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Mode-locking in a two-component, tuned dye laser

The generation of a two-component, mode-locked dye laser tuned by the saturable absorber concentration was investigated. The two-component mixtures: rhodamine 6G:rhodamine B, and rhodamine 6G:uranin were examined. The application of two-component active media improved mode-locking as compared with pure components, and extended the spectral region of applicability of one particular saturable absorber (DODCI). An action as a generator of "gating" pulses for the action of the less effective dye is attributed to the more effective component of the composition.

The broad spectral bandwidth, generated by a dye laser, reciprocal to the pulse-width, predestinates the dye laser to the action in the mode-locking system. This effect was investigated both for flash-lamp pumped [1–3] and for cw dye lasers [4–6]. An additional advantage of a dye laser is the possibility of tuning by a dispersive element introduced into the laser cavity. In a particular case the saturable absorber used for mode-locking may act as the dispersive element, and tuning can be performed by the change of the saturable absorber concentration. This method has been recently used for tuning a mono-component mode-locked dye laser [7].

A dye laser can be additionally tuned by the use of two-component active media [8]. Out test with two-component active media did show an ability of tuning a dye laser by selecting the percental rate of two dyes in the region between generated wavelengths of pure components. Generated bands for some different mixtures of rhodamine 6G: rhodamine B, and rhodamine 6G: uranin solutions are presented in fig. 1. The introduction of the saturable absorber as the dispersive element allowed to expect that the laser can be additionally tuned by the saturable absorber concentration.

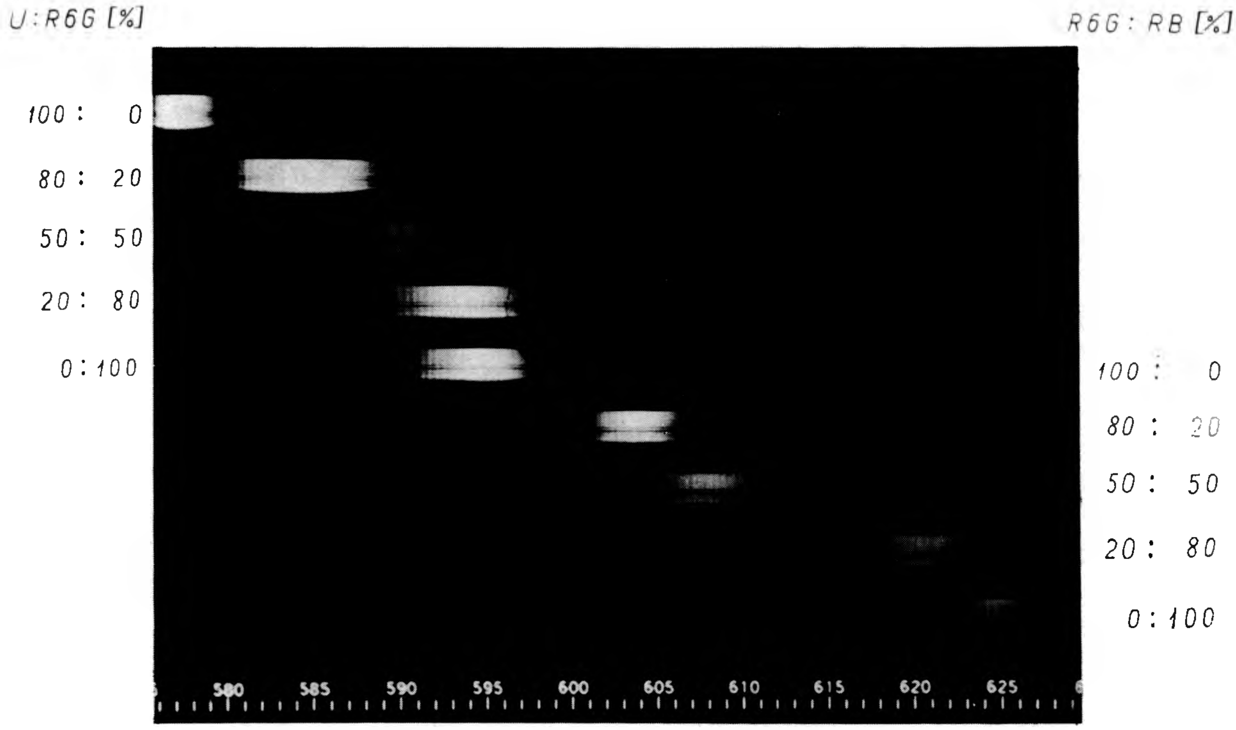

Fig. 1. Bands generated by some rhodamine 6G:uranin and rhodamine 6G:rhodamine B compositions

