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SIMULTANEOUS THREE-WAVELENGTH DYE MIXTURE LASER TUNABLE IN THREE-PRIMARY-COLOR REGION FOR LASER SENSING

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A three-primary-color laser or a white-light laser has many advantages in many scientific and technical area such as laser sensing, color detection and evaluation, display, photograph, and so on. In this report, we describe a dye mixture laser capable of simultaneous three-wavelength tuning in the three-primary-color region.

Three kinds of dye were mixed in one dye cell; Coumarin 460 (C460) for blue output, Disodium Fluorescein (DF) for green output, and Rhodamine 640 (R640) for red output. They were selected for our experimental need to use the dye mixture (C460/DF/R640) laser as a light source for multiwavelength lidar system. The output wavelength of the C460 dye coincides with the absorption wavelength of NO_2 molecule that is well known as an atmospheric pollutant gas. That of the DF dye is very close to the wavelength of a second-harmonic generation YAG laser, and that of the R640 dye is also close to the wavelength of a Ruby laser. These two lasers are widely used for lidar and laser sensing. If the C460/DF/R640 dye mixture laser can be realized, it is possible to detect simultaneously various molecules in the atmosphere such as NO_2, aerosols, and others with only one laser system.

The suitable concentraiton of each dye for the mix was estimated in consideration of our former experimental results and theoretical discussions[1)2)]. The C460/DF/R640 dye mixture was pumped by a Nd:YAG laser with a wavelength of 355nm, a pulse energy of 5mJ, a pulse width of 7ns, and a repetition rate of 10Hz. Three-wavelength output were detected by a CCD sensor mounted on a grating monochromator and also photographed with a camera. The wavelength tuning was done by using an interferance filter inserted in a cavity. The cavity configuration of this filter tuning method is very simple and it is easy to use.

At first, the tuning range of the C460/DF/R640 dye mixture laser was investigated. The schematic diagram of the cavity are shown in Fig.1. The Linear Variable Filter (LVF: Optical Coating Laboratory, Inc.) was used as a tuning element. Its coating thickness was varied on the LVF to pass different wavelengths and the coating was thinner for shorter wavelengths and thicker for longer wavelengths[3)]. The tuning was done by moving the LVF perpendicularilly to the optical axis. Figure 2 shows the tuning spectra (one wavelength). The upper three broad spectra are non-tuning spectra without the LVF. Intensities of each spectram of the broad band output were controlled by adjusting the concentration to be almost the same before the tuning experiment. The intensities of the tuning output in the blue region were larger by several times of the magnitude than that of non-tuning output, and the tuning range in the blue region extended to longer wavelength. Those in the green region showed the same tendency as blue ones, but there were not so large differences between the tuning spectra and the non-tuning ones. In the red region, tuning outputs obtained at longer wavelength region and the intensities were smaller than its non-tuning spectra. It should be added that R640 mixed concentration of 6.1×10^{-5}mol/litter was lower than the threshold concentration of R640 alone.

The configuration of the cavity was extremely changed to be able to get independent and simultaneous three-wavelength tuning output in the three-primary-color region. It is shown in Fig. 3. A conventional fixed wavelength bandpass interferance filter (IF) was inserted into the cavity as a tuning element. It is known that the center wavalength of the IF shifts to shorter one with tilting an incident angle. Although the tuning range is not so wide, it seemed to be enough to our purpose. The laser beam from dye cell was separated into three passes with three dichroic mirrors. Three independent cavities with each IF are constructed. One example of the tuning spectra is shown in Fig.4. It shows the tuning was done in the green region with tilting the angle of the IF2. The wavelengths in blue and red regions were tuned at certain wavelengths set with fixed angles of IF1 and IF3. With increasing the tilt angle, the green wavelength shifted to shorter one depending on the IF2 filter characteristics. It seemed that there were some interactions among the three wavelengths. Namely, the intensity of the blue output decreased when the green wavelength was close to the blue one with inceasing its intensity, and also intensity of red output increased with increasing of the intensity of green output. Other different interactions/phenomena were observed when blue or red wavelength tuning was done. It should seem that investigations of energy transfer mechanism among the three dyes is important to understand the performance characteristics of the dye mixture laser.

It was shown that the simultaneous tunable three-praimary-color laser output could be obtained by using the C460/DF/R640 dye mixture with the filter tuning method, and the spectral characteristics of the laser were investigated. The unique characteristics of the dye mixture laser, the short-duration pulse on a nano-second time scale, the abundance of laser dyes to cover wide spectral region, and above all their simplicity of operation, just mixing laser dyes, make the dye mixture laser potential candidates for wide and varied applications including laser sensing. Our future plan is to develop an amplification system to get enough energy for practical use.

