PROGRAMMED EMISSION-SPECTRUM CONTROL FOR
FREQUENCY RUBY LASER

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Earlier papers [1, 2] have reported on laser-emission spectral-composition control using a disper-
sion resonator with selector-interferometer. It was also indicated [2] that programmed control of frequen-
cy-laser emission wavelength is possible.

The present paper gives the results of experimental research on programmed control of frequency-
ruby-laser emission spectrum using a selector with controllable base line. The selector-interferometer
8 (see Fig. 1) was inside the resonator formed by two plane mirrors 9 (~99%) and 7 (~80%). Here, to sup-
press generation "on reflection" the interferometer was dealigned relative to the resonator optical axis by
~30'. The base line was varied using a piezoelectric element from a special program shaper 1. The gen-
erating spectrum was studied with a recording Fabry–Perot interferometer type IT-51-30 (5), in front of
which were a matte plate 6 and a motion-picture camera SKS-1M (4). To simultaneously record the output
energy, we used a coaxial photoelement FÉK-09 (3) with integrating ladder network and a storage oscillo-
graph S1-37 (2).

The operating specifications for a frequency laser are determined mainly by thermal processes oc-
curring within the illuminator [3]. In particular, a distinctive feature is the presence of a transition pro-
cess due to the establishment of a quasisteady-state active element thermal regime. A typical time depen-
dence for output energy for a plane resonator without internal selector-interferometer is shown in Fig. 2a.
The presence of a decreasing transient portion after generator turn-on is due to loss increase due to ther-
mic-lens formation and induced two-beam refraction [3, 4]. Here, the generating wavelength increases
continuously, following the amplification-factor-profile maximum, whose position is determined by the ac-
tive-element temperature.

When a selector-interferometer is placed inside the resonator, the generating wavelength stabilized
and the time dependence of output energy differs from Fig. 2a and is determined by thermic-lens formation
and induced two-beam refraction and also the relationship between the selector-tuning wavelength $\lambda_T$
and the positions $\lambda_0$ and $\lambda_T$ of the amplification-factor maximum for initial and final (steady state) active-medium
temperatures, respectively. Thus, if $\lambda_0 < \lambda_T < \lambda_T$, then for each subsequent pulse the distance between

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inal article submitted December 29, 1971.

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the amplification-factor-maximum wavelength and the generating wavelength decreases and the amplifica-
tion-factor increment obtained at generating frequency may exceed the loss increase (Fig. 2b).

Figure 3 shows experimental results on programmed control of induced-emission wavelength for a
frequency ruby laser operating at repetition frequency 22 Hz. The corresponding programs are depicted
in Fig. 4. To avoid effects due to the transient regime and described above, the program was turned on
when the laser was operating in the steady-state thermal regime.

If U is the voltage on the piezoelectric sample, then the selector-baseline change is \[ \Delta h = \frac{d_{31}(h/\tau)}{\varepsilon \pi} U \],
where \( h \) is the sample length; \( \varepsilon \) is the thickness; \( d_{31} \) is the piezoelectric modulus. Samples having transverse piezoelectric effect were used in the experiments. In work with a selector having transmission-profile half-width \( \delta \lambda \), significantly smaller than the maximum amplification half-width \( \Delta \lambda \), the interferometer baseline variation is completely determined by generating-wavelength variation \( \Delta \lambda = 2\Delta h/m \), where \( m \) is the interference order, and, consequently,

\[
\Delta \lambda = \frac{2d_{31}h}{\varepsilon \pi} U. \tag{1}
\]

Good agreement with Eq. (1) follows from comparing Figs. 3 and 4. The presence of quasicon-
stant portions in Fig. 3a, b is explained by supplementary wavelength selection in the laser resonator.
Actually, the distance between neighboring quasiconstant portions coincides in accuracy with the dispersion
region of the "interferometer" formed by one of the selector backings. A special study of selector-inter-
ferometer transmission in He - Ne laser light also allowed us to observe this supplementary modulation
with the same period. In this case, the selector-transmission-profile half-width is comparable to the back-
ing-interferometer transmission-profile half-width and persistence occurs (the case of "two resonance
profiles"). Transition from one quasiconstant portion to the next (Fig. 3a, b) occurs when the selector
transmission maximum passes through the backing-"interferometer" transmission minimum. This also
explains the output-energy supplementary modulation.

Figure 3c shows an oscillogram for the output-energy profile obtained with a linear program (Fig.
4a). The contour, after averaging over the period of the above-indicated supplementary modulation, is ap-
ximated well by a parabola. Theoretically, this dependence can be obtained from the expressions in [5]
for maximum-amplification-factor profile and quasisteady-state-generating density and has the form

\[
E(h) = -\frac{\alpha k_{loss}}{\nu_0} \frac{(\lambda_\nu - \lambda_\nu)^2}{(\Delta \lambda)^2} - \frac{\alpha k_{loss}}{\nu_0} \alpha \beta. \tag{2}
\]

Here \( E(h) \) is the generating energy at wavelength \( \lambda_\nu \); \( k_{loss} \) is the emission loss factor; \( \nu_0 \) is the maxi-
mum-amplification-factor profile maximum with active-element temperature \( T \) corresponding to steady-
state thermal regime; \( \alpha \) and \( \beta \) are coefficients determined by active-medium and pumping-radiation para-
meters.

Equation (2) can be used to determine the loss factor for a frequency ruby laser [6]. If lasing with
given pumping breaks off at frequency \( \lambda_\nu \), it follows from Eq. (2) that