## Dye Lasers

Edited by F.P. Schäfer

With Contributions by K.H. Drexhage H. Gerhardt T.W. Hänsch E.P. Ippen F.P. Schäfer C.V. Shank B.B. Snavely J.J. Snyder

Third Enlarged and Revised Edition

With 126 Figures

Springer-Verlag Berlin Heidelberg New York London Paris Tokyo Hong Kong

## **Contents**

1.	Principles of Dye Laser Operation	
	By F.P. Schäfer (With 69 Figures)	1
	1.1 General Properties of Organic Compounds	4
	1.2 Light Absorption by Organic Dyes	g
	1.3 Deactivation Pathways for Excited Molecules	26
	1.4 Laser-Pumped Dye Lasers	31
	1.4.1 Oscillation Condition	31
	1.4.2 Practical Pumping Arrangements	35
	1.4.3 Time Behavior and Spectra	43
	1.5 Flashlamp-Pumped Dye Lasers	52
	1.5.1 Triplet Influence	52
	1.5.2 Practical Pumping Arrangements	59
	1.5.3 Time Behavior and Spectra	62
	1.6 Wavelength-Selective Resonators for Dye Lasers	66
	1.6.1 Distributed-Feedback Dye Lasers	78
	1.6.2 Thin-Film and Waveguide Dye Lasers	82
	1.7 Dye-Laser Amplifiers	84
	1.8 Outlook	87
2.	Continuous-Wave Dye Lasers I	_
	By B. B. Snavely (With 18 Figures)	9:
	2.1 Gain Analysis of the cw Dye Laser	9.
	2.1.1 Analysis at Laser Threshold	95
	2.1.2 Gain Analysis Above Laser Threshold	10:
	2.2 Tuning of the cw Dye Laser	106
	2.3 Performance of Experimental Systems	113
	2.4 Conclusion	120
2	Continuous Ways Day Losses II	
э.	Continuous-Wave Dye Lasers II	12
	By H. Gerhardt (With 10 Figures)	12
	3.1 Linear Dye Laser	121
	3.1.1 Active Region	123
	3.1.2 cw Dye Laser Tuning	12:
	3.1.3 Dyes for cw Operation	129
	3.2 Single-Mode Operation of Linear Dye Lasers	129
	3.2.1 Spatial Hole Burning	
	3.2.2 Single Mode Selection Techniques in a Linear Dye Laser	13

УШ	Contents
	Contents

		3.2.3 Frequency Stability and Output Power	
		of a Linear Dye Laser	132
	3.3	Single-Mode Operation of Ring Dye Lasers	133
		3.3.1 Principles of Ring Dye Laser Operation	133
		3.3.2 High-Performance Ring Dye Lasers	134
	3.4	Frequency Doubling	136
4.	Ultra	ashort Pulse Dye Lasers	
		C.V. Shank and E.P. Ippen (With 12 Figures)	139
	4.1	Progress in Ultrashort Pulse Generation with Dye Lasers	139
	4.2	Mode-Locking	140
	4.3	Pulsewidth Determination	141
	4.4	Flashlamp-Pumped Dye Lasers	144
	4.5	Continuously Mode-Locked Dye Lasers	144
	4.6	Active Mode-Locking	145
	4.7	Passive Mode-Locking	146
	4.8	Amplification of Ultrashort Pulses	150
	4.9	Ultrashort Pulse Distributed Feedback Dye Lasers	151
		Traveling Wave Pumped Pulse Dye Laser	152
		Conclusion	153
5.	Strue	cture and Properties of Laser Dyes	
		K.H. Drexhage (With 6 Figures)	155
		Physical Properties of Laser Dyes	155
	5.2	Internal Conversion $S_1 \rightarrow S_0$	157
		5.2.1 Structural Mobility	158
		5.2.2 Hydrogen Vibrations	159
		5.2.3 Other Intramolecular Quenching Processes	161
		5.2.4 Determination of Fluorescence Yields	161
	5.3	Intersystem Crossing $S_1 \rightarrow T_1$	162
		5.3.1 Dependence on $\pi$ -Electron Distribution	162
		5.3.2 Heavy-Atom Substituents	164
		5.3.3 Determination of Triplet Yields	164
	5.4	Light Absorption in the States $S_1$ and $T_1$	165
	5.5	Environmental Effects	166
		5.5.1 Fluorescence Quenching by Charge Transfer	
		Interactions	166
		5.5.2 Quenching by Energy Transfer	167
		5.5.3 External Heavy-Atom Effect	167
		5.5.4 Aggregation of Dye Molecules	167
		5.5.5 Excited State Reactions	169
	5.6	Coumarin Derivatives	169
	-	5.6.1 Absorption and Fluorescence	170
		5.6.2 Acid-Base Equilibria	172
	5.7	Xanthene Dyes	175
		5.7.1 Absorption Spectra	175
		<u>r</u>	- • •

	÷	Contents	IX			
		5.7.2 Fluorescence Properties	179			
	5.8	Related Classes of Efficient Laser Dyes	180			
		5.8.1 Oxazine Dyes	180			
		5.8.2 Carbon-Bridged Dyes	182			
		5.8.3 Naphthofluorescein and Related Dyes	183			
	5.9	Other Efficient Laser Dyes	184			
	5.10	Purity and Chemical Identity of Dyes	185			
	5.11	Concluding Remarks	185			
6.	Lase	r Wavemeters				
	By J	J. Snyder and T.W. Hänsch (With 11 Figures)	201			
	6.1	Wavelength Measurements Based on Reference Spectra	202			
	6.2	Wavelength Measurements Based on Spectrographs	205			
	6.3	Wavelength Measurements Based on Interferometry	206			
		6.3.1 Dynamic Michelson Wavemeters	207			
		6.3.2 Dynamic Fabry-Perot Wavemeters	210			
		6.3.3 Static Michelson Wavemeters	<b>2</b> 11			
		6.3.4 Static Fabry-Perot Wavemeters	212			
		6.3.5 Fizeau Wavemeters	213			
	6.4	Direct Frequency Measurements	216			
	6.5	Conclusion	219			
R	eferen	ces	221			
c.	Subject Index					