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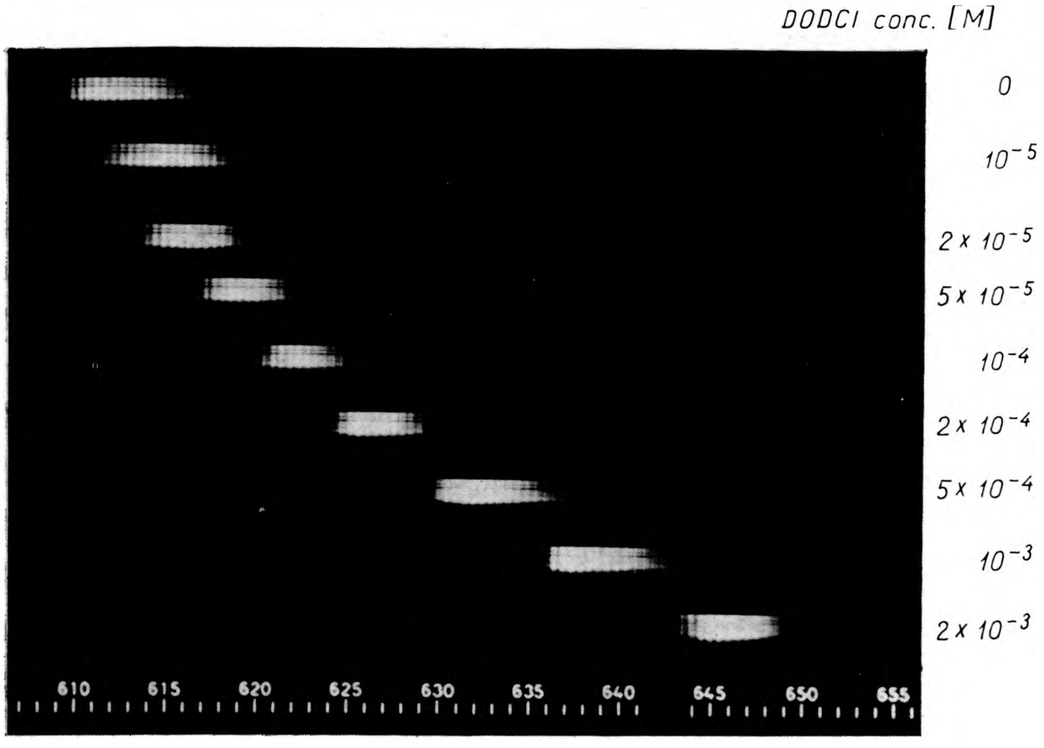

Fig. 2. The shift of bands generated by the rhodamine 6G:rhodamine B (1:1 ratio) composition increasing with the increase of DODCI concentration

The investigations were carried out by the use of a dye laser pumped with two linear flash-lamps supplied with an energy up to 150 J. A 35 cm long cavity was terminated by two flat broad-band dielectric mirrors with the 100% and 95% reflectivities. A 1 mm thick cell with the saturable absorber was placed close to the output mirror. As active media mixtures of 2×10^{-4} M methanolic solutions of rhodamine 6G (R6G): rhodamine B (RB), and rhodamine 6G: uranin (U) with an additive of 10^{-2} M cyclooctatetraene was used. The ratio of the R6G: RB and R6G: U mixtures was fixed as 1:1. Ethanolic solutions of DODCI were used as the saturable absorber. The concentration of DODCI was varied from 10^{-5} M to 2×10^{-3} M. The laser emission spectra were recorded with a Zeiss PGS 2 grating spectrograph. Mode-locked laser pulses were detected by a Motorola MRD 500 photodiode and a Schlumberger OCT 559B oscilloscope. The oscilloscope traces were recorded by the use of a 1.5/75 mm lens on a 27 DIN photographic film.

