ILL: 183591694

Call Number: Vol 3 - Vol 48:6 (1964-2009:Feb)

Location:

Maxcost: 10.00IFM

DateReq: 11/7/2017

Date Rec: 11/7/2017

Borrower: OWS

☐ Yes
☐ No
☐ Conditional

OCLC Number: 1481728

Source: ILLiad

LenderString: *OIT,HTM,ORZ,UPP,OPU

Request Type: COPY

Affiliation: OBEGROUP, LVIS

Staff Email: ill@willamette.edu

Billing Notes:

Title: Applied optics.

Uniform Title:

Author:

Edition:

Imprint: Easton, Pa. : Optical Society of America, [©1962?]-©1989.

Article: 'Cox, A. J., and Gary W. Scott.' Short-cavity picosecond dye laser design

Copyright: CCL

Vol: 18 No.: 4 Pages: 532-535 Date: 1979

Dissertation:

Verified: <TN:158904><ODYSSEY:158.104.100.188/ILL> OCLC 0003-6935

Borrowing Notes:

ShipTo: Willamette University Library
900 State Street
Interlibrary Loan
Salem US-OR 97301

E-delivery Addr:

Ship Via: First class/Odyssey

ShipVia: **First class/Odys**

Return To:

Oregon Institute of Technology
Library
3201 Campus Drive
Klamath Falls, OR 97601-8801

Ship To:

Willamette University Library
900 State Street
Interlibrary Loan
Salem US-OR 97301
US

NeedBy: 12/7/2017

Borrower: OWS

ILL: 183591694 Lender: OIT

Req Date: 11/7/2017 OCLC #: 1481728

Patron:

Author:

Title: **Applied optics.**

Article: 'Cox, A. J., and Gary W. Scott.' Short-cavity picosecond dye laser design

Vol.: 18 No.: 4

Date: 1979 Pages: 532-535

Verified: <TN:158904><ODYSSEY:158.104.100.188

Maxcost: 10.00IFM Due Date:

Lending Notes:

Bor Notes:

Short-cavity picosecond dye laser design

A. J. Cox and Gary W. Scott

The design of a short-cavity dye laser is described. The laser produces a 2-psec pulse which is tunable in the range between 400 nm and 470 nm when pumped with an 8-psec 355-nm third-harmonic pulse from a mode-locked Nd^{+3}:glass laser. The laser features a variable calibrated cavity length (10–500 μm), a dye cell through which dye can be continuously flowed, and a compact rugged design. The laser has been incorporated into several picosecond spectroscopy experiments and has proved to be a convenient and useful tunable blue source.

I. Introduction

A short-cavity dye laser has been constructed which produces a narrow linewidth, tunable, blue picosecond pulse when pumped with a single picosecond uv pulse from a mode-locked laser.[1,2] The dye laser features a continuously variable calibrated cavity length, a dye cell through which dye can be flowed for easy dye exchange or cleaning, and a compact rugged design. This paper presents the details of the design and summarizes the laser's operating characteristics.

The short output pulse duration is due to the laser's extremely short cavity photon lifetime.[3] This lifetime results from the short optical cavity lengths, typically in the 50–300-μm range. By pumping with a single uv picosecond pulse (third harmonic of a mode-locked Nd^{+3}:glass laser) and using blue dyes, the laser produces a picosecond pulse in the 400–470-nm range. It is thus a convenient source of tunable blue picosecond pulses for use in spectroscopy experiments.

II. Design

The optical cavity is formed by two closely spaced mirrors which are each coated on 2.54-cm diam, 0.95-cm thick quartz substrates, flat to $\lambda/20$. A schematic diagram of the laser is shown in Fig. 1. The laser is axially pumped by a focused uv pulse at 355 nm. The first surface of mirror 1 ($M1$) has an antireflection V-coat at 355 nm ($AR1$), and the second surface has a special dichroic coating ($R1$) which transmits 85% of the uv pump pulse and reflects more than 95% from 390 nm to 460 nm. The first surface of mirror 2 ($M2$) is coated ($R2$) to reflect 30–50% in the same wavelength region, while its second surface is broadband AR coated ($AR2$).[4]

The mirrors form a flat-flat optical cavity with a length that can be continuously varied in the 0–500-μm range. This cavity is entirely filled with dye solution which can be flowed uniformly between the cavity mirrors. The laser is designed so that the only available path for dye flow is across the thin optical cavity. Efficient dye exchange and cleaning can be accomplished without disassembling or moving the laser.

