

AD-A264 887



1 PAGE

Form Approved  
OMB No 0704-0188Public Release  
gathering a  
collection of  
Davis HighFor per response, including the time for reviewing instructions, searching existing data sources,  
ion of information. Send comments regarding this burden estimate or any other aspect of this  
Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson  
to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503

|                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                             |                                                            |                                      |                                                               |  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|------------------------------------------------------------|--------------------------------------|---------------------------------------------------------------|--|
| 1. AGENCY USE ONLY (Leave blank)                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                             | 2. REPORT DATE<br>17 May 1993                              |                                      | 3. REPORT TYPE AND DATES COVERED<br>Technical Report for FY93 |  |
| 4. TITLE AND SUBTITLE<br><br>EFFICIENT LASER ACTION FROM TWO CW LASER PUMPED<br>PYRROMETHENE-BF <sub>2</sub> COMPLEXES                                                                                                                                                                                                                                                                                                                              |                                                             |                                                            |                                      | 5. FUNDING NUMBERS<br><br>N0001493WX24245<br><br>4131011      |  |
| 6. AUTHOR(S)<br><br>S. Guggenheimer, J. H. Boyer, K. Thangaraj, M. Shah,<br>M.-L. Soong, and T. G. Pavlopoulos                                                                                                                                                                                                                                                                                                                                      |                                                             |                                                            |                                      |                                                               |  |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br><br>NCCOSC RDTE DIV<br>53560 Hull St.<br>San Diego, CA 92152-5001                                                                                                                                                                                                                                                                                                                             |                                                             |                                                            |                                      | 8. PERFORMING ORGANIZATION<br>REPORT NUMBER<br><br>26         |  |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)<br><br>OFFICE OF NAVAL RESEARCH<br>800 North Quincy St.<br>Arlington, VA 22217-5000                                                                                                                                                                                                                                                                                                         |                                                             |                                                            |                                      | 10. SPONSORING/MONITORING<br>AGENCY REPORT NUMBER<br><br>n/a  |  |
| 11. SUPPLEMENTARY NOTES<br><br>Applied Optics, in print                                                                                                                                                                                                                                                                                                                                                                                             |                                                             |                                                            |                                      |                                                               |  |
| 12a. DISTRIBUTION/AVAILABILITY STATEMENT<br><br>unlimited                                                                                                                                                                                                                                                                                                                                                                                           |                                                             |                                                            |                                      | 12b. DISTRIBUTION CODE                                        |  |
| 13. ABSTRACT (Maximum 200 words)<br><br>Two new pyrromethene-BF <sub>2</sub> dyes P-556 and P-567 were tested for cw laser<br>Operation. P-556 demonstrated a significant advance in the 530-620 nm<br>region over commercially dyes currently available, where the best cw dyes<br>in any range have peak efficiencies on the order of 35% and dyes in this<br>range typically less than 25%. The P-556 has a cw efficiency of 45% at<br>the peak. |                                                             |                                                            |                                      |                                                               |  |
| 14. SUBJECT TERMS                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                             |                                                            |                                      | 15. NUMBER OF PAGES                                           |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                             |                                                            |                                      | 16. PRICE CODE<br>n/a                                         |  |
| 17. SECURITY CLASSIFICATION<br>OF REPORT<br>unclassified                                                                                                                                                                                                                                                                                                                                                                                            | 18. SECURITY CLASSIFICATION<br>OF THIS PAGE<br>unclassified | 19. SECURITY CLASSIFICATION<br>OF ABSTRACT<br>unclassified | 20. LIMITATION OF ABSTRACT<br><br>UL |                                                               |  |

DTIC  
ELECTE  
MAY 20 1993  
S E D

93-11225



FORM 1

OFFICE OF NAVAL RESEARCH

CONTRACT: N0001493WX24245

R & D Code 4131011

Technical Report No. 26

|                    |                                           |
|--------------------|-------------------------------------------|
| Accession For      |                                           |
| NTIS               | CRA&I <input checked="" type="checkbox"/> |
| DTIC               | TAB <input type="checkbox"/>              |
| Unannounced        | <input type="checkbox"/>                  |
| Justification      |                                           |
| By                 |                                           |
| Distribution/      |                                           |
| Availability Codes |                                           |
| Dist               | Avail and/or Special                      |
| A-1                |                                           |

