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# PRELIMINARY INVESTIGATION OF THE EFFECTS OF DYE CONCENTRATION ON THE OUTPUT OF A MULTIWAVELENGTH DYE LASER

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16. Abstract

The effects of dye concentration on the output wavelength and energy of a multiwavelength dye laser have been investigated. The dyes tested were Coumarin 2 in methyl alcohol and Rhodomine 6G, Acridine Red, and 7-diethylamino-4-methyl Coumarin (7DA 4MC) in ethyl alcohol.

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# PRELIMINARY INVESTIGATION OF THE EFFECTS OF DYE CONCENTRATION ON THE OUTPUT OF A MULTIWAVELENGTH DYE LASER

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## INTRODUCTION

A multiwavelength dye laser has been developed at the Langley Research Center.[1] This laser is incorporated in a lidar system applied to the remote sensing of chlorophyll a in phytoplankton. As is generally the case with a lidar system, the data processing is sensitive to the output energy and wavelength of the laser, the absorption and fluorescence cross sections of the subject, and the attenuation of the media. This report deals with the output energy and wavelength of the laser as it is affected by dye concentration.

## EQUIPMENT AND PROCEDURE

### Laser

The laser itself has a laser head which consists of four elliptical cylinders spaced 90° apart with a common focal axis. Along the common axis is a water-jacketed linear flashlamp which energizes the dyes in cuvettes located at the other focus of each of the cylinders. This results in four dye lasers with a common energy source. When in use, the lasing of three of these dyes is prevented by placing a shutter between the dye cuvettes and the output mirrors. By rotating the shutter, this allows the selection of any of the four dye lasers.

To insure a uniform, cool working temperature, each dye was circulated by means of a mechanical gear pump through the laser head, a reservoir, and a bubble trap. The reservoir and the bubble trap for each of the dye systems was immersed in a cooling bath and kept at a temperature of 21° C by means of a thermocouple controlled refrigerator. The water used in the cooling bath was also circulated around the flashlamp as a coolant. This cooling procedure gave the added benefit of filtering most of the ultraviolet from the flashlamp which generally contributes little to the output power, but which greatly reduces the life of the dyes. A schematic of the dye circulatory system is shown in figure 1a.

For the purposes of monitoring the dye conditions and adding dye, the line between the drain and fill valves was closed and the system shown schematically in figure 1b was added.

The dye temperature proved to be stable at 21° $\pm$ 1° C and the designed pump flow rate was typically 0.95 liters/minute.

All laser hardware materials were quartz, stainless steel, or teflon. Each of the four laser systems had primary mirrors which had a reflectance of 99 percent and the output mirrors were 50 percent, 95 percent, 70 percent, and 70 percent reflective for the individual lasers, respectively. These values of mirror reflectance were measured by the mirror manufacturer and furnished to NASA with the mirrors.

The dyes chosen for study were Rhodamine 6G, Rhodamine 110, Acridine Red, and 7-diethylamino-4-methyl Coumarin (7DA4MC) in ethyl alcohol and Coumarin 2 in methyl alcohol.

In order to obtain accurate dye concentrations, the appropriate laser system was first flushed four times with pure alcohol and the monitoring system shown in figure 1b was added. Then, 750 ml of pure alcohol was placed in the system and the desired concentration obtained by injecting concentrated dye through the injection system.

## Wavelength Measurement

The laser wavelengths were obtained by photographic analysis of the output of a spectrograph. Initially, a 1.0 meter spectrograph was used to measure the dye wavelength but because of more pressing research, it was necessary to change to a 0.5 meter spectrograph for later measurements. A 1.0 meter spectrograph with 1200 grooves/mm diffraction grating was employed to measure the wavelength of Rhodamine 6G and Coumarin 2 dyes. For Acridine Red and 7-diethylamine-4-methyl Coumarin (7DA4MC) dyes, a 0.5 meter spectrograph with 1200 grooves/mm diffraction grating was used.