The dye cell is formed by cementing the two mirrors into aluminum support rings ($AL1$ and $AL2$), which are 7.62 cm in diameter and 1.59 cm thick. The two mirror surfaces protrude approximately 0.05 cm beyond each aluminum ring surface. The $AL1$ ring has a 0.10-cm deep o-ring groove machined around the outside of the mirror. The mirror $M2$ has two flat bevels, each 1.43 cm long, ground off the edges at 45° to the mirror surface on opposite sides of the mirror. When $M2$ is mounted in $AL2$, small spaces are thus left between the aluminum and the beveled mirror edge on the opposite sides of the mirror. Two holes, 0.24 cm in diameter, are drilled at a 45° angle into $AL2$ starting at each of these spaces. These holes open into 0.86-cm diam port holes, perpendicular to the small holes. When the aluminum rings are brought together with the o-ring in place, the o-ring serves as the side wall of the very short optical cavity-dye cell. Dye solutions are introduced into one of the 0.86-cm diam ports by way of Teflon tubing and a Swagelock brass fitting. The dye flows into the port, through the smaller angled hole, to the space between the o-ring and the beveled edge of $M2$, then across the dye cell to the opposite beveled edge-o-ring space, and out through the opposite port.

Two 1.27-cm long 0.32-cm diam alignment pins are press-fitted into holes in the face of an aluminum ring $AL1$ on opposite sides of the mirror. These pins fit

A. J. Cox is with University of Redlands, Physics Department, Redlands, California 92373, and G. W. Scott is with University of California at Riverside, Chemistry Department, Riverside, California 92521.

Received 16 June 1978.
0003-6935/79/040532-04$00.50/0.

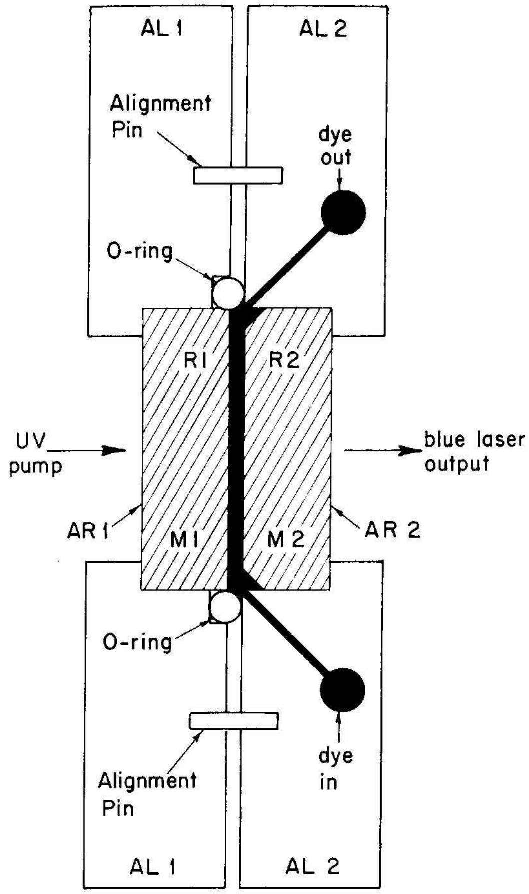

Fig. 1. Schematic cross section of the short-cavity dye laser. Mirrors ($M1$ and $M2$) are cemented with RTV (G.E. Silicone Seal) into concentric aluminum rings ($AL1$ and $AL2$, respectively). The optical cavity is sealed with a viton o-ring, which is held in an o-ring groove in $AL1$ by pressure from $AL2$.

loosely into mating holes in the face of the other aluminum ring $AL2$. The pins maintain approximate alignment of the two mirror surfaces, perpendicular to the common optical axis, as the mirror–ring combination is brought together during assembly. When the o-ring is only slightly compressed during assembly, the mirrors are spaced by approximately 500 μm. The variable short cavity lengths are achieved by pushing the mirror–ring assembly, $M2$-$AL2$, against the fixed assembly, $M1$-$AL1$, and thus compressing the o-ring, as described below.