EFFICIENT LASER ACTION FROM TWO CW LASER PUMPED

PYRROMETHENE-BF<sub>2</sub> COMPLEXES

by

S.C. Guggenheimer, J. H. Boyer, K. Thangaraj, M. Shah,

M.-L. Soong, and T. G. Pavlopoulos

Prepared for publication in

Applied Optics, in print

NAVAL COMMAND, CONTROL AND OCEAN SURVEILLANCE CENTER

Research, Development, Test and Evaluation Division

17 May 1993

Reproduction in whole, or in part, is permitted for the purpose of the United States Government.

This document has been approved for public release and sale; its distribution is unlimited.

EFFICIENT LASER ACTION FROM TWO CW LASER PUMPED  
PYRROMETHENE-BF<sub>2</sub> COMPLEXES

Steven C. Guggenheimer  
Spectra-Physics Lasers, Applications Laboratory  
Mountain View, California 94042

Joseph. H. Boyer, Kannapan Thangaraj, Mayur Shah,  
and Mou-Ling Soong  
University of New Orleans, Department of Chemistry  
New Orleans, Louisiana 70148

Theodore G. Pavlopoulos  
U.S. Naval Command, Control and Ocean Surveillance Center  
Research, Development, Test and Evaluation Division  
San Diego, California 92152

Two new pyrromethene-BF<sub>2</sub> dyes P-556 and P-567 were tested for cw laser operation. P-556 demonstrated a significant advance in the 530-620 nm region over commercially dyes currently available, where the best cw dyes in any range have peak efficiencies on the order of 35% and dyes in this range typically less than 25%. The P-556 had a cw efficiency of 45% at the peak.

Among lasers, cw dye lasers have found very wide applications as sources of broad tunable radiation. Using different laser dyes, one can cover the near UV to the near IR portion of the spectrum. Besides tunability, cw dye lasers can also provide high power outputs. However, a serious drawback of cw dye lasers, especially where high power outputs are required, is the high cost of the optical pump. In most cases, the pump source is either a cw ion argon or krypton laser [1].

Other than the construction of the cw dye laser itself, output powers critically depend on the power output of the cw pump source and on the laser dyes employed.

Therefore, a rather simple and inexpensive method to increase the power output of all cw dye lasers, may simply involve the replacement of presently used laser dyes with improved laser dyes. We define an improved laser dye as a dye, which besides a high quantum fluorescence yield  $Q_F$ , has lower triplet-triplet absorption over the fluorescence spectral region when compared to conventional laser dyes.

Efficient laser action under flashlamp excitation has been obtained from some pyrromethene- $\text{BF}_2$  ( $\text{P-BF}_2$ ) complexes [2-5]. We wanted to test their suitability for laser action under cw laser excitation.

The  $\text{P-BF}_2$  complexes present a new class of laser dyes, their spectral region of laser action stretches from the green/yellow to the red portion of the spectrum. Like the xanthene (rhodamine) laser dyes, they possess high quantum fluorescence yields  $Q_F$ , which are generally in the 0.80 to 0.95 range.

Significantly, the triplet extinction coefficient  $\tau$  over the laser action spectral region of some of the P-BF<sub>2</sub> complexes is only about one fifth of the rhodamine laser dyes [5].

The dyes disodium 1,3,5,7,8-pentamethylpyrromethene-2,6-disulfonate-BF<sub>2</sub> complex (Exciton P-556) and 1,3,5,7,8-pentamethyl-2,6-diethylpyrromethene-BF<sub>2</sub> complex (Exciton P-567) were previously described [3,4]. These two dyes were tested under cw lasing conditions.

The test equipment employed was a cw argon ion laser (Spectra-Physics model 2080), a linear standing wave dye laser with a 300  $\mu$ m jet (Spectra-Physics model 375B), and a water cooled circulator running at 120 PSI.