The free running laser with the R6G:RB composition generated a band centred at about 612.5 nm. The insertion of the saturable absorber into the cavity caused a shift of the generated band towards the long-wave region. This shift increased with the increase of the concentration of the saturable absorber, as illustrated in fig. 2. The laser pulses were fully mode-locked (100% modulated), however for the pure RB solution under these same conditions they were only partly mode-locked. Full mode-locking occurred only in the pure R6G solution [7]. Typical oscilloscope traces with fully and partly mode-locked pulses are illustrated in fig. 3. At higher than 5×10^{-4} M DODCI concentrations the laser pulse was partly mode-locked. This fact was caused by the shift of the generated band into the spectral region where the absorption of DODCI was insignificant.

The free running laser with the R6G:U composition generated a band centred at about 585.0 nm. The insertion of the saturable absorber into the cavity caused a separation of the bands generated by these two components. The band arising from R6G was shifted towards the long-wave region, while the band arising from U was shifted towards the short-wave region. The separation increased with the increase of the saturable absorber concentration, as shown in fig. 4. Mode-locking in the both generated bands selected by proper filters was full, whereas for the pure U solution under the same conditions no complete mode-locking effect could be obtained. Furthermore, at higher DODCI concentrations, as used in these experiments, the pure U solution did not generate at all [7]. The whole mode-locked laser pulse arising from the both bands revealed only one repetition rate corresponding to the round-trip time of the cavity. This yields the evidence that these two pulse trains in the both bands were synchronized.

One of the most important requirements for mode-locking is the overlapping of the emission band of

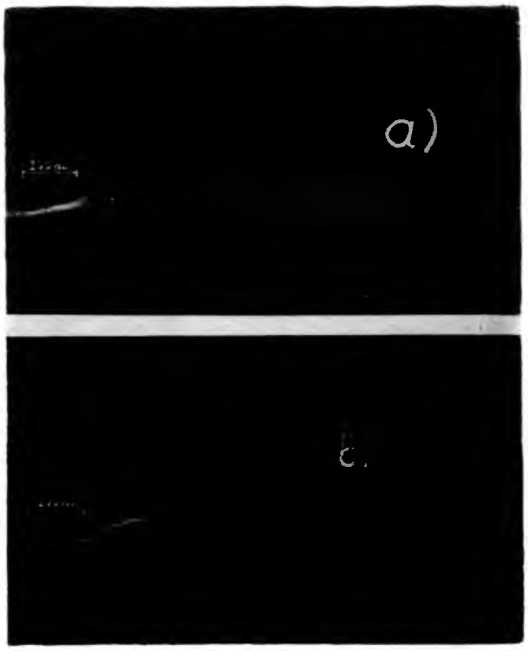

Fig. 3. Typical oscilloscope traces of (*a*) fully, and (*b*) partly mode-locked laser pulse

the laser and the absorption spectrum of the saturable absorber. This condition is well satisfied for the free running laser with the R6G solution which generates a band at about 596.0 nm, because the absorption spectrum of the ethanolic DODCI solution is centred at about 591.0 nm. The band generated by the free running RB laser (621.5/nm) is placed on the long-wave slope, while the band generated by the free running U laser (576.0 nm) is placed on the short-wave slope of the absorption spectrum of DODCI. The absorption spectrum of DODCI and the maxima of bands generated by free running U, R6G and RB lasers are illustrated in fig. 5. The bands generated by the R6G:RB, as well as by the pure R6G and RB laser [7] are shifted with the increase of DODCI concentration towards the spectral region where the absorption losses are smaller. Similarly, the separation of bands generated by the R6G:U laser increases with the increase of the DODCI concentration. The band arising from R6G was shifted towards the long-wave region, while the band arising from U — similarly to the band generated by the pure U laser [7] — towards the short-wave region.

In a mode-locked dye laser operating with a mixture of two dyes (of which one is more efficient and better matched spectrally than the other) the more efficient dye can act as a generator of "gating" pulses for the action of the other one. This effect observed in the R6G:RB composition becomes more evident in the R6G:U mixture. The addition of the "gating" R6G component enabled the mode-locked generation of the U component.

