

Contents

1	Introduction	13
2	Light sources for gravitational wave detectors	17
2.1	Laser requirements	22
2.2	Best available laser technology in GWDs	24
2.3	Laser concept	26
3	Models for system development	31
3.1	Thermo-optical effects in end-pumped Nd:YAG crystals	31
3.1.1	Analytical treatment	32
3.1.2	Numerical treatment	34
3.2	Gaussian beams and higher-order modes	40
3.2.1	Higher-order Gaussian modes	40
3.2.2	Matrix formalism	44
3.3	Dynamically stable resonators with an aspherical thermal lens	47
3.4	Injection locking	49
3.4.1	Single-frequency operation	50
3.4.2	Pound-Drever-Hall injection locking	52
4	High power oscillator development	57
4.1	Mode discrimination by resonator geometry	57
4.1.1	The two head laser	58
4.1.2	Power-scaling	62
4.1.3	Four head resonator setup	68
4.2	Laser head module	71
4.2.1	FEM heat load analysis	74
4.2.2	Pump source	77
4.2.3	Pump light delivery	82
4.2.4	Pump light diagnostic	84
4.2.5	Imaging optics	86



IV

4.2.6	Dichroic pump mirror	89
4.2.7	Laser crystal cooling chamber	93
4.3	High power oscillator setup	97
4.3.1	Water cooling scheme	99
4.3.1.1	Laser cooling circuit	99
4.3.1.2	Diode laser cooling circuit	102
4.3.1.3	Materials in contact with water	103
4.3.2	Piezo actuated mirror	104
4.3.3	Laser housing, base-plate and internal components	107
4.3.4	Active resonator expansion compensation	110
4.3.5	Monitoring and safety	111
5	Injection-locked laser performance	115
5.1	Output power and beam profile	115
5.2	Injection-locking characteristics	118
5.3	Higher-order mode content	123
5.4	Relative power and frequency noise	124
5.5	Long term stability	126
5.6	Actively stabilized output characteristics	127
6	Outlook	131
6.1	Production, delivery and on-site-support	131
6.2	Laser for the 3rd generation of gravitational wave detectors	134
6.2.1	Laser at 1064 nm	137
6.2.2	Laser at 1550 nm	141
7	Conclusion	143
A	Material properties	145
B	Rod designer program interface	157
C	Stress and strain coefficients	159
D	SPC laser control visualization	161
References		165
Publications and Conferences		175