2	Strong-Field Approximation	50
3.3.3	Phase-Matching in High-Order Harmonic Generation	52
3.4	Generation of Isolated Attosecond Pulses	53
3.4.1	Spectral Gating	53
3.4.2	Temporal Gating	55
3.5	Spatial Gating.	58
3.6	Conclusions	60
	References.	60
4	Overview on HHG High-Flux Sources	63
	Willem Boutu, Mathieu Ducoussou, Jean-François Hergott and Hamed Merdji	
4.1	Introduction	63
4.2	Optimization of the Atomic Response	64
4.3	Phase Matching	66
4.3.1	Loose Focusing.	67
4.3.2	Quasi Phase Matching	69
4.3.3	Artificial Tailoring of the Laser Pulses.	72
4.4	High Repetition Rate Sources	73
4.5	Conclusion.	74
	References.	75

5	Seeding Free Electron Lasers with High Order Harmonics Generated in Gas	79
	Marie-Emmanuelle Couprie and Luca Giannessi	
5.1	Introduction	80
5.2	Seeding and Harmonic Generation, a Particular FEL Configuration	81
5.2.1	Oscillator	81
5.2.2	High Gain and Self Amplified Spontaneous Emission	82
5.2.3	Seeding and Harmonic Generation.	84
5.3	HHG Seeding and Harmonic Generation Process	87
5.3.1	Shot Noise and Comparison with Available Seed Power	88
5.3.2	HHG Seeded FEL Dynamics	92
5.4	Coupling the Seed Source to the FEL	96
5.4.1	HHG Chamber Design for FEL Seeding	96
5.4.2	Spectral Tuning, Tuneability, Polarisation Matching, Optical Transport and Synchronization.	97
5.5	Achievements with HHG Seeding	98
5.5.1	Direct Seeding Mode.	98
5.5.2	Cascaded FEL Configuration	101
5.6	Conclusion.	103
	References.	104
6	Temporal Characterization of Ultrashort Extreme-Ultraviolet and Soft X-ray Pulses	115
	Michele Devetta, Matteo Negro, Salvatore Stagira and Caterina Vozzi	
6.1	Measurement of Attosecond Pulses	115
6.1.1	The Attosecond Streak Camera	116
6.1.2	Semiclassical Model for Attosecond Streaking	118
6.1.3	RABBIT: Measurement of Attosecond Pulse Trains.	120
6.1.4	Isolated Attosecond Pulse Characterization: Experimental Results	121
6.1.5	XUV Non-linear Optics	123
6.2	Temporal Characterization of Pulses Generated by FELs	126
6.2.1	Autocorrelation of XUV FEL Pulses	126
6.2.2	Cross-Correlation Measurements Involving XUV FEL Pulses.	127
6.3	Conclusions	132
	References.	133

7	Optical Metrology—On the Inspection of Ultra-Precise FEL-Optics.	137
	Frank Siewert	
7.1	Introduction	137
7.2	Slope Error and Micro-Roughness.	138
7.2.1	The Principle of Slope Measurement	141
7.2.2	On the Calibration of Slope Measuring Profiler.	145
7.2.3	Super Polished Mirrors for FEL Application.	145
	References.	148
8	Multilayer Mirrors for Coherent Extreme-Ultraviolet and Soft X-ray Sources	151
	Charles Bourassin-Bouchet, Sébastien de Rossi and Franck Delmotte	
8.1	Multilayer Mirrors for the XUV Spectral Range	152
8.1.1	Multilayer Mirrors: Theory and Design	152
8.1.2	Deposition and Characterization of Multilayers	154
8.1.3	State-of-the-Art of Normal Incidence Multilayer Mirrors	155
8.1.4	Specificities of Multilayer Mirrors for Coherent X-ray Sources.	156
8.2	Multilayer Mirrors for Picosecond and Femtosecond Sources	157
8.2.1	High Reflectivity Mirrors	157
8.2.2	High Selectivity Mirrors.	158
8.2.3	High Stability Mirrors	162
8.3	Multilayer Mirrors for Attosecond Sources.	163
8.3.1	Specificities of the Attosecond Regime	163
8.3.2	Design of Attosecond Mirrors.	165
8.3.3	Characterization of Attosecond Mirrors	166
8.4	Conclusion.	170
	References.	170
9	Gratings for Ultrashort Coherent Pulses in the Extreme Ultraviolet	175
	Taro Sekikawa	
9.1	Introduction	175
9.2	Grating for the Extreme Ultraviolet and Soft X-ray	177
9.2.1	Absorption and Reflectance	177
9.2.2	Grating	178
9.3	Time-Preserving Monochromator Using a Single Grating	182
9.4	Time-Delay Compensated Monochromator.	183
9.4.1	Compensation of Time Delay Introduced by Diffraction.	183

9.4.2	Experimental Demonstration of a Time-Delay Compensated Monochromator.	184
9.4.3	Future Applications	190
9.5	Conclusions	191
	References.	192
Index		195