Figure 2 shows the complete dye laser assembly, and a photograph of the actual device is shown in Fig. 3. As shown in these figures, $AL1$ is bolted to a larger aluminum ring 10.16 cm in diameter and 1.27 cm thick. The larger ring is rigidly attached to a mounting plate and serves as the fixed end plate of the laser main frame. Three 0.95-cm diam 8.45-cm long brass connecting rods are bolted to this end plate and also to a second large ring, 10.16 cm in diameter and 2.29 cm thick, the opposite end plate of the laser main frame. Three micrometer heads are mounted symmetrically in the second end plate. The micrometers are positioned to push the mirror assembly, $M2$-$AL2$, against $M1$-$AL1$. The micrometer heads are Mitutoyu model 51-222 calibrated to 1 μm. The flat carbon-steel tips of the micrometer heads push against 0.64-cm steel ball bearings which are embedded to one half their diameter in the mirror mount ring $AL2$. By adjusting the micrometers the amount of o-ring compression and thus the optical cavity-dye cell length may be varied. Therefore, the o-ring serves both for sealing the sides of the dye cell and also as a preloaded spring against which the micrometers press. Adjustments of individual micrometers are also used to bring the mirrors into parallel alignment.

Support ring $AL2$ is mounted so that the dye ports are horizontal. Dye is introduced through the bottom

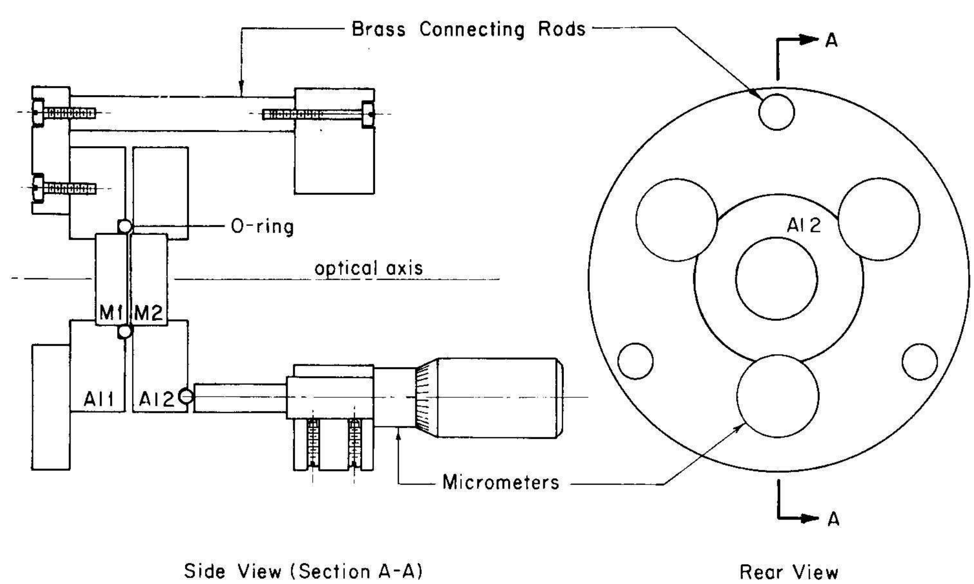

Fig. 2. A schematic drawing of the short cavity dye laser (not to scale) showing the mirror-ring assembly ($M1$-$AL1$ and $M2$-$AL2$), the main frame ends connected by the brass connecting rods, and the micrometers. In the side view shown, laser pulses would travel from left to right.

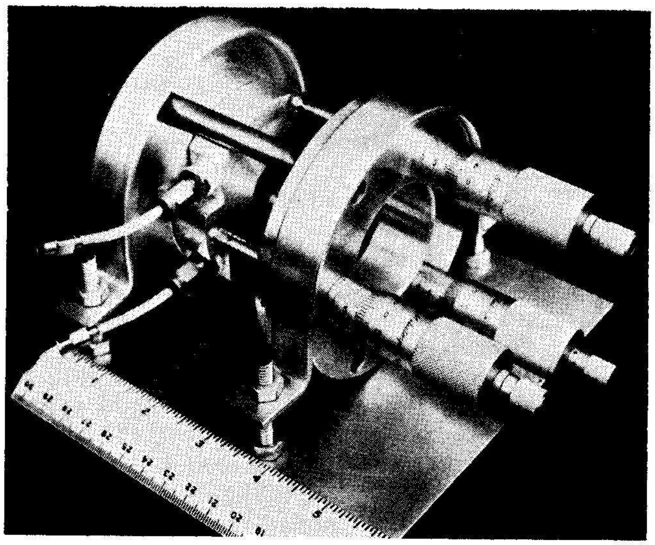

Fig. 3. The dye laser on its mounting plate.