The P-556 dye was dissolved in pure ethylene glycol (EG) to concentrations of 0.5 to 2.0 x 10<sup>-3</sup> Mole/L, with 1.5 x 10<sup>-3</sup> Mole/L being the optimum. Because the absorption peak for P-556 is at 500 nm (Fig. 1), we used all-lines (457.9 to 511.5 nm) for excitation. With 5 Watts of pump power, the dye lased from 530 to 624 nm with a peak power of 2.25 Watts at 553 nm (Fig. 2). This represents a 45% efficiency as compared to typical values of <25% for Rhodamine 110 (Rh110) and Coumarin 6 (C6) the standard dyes in this wavelength range. Also, we believe 45% is one of the highest efficiencies of any cw dye reported in a commercial dye laser system. The half life of P-556 was measured to be 350 Watts/Hrs on a one time sample.

The P-567 dye was dissolved in a combination of n-methyl-2-pyrrolidinone (NMP) and propylene glycol monophenyl ether (PPH) to a concentration of 1.5 x 10<sup>-3</sup> Mole/L. With 5 Watt all-lines

pump power, this dye lased from 552 to 608 nm with peak power of 1.8 Watts at 571 nm (Fig. 2). The half life for P-567 was measured to be 460 Watts/Hrs on one sample. However, the half life of this dye may have been limited by the solvent incompatibility used in the circulator.

Rhodamine 6G tested in the same laser produced 1.5 Watts for a 32% cw efficiency. It has a broader tuning range and a much longer half life.

In summary, of the two dyes tested, P-556 was far superior to other dyes, encompassing the dye P-567. Compared with currently available laser dyes like C6 and Rh110, P-556 had greater cw efficiency, was more readily dissolved in EG with no triplet quencher required, and had a half life that was over 3 times longer than C6 or Rh110.

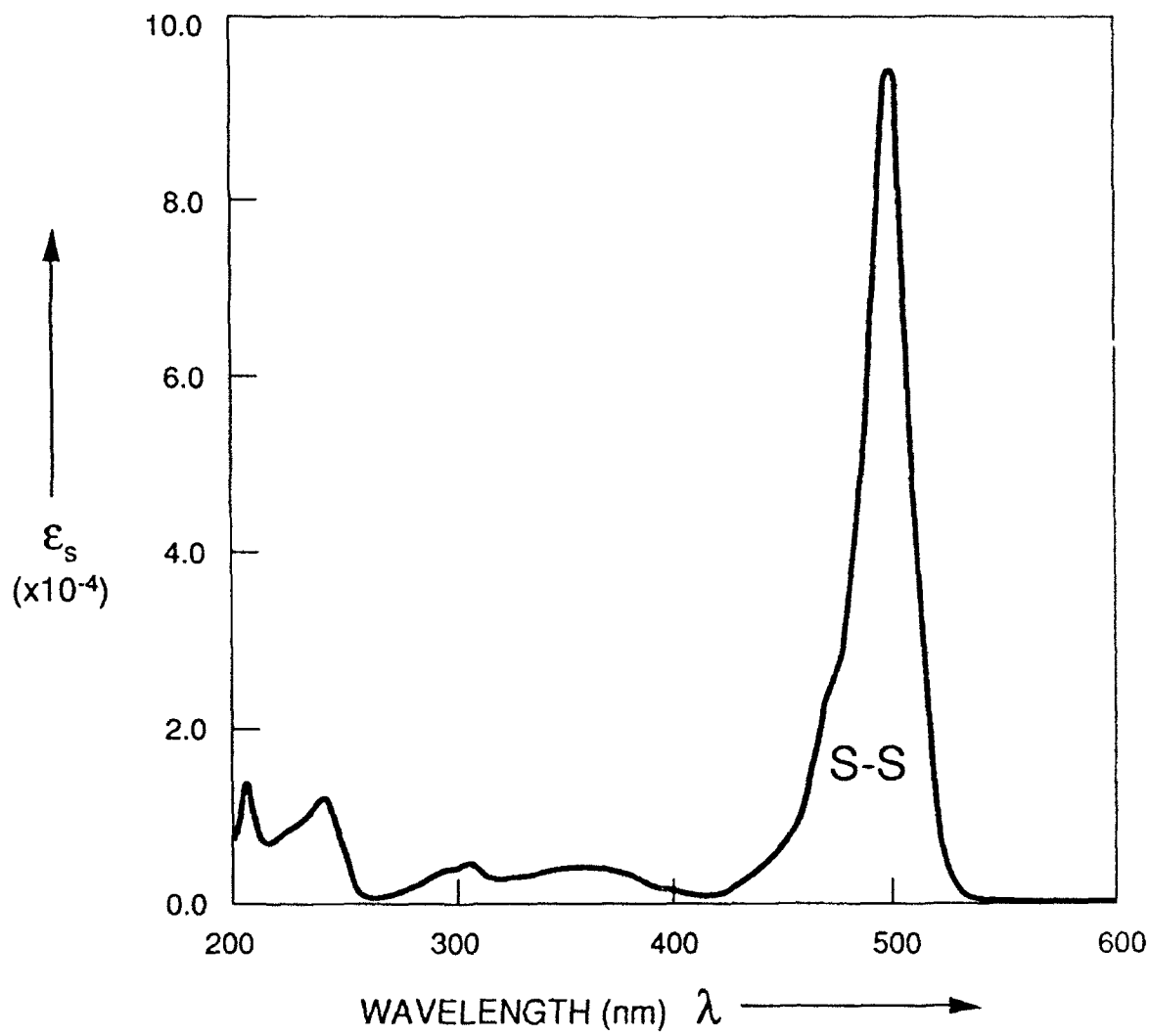
(J.H.B.) wishes to thank the Board of Regents, Louisiana Education Quality Support Fund for support. (T.G.P.) gratefully acknowledges the support provided by the Office of Naval Research.