## Energy Measurement and Calibration

At each step of concentration, the wavelength was measured and then a photodiode with neutral density filters was raised into position on a lab jack to measure the laser energy. By mounting this sensor on a jack, the effects of repeated repositioning were minimized. A PIN-10 CAL photodiode with a ninety volt bias and a fifty ohm terminator was used as the sensor. For calibration purposes, two ballistic thermopiles, 222 microvolts/joule and 486 volts/joule sensitivities, were also used to measure the output of the Rhodamine 6G laser. This was necessary as only the Rhodamine 6G laser was energetic enough to be measured with a thermopile. The thermopiles were monitored with a strip-chart recorder while an oscilloscope and camera were used for the photodiode.

# RESULTS AND DISCUSSION

Laser wavelength as a function of concentration is shown in figure 2. Neither of the Coumarin dyes showed any wavelength dependence on concentration over the range investigated. The Rhodamine 6G and Acridine Red dyes showed mutually similar wavelength dependences on concentration. The wavelength of each increased rapidly near the laser threshold. As the concentration increased, rate of change of the wavelength decreased and became linear.

Energy output as a function of concentration is shown in figure 3. Unlike the wavelength curves, all four of the energy curves appear rather similar. The only notable exception to this is the sudden drop in the 7DA4MC Coumarin curve at 6 X $10^{-4}$ molar. This is thought to have been caused by a failure in the photodiode biasing batteries rather than as an actual abnormality in the curve. All of the energies peaked between 3 X $10^{-4}$ molar and 5 X $10^{-4}$ molar and all have a relatively flat region around the peak. Thus it would appear that minor variations in concentration near the peak will not greatly affect the laser output and that small variations in concentration when preparing the dye solutions for the multiwavelength dye laser system could be tolerated. The variations of energy and laser wavelength near the peak of the four dyes tested are summarized in table I.

## CONCLUDING REMARKS

The effects of dye concentration on the output wavelength and energy of a multiwavelength dye laser have been investigated. The dyes tested were Coumarin 2 in methyl alcohol and Rhodamine 6G, Acridine Red, and 7-diethylamino-4-methyl Coumarin (7DA4MC) in ethyl alcohol. Wavelength measurements were made using 0.5 meter and 1.0 meter spectrographs, with 1200 grooves/millimeter diffraction gratings. Energy determination and calibration were done with a PIN-10 CAL photodiode and ballistic thermopiles.

The two Coumarin dyes showed no wavelength dependence on concentration while the Rhodamine 6G and Acridine Red dyes showed mutually similar curves with their wavelengths increasing with increasing concentration.

All four dyes showed a peak in output energy between $3 \times 10^{-4}$ molar and $5 \times 10^{-4}$ molar followed by a decrease in energy.

All four of the dyes showed little variation in output energy or wavelength near the concentration for peak energy. Hence, it would appear that small variations in concentration when preparing the dye solutions for the multi-wavelength dye laser system could be tolerated.