References

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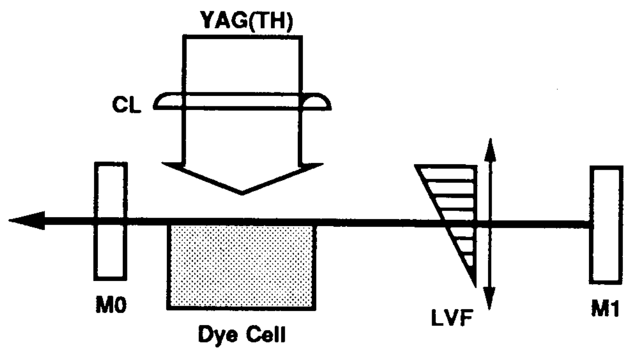
2) Y. Saito et al., Applied Optics 31, (1992), pp.4298-4304.
3) R. I. Seddon et al., Laser Focus World, September, (1991).



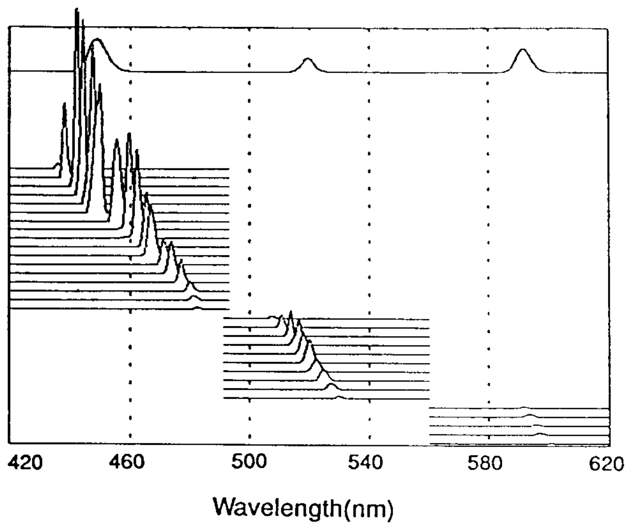
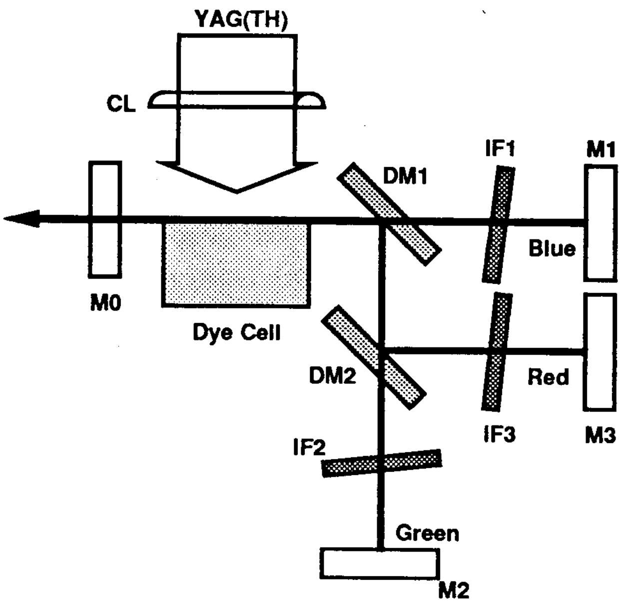


Fig. 1 Schematic diagram of the cavity for dye mixture laser tunable in the three-primary-color region. CL; Cylindrical Lens, M; Mirror, LVF; Linear Variable Filter.

Fig. 2 Tuning spectra of the C460 ($5.0x10^{-3}$ mol/litter)/DF ($1.5x10^{-4}$mol/l)/R640 ($6.1x10^{-5}$mol/l) dye mixture laser.



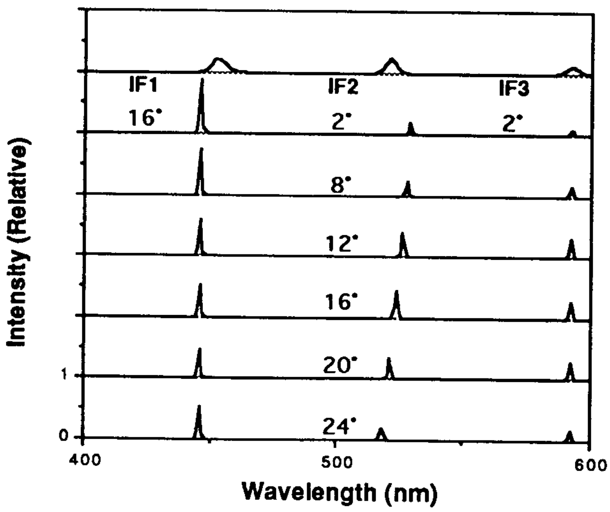


Fig. 3 Schematic diagram of the cavity for simultaneous tunable three-wavelength dye mixture laser. CL; Cylindrical Lens, M; Mirror, DM; Dicroic Mirror, IF; Interferance Filter.

Fig. 4 Simultaneous three-wavelength tuning spectra of the C460 ($5.1x10^{-3}$mol/l)/DF ($2.2x10^{-4}$mol/l)/R640 ($9.8x10^{-5}$mol/l) dye mixture laser.