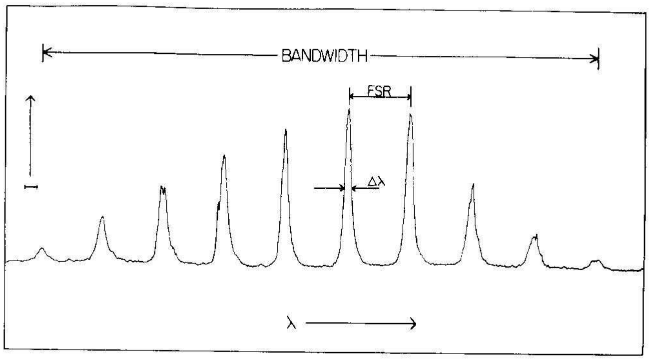

Fig. 4. Spectral output of the short-cavity dye laser. The figure shows a densitometer trace of a film record, obtained using a 1-m spectrograph at 0.020-nm resolution. The dye laser cavity length was 79 μm, and it contained a 3.2×10^{-3}-M Bis-MSB in dioxane solution. For this recording, the free spectral range (FSR) was 0.79 nm, the representative linewidth ($\Delta\lambda$) was 0.09 nm, and the bandwidth was 7.1 nm, centered at 421.9 nm.

port and flows up through the cavity-dye cell, thus eliminating bubbles in the dye. With this design the dye can be continuously pumped through the cell, as might be required for high repetition rate operation. However, only occasional dye exchange is required for low repetition rate operation, and plastic syringes (5 ml each) serve to hold the dye before and after passing through the cell. A 2.54-cm diam Millipore filter holder with filter (FGLP02500) is fitted between the input syringe and the Teflon tubing which leads to the dye inlet port. When changing from one dye to another, the cell is flushed with 20 ml of pure solvent and blown dry with nitrogen or clean air before filling with the new dye solution. Every few months of operation the cell is disassembled, the mirrors are cleaned with ethanol, and the o-ring is replaced if required.

III. Alignment and Calibration

To align the optical cavity, an extended mercury green line lamp[5] is placed near the input mirror $M1$ of the laser. A 36-mm focal length lens in a simple holder is placed against the output mirror $M2$ so that the Fabry-Perot fringes may be easily observed. The alignment is accomplished by adjusting the micrometers, so that the fringes are centered about the optical axis of the laser. The alignment has been found to be mechanically stable for several weeks, but since the above procedure is so simple, it is checked daily.

The length was first calibrated by passing collimated white light through the cavity along the optical axis and into a scanning monochromator.[6] The monochromator was scanned, and a photomultiplier, electrometer, and strip chart recorder were used to record the axial transmission modes of the optical cavity. The axial modes are separated by the free spectral range $\Delta\lambda$ given by

$$\Delta\lambda = \lambda^2/(2nd), \tag{1}$$

where d is the cavity length and n the refractive index of the intracavity medium. Measurement of the mode spacing thus yields accurate values of d. Once the micrometers were calibrated, the cavity could be reset to any length between 10 μm and 500 μm with a reproducibility of ~1 μm simply by using the micrometer calibration. When the laser is to be operated at a specific cavity length, the micrometers are set by using the calibrated values, and alignment is checked and adjusted using two of the micrometers, while viewing the interference fringes. The laser calibration is verified by photographically recording the multimode laser output with a spectrograph.

Table I. Spectral Features of the Short Cavity Dye Laser Output for the Dyes Investigated

Dye	Solvent	Concentration (moles/liter)	Gain center (nm)	Approximate gain bandwidth (nm)
α-NPO	Ethanol	6.4×10^{-3}	408	23
Bis-MSB	Dioxane	3.5×10^{-3}	423	9
Coumarin 120	Ethanol	8.7×10^{-3}	440	20
Coumarin 1	Ethanol	2.9×10^{-2}	455	20
Coumarin 102	Ethanol	2.7×10^{-2}	462	15

IV. Operation and Performance

The laser is pumped by a single third harmonic (355-nm) pulse from a mode-locked Nd^{+3}:glass laser, which is focused into the dye cavity to a spot size of a few hundred microns by a 15.24-cm focal length lens. The dye concentration is chosen to provide an absorbance between 1 and 2 at 355 nm. The divergent laser output is collimated with a second lens. The output consists of several axial modes within the dye's gain profile, which is typically 7–20 nm wide depending on the dye. The individual modes are approximately 0.1 nm wide, and little modewidth variation is observed between operation at a cavity length of 79 and at 305 μm. Figure 4 shows a densitometer trace of a spectrographic record of a typical multimode laser output pulse.