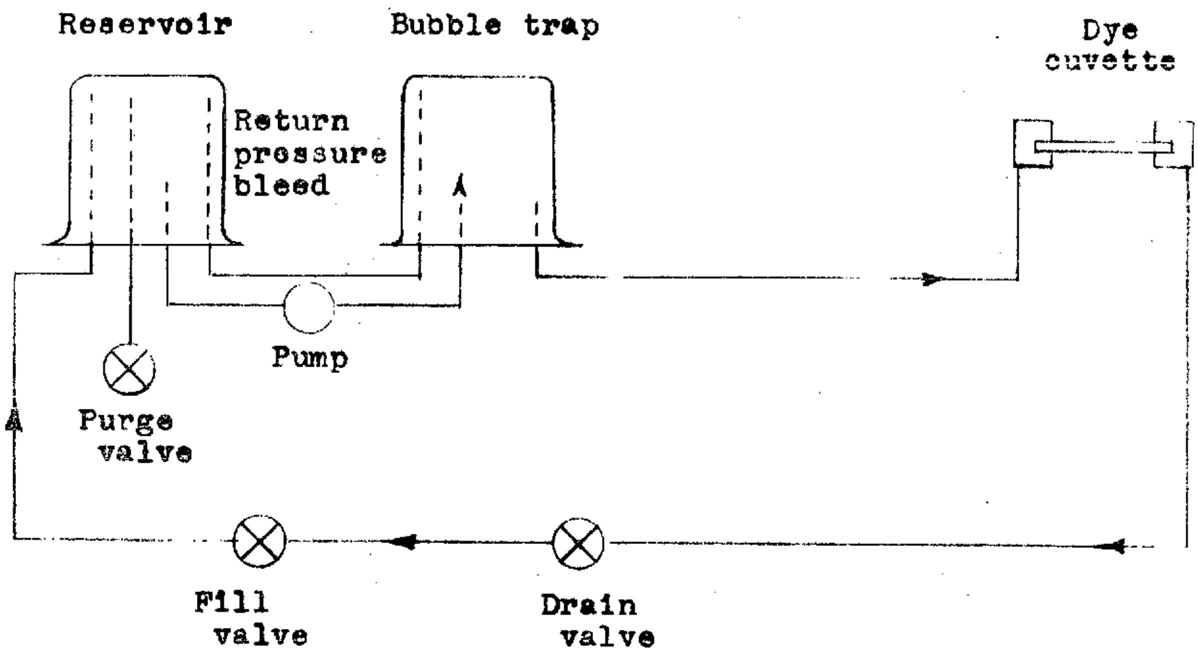
## REFERENCES

1. Mumola, P. B.; Jarrett, O., Jr.; and Brown, C. A., Jr.: Multiwavelength Lidar for Remote Sensing of Chlorophyll a in Phytoplankton, presented at the Second Environmental Quality Sensor Conference; Las Vegas, Nevada; October 1973.

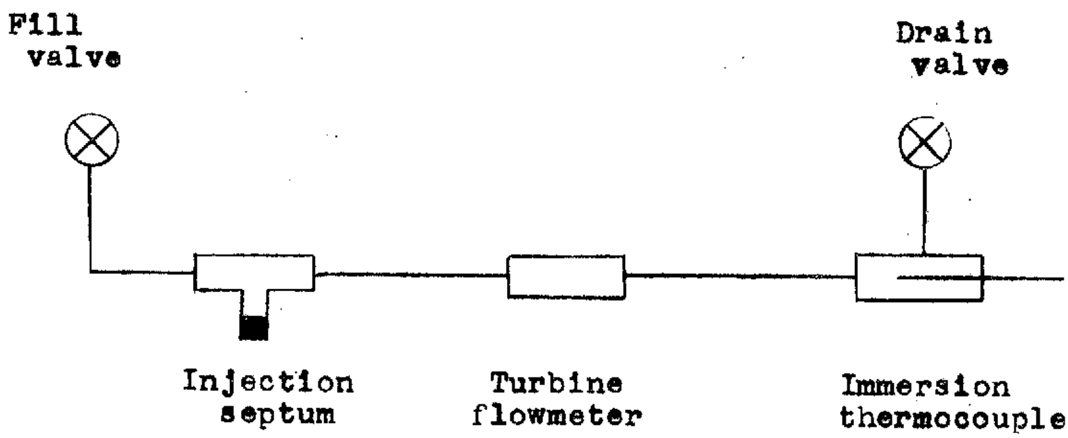
TABLE I

VARIATION OF ENERGY & OUTPUT WAVELENGTH NEAR PEAK LASER ENERGY

| Dye | Maximum Energy (Milli Joules) | Dye Concentration at Maximum Energy $X\ 10^{-4}$ M | Wavelength at Maximum Energy Å | % Decrease in Energy per $10^{-4}$ M | Wavelength Change per $10^{-4}$ M (Å/M) |
|---|---|---|---|---|---|
| oumarin 2 | 0.37 | 3.7 | 4532 | 13.89 | 0 |
| oumarin 7 DA4MC | 1.48 | 4.2 | 4540 | 22.25 | 0 |
| hodamine 6G | 11.1 | 3.1 | 5938 | 15.38 | 24 |
| cridine Red | 0.59 | 4.7 | 6189 | 8.47 | 4 |




(a) Schematic of circulatory system for one dye of the multi-wavelength dye laser system.