The application of a "gating" dye in two-component dye lasers suggests a possible extension of the applicability of one particular saturable absorber for mode-locking in several dyes, on the condition that the generated band of the "gated" dye still partly overlaps the absorption spectrum of the saturable absorber. The possibility of the generation of two

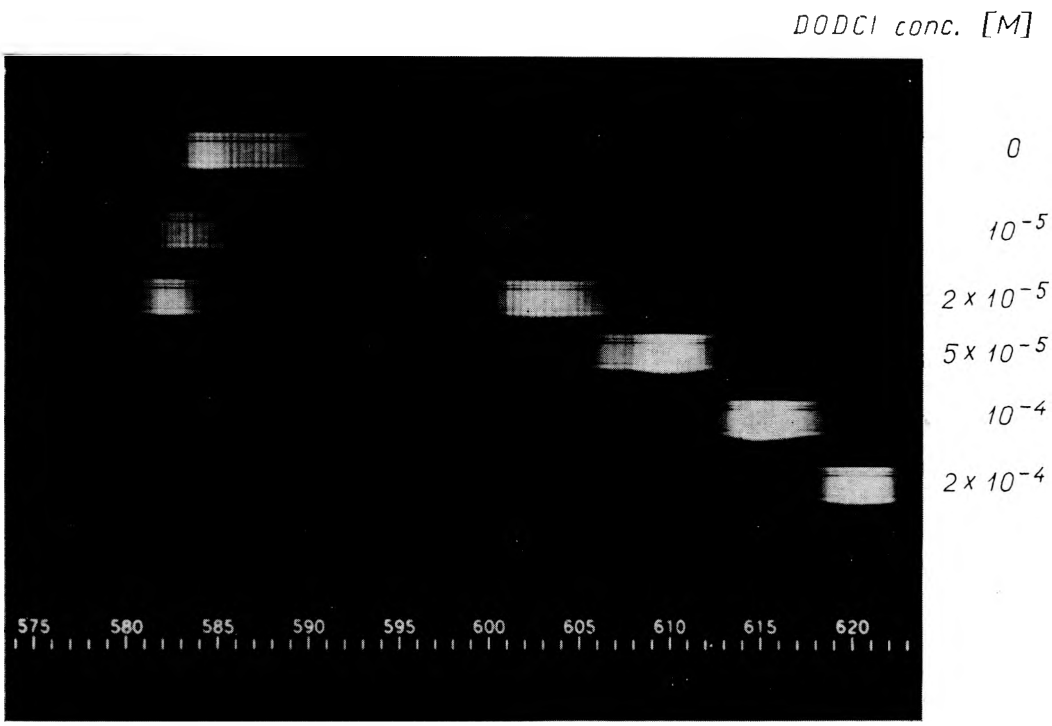

Fig. 4. The separation of bands generated by the rhodamine 6G:uranin (1:1 ratio) composition increasing with the increase of DODCI concentration

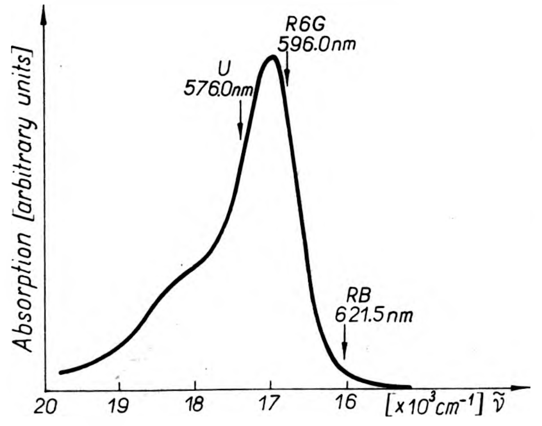

Fig. 5. Absorption spectrum of the ethanolic DODCI solution. Arrows indicate the maxima of free running uranin, rhodamine 6G and rhodamine B lasers

synchronized ultrashort pulse trains at different and tunable wavelengths suggests many applications, especially in sum and difference frequency generation, and in two-photon processes investigations.

Синхронизация модов в двухкомпонентном настраиваемом красительном лазере

Исследовали генерацию двухкомпонентных красительных лазеров с синхронизацией модов, настраиваемых путём насыщаемой концентрации абсорбера. Анализировались двухкомпонентные смеси: родамины В и родамины G6 с уранином. Применение двухкомпонентных активных центров улучшало синхронизацию модов по сравнению со случаем применения чистых компонентов, а также расширяло спектральный предел применяемости определённого насыщаемого абсорбера (DODCI). Действие „как генератора портальных импульсов" для менее эффективных красителей приписывается более активным компонентам соединения.

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