## References

1. L. Hollberg, "CW dye lasers," in Dye Laser Principles, p. 185-238, Ed. F. J. Duarte and L. W. Hillman, Academic Press New York 1990.
2. T. G. Pavlopoulos, M. Shah, and J. H. Boyer, "Laser action from a tetramethylpyrromethene-BF<sub>2</sub> complex," Appl. Opt. 27, 4998-4999 (1988).
3. T. G. Pavlopoulos, M. Shah, and J. H. Boyer, "Efficient laser action from 1,3,5,7,8-pentamethylpyrromethene-BF<sub>2</sub> complex and its disodium 2,6-disulfonate derivative," Opt. Commun. 70, 425-427 (1989).
4. M. Shah, K. Thangaraj, M.-L. Soong, L. T. Welford, J. H. Boyer, I. R. Politzer and T. G. Pavlopoulos, "Pyrromethene-BF<sub>2</sub> complexes as laser dyes: 1," Heteroatom Chem. 1, 389-399 (1990).
5. T. G. Pavlopoulos, J. H. Boyer, M. Shah, K. Thangaraj, and M.-L. Soong, "Laser action from 2,6,8-position trisubstituted 1,3,5,7-tetramethylpyrromethene-BF<sub>2</sub> complexes: part 1," Appl. Opt. 29, 3885-3886 (1990).