(b) Schematic for monitoring and injection add-on for experimental setup.

Figure 1. - Schematic of circulatory system and monitoring and injection of add-on used in the laboratory.

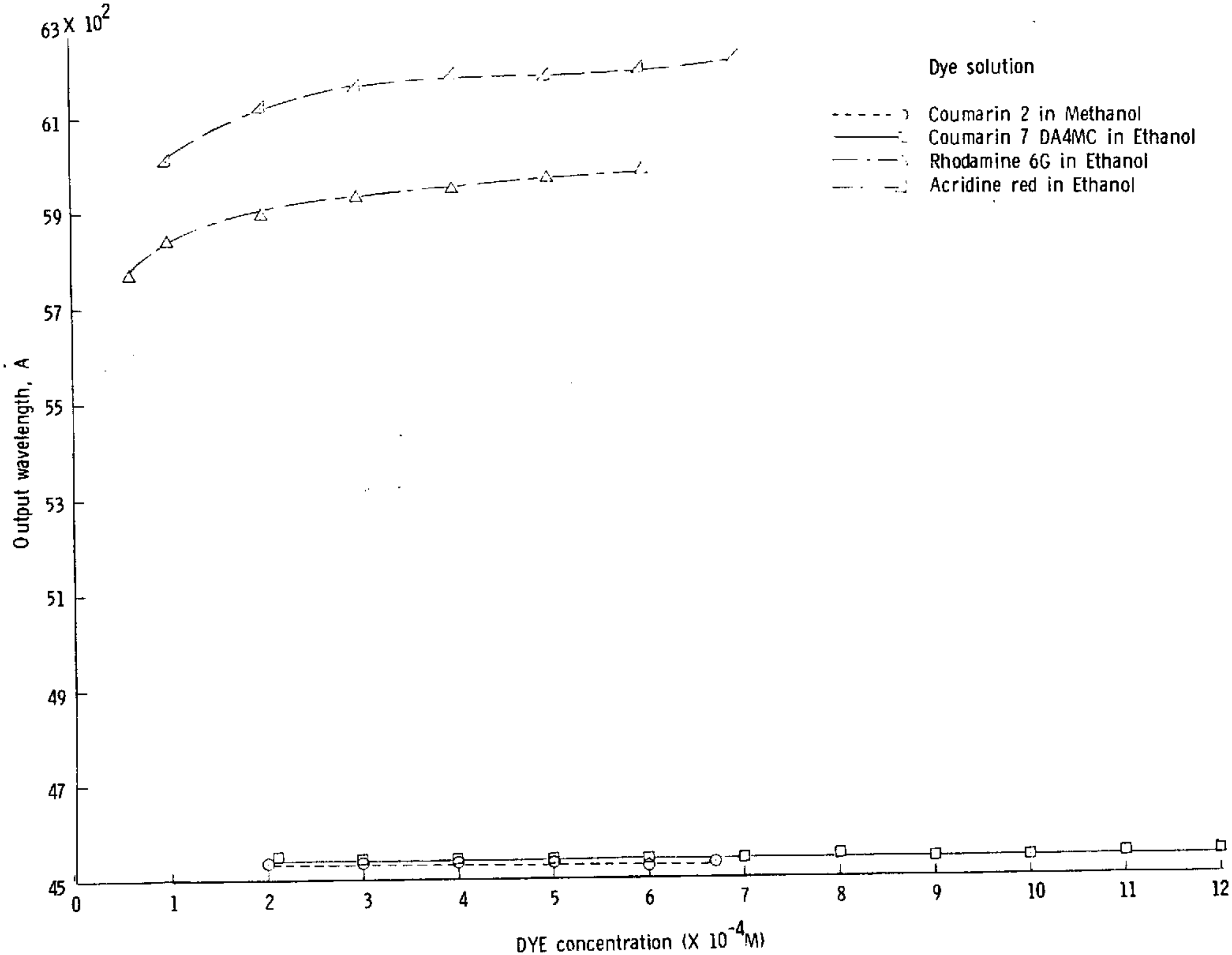



Figure 2.- Variation of output wavelength of laser with dye concentration for different dyes.

