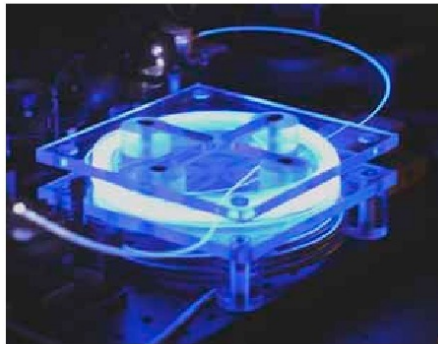




Peter Adel (Autor)  
**Pulsed fiber Lasers**

Peter Adel

**Pulsed fiber lasers**



Cuvillier Verlag Göttingen

<https://cuvillier.de/de/shop/publications/2908>

Copyright:

Cuvillier Verlag, Inhaberin Annette Jentsch-Cuvillier, Nonnenstieg 8, 37075 Göttingen,  
Germany

Telefon: +49 (0)551 54724-0, E-Mail: [info@cuvillier.de](mailto:info@cuvillier.de), Website: <https://cuvillier.de>

# CONTENTS

<b>1 INTRODUCTION .....</b>	<b>1</b>
<b>2 BASICS OF PULSED FIBER LASER SYSTEMS .....</b>	<b>5</b>
2.1 BASICS OF FIBER OPTICS .....	5
2.1.1 <i>Fiber modes</i> .....	6
2.1.2 <i>Chromatic dispersion</i> .....	8
2.1.3 <i>Modal birefringence</i> .....	9
2.2 NONLINEAR EFFECTS IN FIBERS .....	10
2.2.1 <i>Kerr-Effect</i> .....	11
2.2.2 <i>Self- and cross-phase-modulation</i> .....	12
2.2.3 <i>Stimulated Raman scattering</i> .....	13
2.2.4 <i>Stimulated Brillouin scattering</i> .....	15
2.2.5 <i>Four-wave-mixing</i> .....	15
2.3 PULSES IN OPTICAL FIBERS .....	16
2.3.1 <i>Dispersion pulse broadening</i> .....	17
2.3.2 <i>Polarization mode dispersion</i> .....	19
2.3.3 <i>Interaction of GVD and SPM</i> .....	19
2.3.4 <i>Stimulated Raman scattering of pulsed signals</i> .....	21
2.4 FIBER LASER AND AMPLIFIER .....	22
2.4.1 <i>Ytterbium gain fibers</i> .....	24
2.4.2 <i>Erbium gain fibers</i> .....	27
2.5 GENERATION OF LASER PULSES .....	31
2.5.1 <i>Passive Q-switching and relaxation oscillations</i> .....	32
2.5.2 <i>Mode-locking</i> .....	32
2.6 STRETCHING AND COMPRESSION OF OPTICAL PULSES .....	35
<b>3 PASSIVE Q-SWITCHED YB<sup>3+</sup>-FIBER LASER.....</b>	<b>39</b>
3.1 EXPERIMENTAL SET-UP .....	40
3.2 Q-SWITCHED LASER OPERATION .....	41
3.2.1 <i>Influence of output coupling</i> .....	43
3.2.2 <i>Influence of fiber length</i> .....	44
3.2.3 <i>Signal linewidth</i> .....	45
3.2.4 <i>Wavelength tuning</i> .....	48
3.2.5 <i>Laser operation without spectral selective elements</i> .....	49
3.3 PHYSICAL MECHANISM OF PASSIVE PULSE GENERATION.....	51
3.3.1 <i>Effects of Tm<sup>3+</sup>-codoping</i> .....	51
3.3.2 <i>Relaxation oscillations</i> .....	54
3.3.3 <i>Polarization effects</i> .....	56
3.4 CONCLUSION AND OUTLOOK .....	57

<b>4 MODE-LOCKED YB<sup>3+</sup>-FIBER LASER</b> .....	<b>59</b>
4.1 EXPERIMENTAL SET-UP .....	59
4.2 MODE-LOCKED LASER OPERATION .....	61
4.3 PULSE ENERGY QUANTIZATION .....	64
4.4 CAVITY DISPERSION .....	66
4.5 SIGNAL CHIRP.....	68
4.6 INTRA-CAVITY PULSE DYNAMIC .....	71
4.7 CONCLUSION AND OUTLOOK .....	73
<b>5 SUPER-BROADBAND YB<sup>3+</sup>-FIBER LASER</b> .....	<b>75</b>
5.1 EXPERIMENTAL SETUP.....	75
5.2 BROADBAND MODE-LOCKED LASER OPERATION .....	76
5.2.1 <i>Filtering versus spectral broadening</i> .....	80
5.3 BROADENING MECHANISM .....	82
5.3.1 <i>Linear effects of the spectral filtering</i> .....	82
5.3.2 <i>Nonlinear broadening mechanism</i> .....	84
5.4 CONCLUSION AND OUTLOOK .....	85
<b>6 FEMTOSECOND ER<sup>3+</sup>-FIBER OSCILLATOR-AMPLIFIER SYSTEM</b> .....	<b>87</b>
6.1 EXPERIMENTAL SET-UP OF THE ER <sup>3+</sup> -OSCILLATOR-AMPLIFIER SYSTEM.....	88
6.1.1 <i>Femtosecond Er<sup>3+</sup>-fiber oscillator</i> .....	88
6.1.2 <i>Fiber-stretcher</i> .....	91
6.1.3 <i>Pulse picking unit</i> .....	93
6.1.4 <i>Preamplifier</i> .....	95
6.1.5 <i>Power-amplifier</i> .....	97
6.1.6 <i>Grating compressor</i> .....	100
6.2 EXPERIMENTAL RESULTS FOR THE OSCILLATOR-AMPLIFIER SYSTEM.....	102
6.2.1 <i>Output signal of the fiber amplifier</i> .....	102
6.2.2 <i>Transmission properties of the grating compressor</i> .....	105
6.2.3 <i>Temporal pulse recompression</i> .....	108
6.3 NONLINEAR EFFECTS IN THE FIBER AMPLIFIER.....	112
6.3.1 <i>Spectral modulations</i> .....	112
6.3.2 <i>Nonlinear dispersion</i> .....	116
6.3.3 <i>Four-wave mixing</i> .....	117
6.3.4 <i>Gain saturation</i> .....	120
6.3.5 <i>Fiber surface damages</i> .....	123
6.4 CONCLUSION AND OUTLOOK .....	125
<b>7 SUMMARY AND OUTLOOK</b> .....	<b>127</b>
<b>APPENDIX</b> .....	<b>131</b>
A CALCULATION OF OPTICAL FIBER PROPERTIES.....	131
A.1 <i>Numerical approximation of the field distribution in an optical fiber</i> .....	131
A.2 <i>Calculation of the waveguide dispersion of an optical fiber</i> .....	135
B UNITS IN FIBER OPTIC TELECOMMUNICATION AND LASER PHYSICS.....	136
C DOPING CONCENTRATIONS IN SILICA FIBERS .....	137
D ABBREVIATIONS.....	139

<b>REFERENCES .....</b>	<b>141</b>
<b>PUBLICATIONS .....</b>	<b>151</b>
<b>CURRICULUM VITAE.....</b>	<b>155</b>
<b>DANKSAGUNG .....</b>	<b>157</b>