Tuning can be accomplished in several ways. The dye may be chosen so that its gain bandwidth overlaps the desired wavelength. Table I shows several dyes, solvents, concentrations, and their gain characteristics which have been used in the laser. The wavelengths and separation of axial modes may be changed by varying the cavity length. The axial modes can be continuously fine tuned by tilting the laser axis relative to the pump beam axis, while keeping the pump focusing and colimating lenses fixed. Each mode may be tuned over several free spectral ranges by varying the pumping angle. For example, by tilting the laser through angles between 4.5° and 7.5°, a particular laser mode was tuned from 456.4 nm to 454.7 nm.[2]

An output pulse from this dye laser contains about 40 μJ of energy for a uv input pulse energy of about 0.7 mJ, corresponding to 6% energy conversion efficiency. The pump pulse duration used in testing the laser was 8 ± 3 psec. The resulting dye laser pulse was 2 ± 2 psec for a cavity length of 79 μm using the dye Bis-MSB in *p*-dioxane solution. Pulse duration measurements were made as described elsewhere.[7,8]

The cavity photon lifetime for the short cavity dye laser is given by

$$t_c = (nd)/[(1 - R)c], \tag{2}$$

where n is the refractive index of the dye solution, d is the cavity length, R is the geometric mean of the mirror reflectivities, and c is the speed of light. At a length of 79 μm, t_c is 0.8 psec. A rate equation treatment of cavity transient pulse formation predicts a dye laser pulse length of ~1.6 psec under these operating conditions and when pumped at 10 times threshold.[2] These predictions are in close agreement with the observed performance.

V. Conclusion

In conclusion, the design of a short cavity dye laser which produces a 2-psec 40-μJ pulse in the 400–470-nm range has been described. The output spectrum consists of from one to many axial modes each about 0.1 nm in width, each of which may be tuned within the dye's gain bandwidth. The compact mechanically stable design and the useful temporal and spectral characteristics of this laser make it a practical new light source for picosecond experiments. It has been used as a probe source in several picosecond kinetics experiments in our laboratory.[7,8] Other workers have reported similar short-cavity dye lasers that operate in the red using rhodamine B and rhodamine 6G dyes.[9,10] Compared to continuum generation, as a picosecond probe source, the short-cavity dye laser has more easily characterized temporal properties, much higher conversion efficiency, and more energy within the narrow bandwidths of its modes. The narrow bandwidth of this laser makes it particularly suitable for use in picosecond kinetics studies of gas phase and low temperature crystal samples.

The authors thank Larry D. Talley for his assistance with the dye laser performance experiments and John Pollock, Jr., who helped with machining of the dye laser components.

This research was supported by the National Science Foundation, the Research Corporation, and the Committee on Research of the University of California, Riverside.

References

1. A. J. Cox, G. W. Scott, and L. D. Talley, Appl. Phys. Lett. **31**, 389 (1977).
2. G. W. Scott and A. J. Cox, *Advances in Laser Spectroscopy I*, A. H. Zewail, Ed., Proc. Soc. Photo-Opt. Instrum. Eng., (1977), Vol. 113, p. 25.
3. D. Roess, J. Appl. Phys. **37**, 2004 (1966).
4. These mirrors were obtained from CVI Laser Corporation, Albuquerque, N. Mex.
5. Unilamp, Midwest Scientific Co., Mission, Kan.
6. Hilger-Engis model 1000.
7. G. W. Scott and L. D. Talley, Chem. Phys. Lett. **52**, 431 (1977).
8. G. W. Scott, L. D. Talley, and A. J. Cox, in *Advances in Laser Chemistry*, A. H. Zewail, Ed., Springer Series in Chemical Physics (Springer, Berlin, 1978), p. 187.
9. B. Fan and T. K. Gustafson, Appl. Phys. Lett. **28**, 202 (1976).
10. J. A. Duncanson, Jr., and W. S. Struve, J. Appl. Phys. in press.