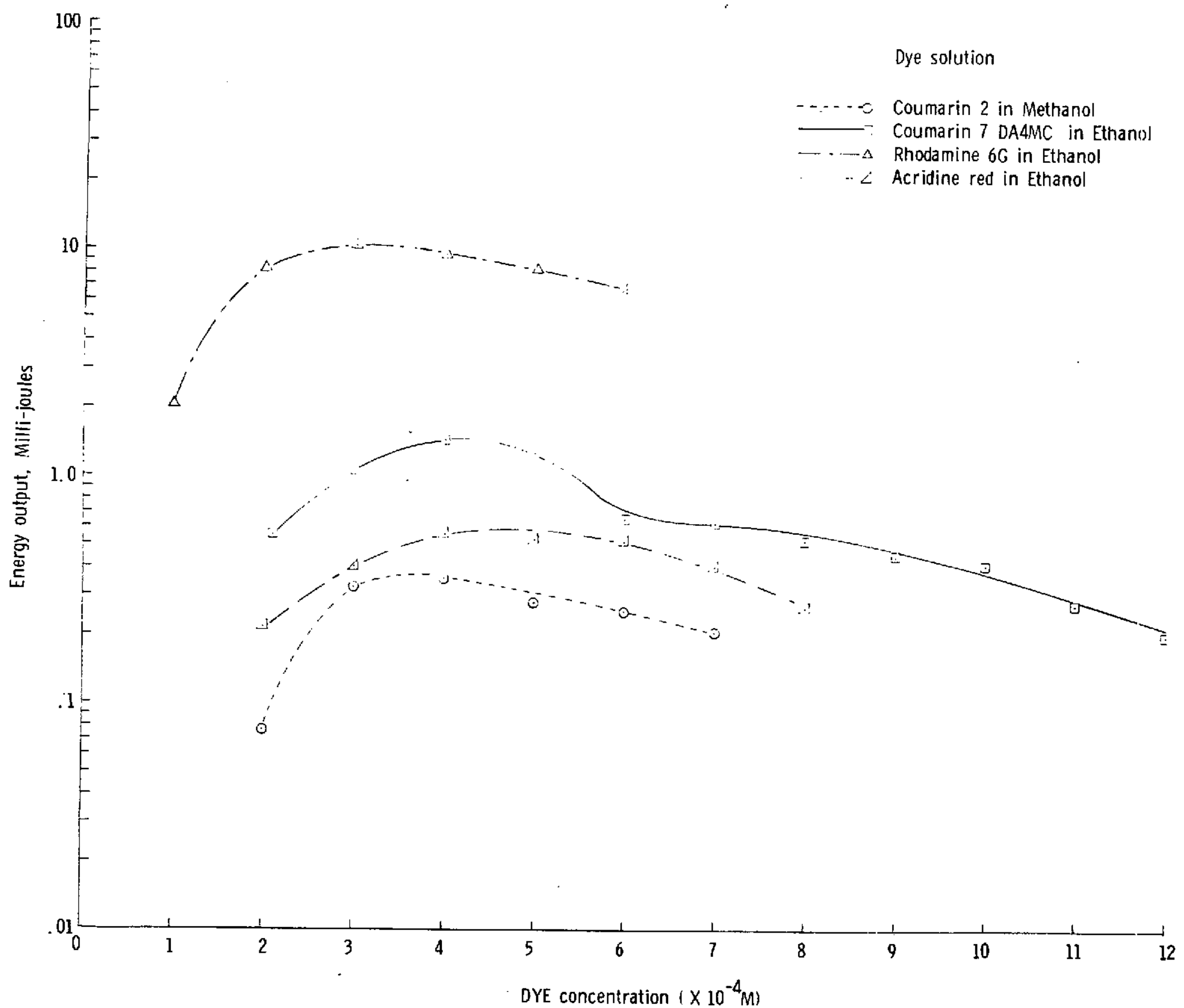



Figure 3.- Variation of energy output of laser with dye concentration for different dyes.