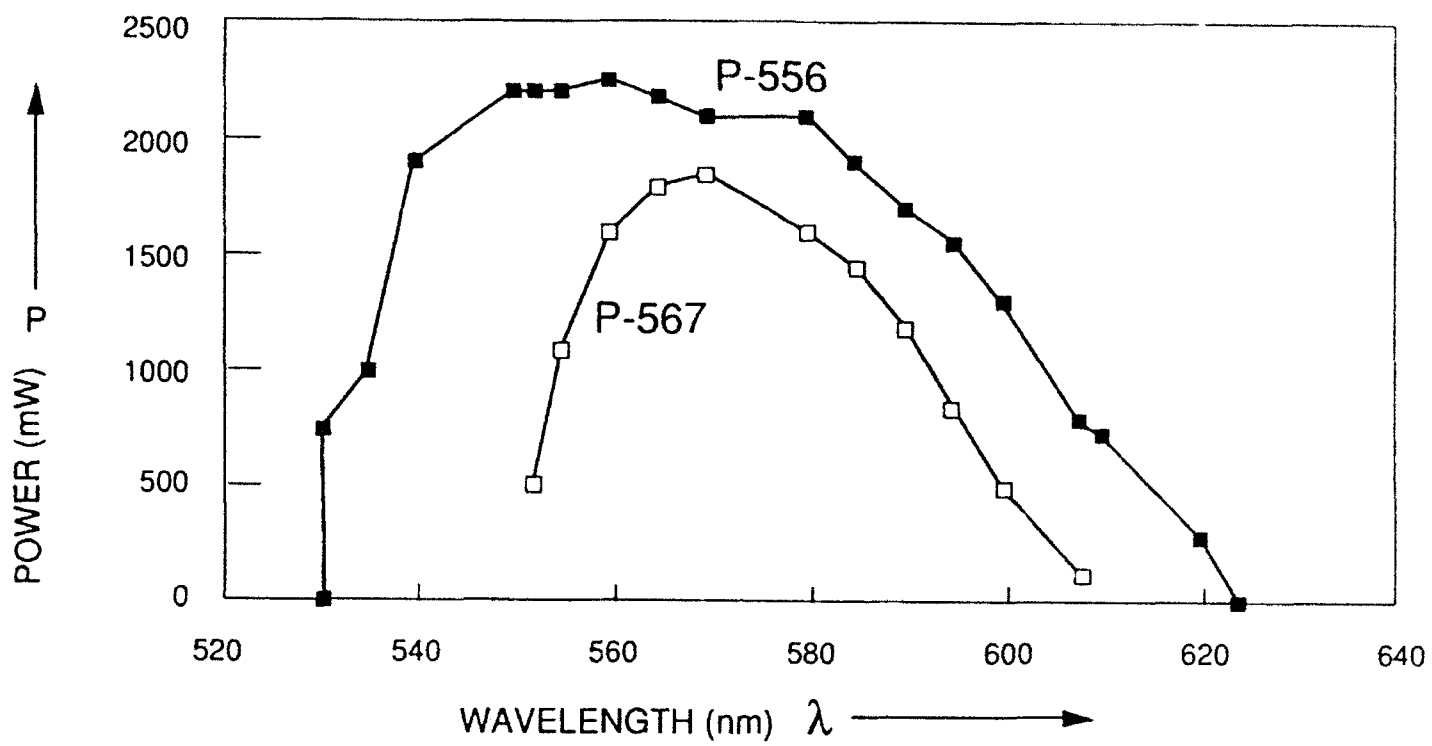
Figure 1

Absorption (S-S) spectrum of the pyrromethene-BF<sub>2</sub> complex  
P-556, dissolved in ethylene glycol.



**Figure 2**

**Tuning curves of the pyrromethene-BF<sub>2</sub> complexes P-556 and P-567.**



TECHNICAL REPORT DISTRIBUTION LIST - GENERAL

Office of Naval Research (2)\*  
Chemistry Division, Code 1113  
800 North Quincy Street  
Arlington, Virginia 22217-5000

Dr. James S. Murday (1)  
Chemistry Division, Code 6100  
Naval Research Laboratory  
Washington, D.C. 20375-5000

Dr. Robert Green, Director (1)  
Chemistry Division, Code 385  
Naval Air Weapons Center  
Weapons Division  
China Lake, CA 93555-6001

Dr. Elek Lindner (1)  
Naval Command, Control and Ocean  
Surveillance Center  
RDT&E Division  
San Diego, CA 92152-5000

Dr. Bernard E. Douda (1)  
Crane Division  
Naval Surface Warfare Center  
Crane, Indiana 47522-5000

Dr. Richard W. Drisko (1)  
Naval Civil Engineering  
Laboratory  
Code L52  
Port Hueneme, CA 93043

Dr. Harold H. Singerman (1)  
Naval Surface Warfare Center  
Carderock Division Detachment  
Annapolis, MD 21402-1198

Dr. Eugene C. Fischer (1)  
Code 2840  
Naval Surface Warfare Center  
Carderock Division Detachment  
Annapolis, MD 21402-1198

Defense Technical Information  
Center (2)  
Building 5, Cameron Station  
Alexandria, VA 22314

\* Number of copies to forward