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SEPARATION OF ONE MODE IN A LASER

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Much attention is being paid nowadays to modifications of optical resonators and laser operating conditions which would make it possible to generate at one mode in resonators of large length, when only several modes of high Q fit the active-medium gain line width. Whereas the selection of transverse modes is a relatively simple matter, say by using a diaphragm or choosing the mirror curvature radii, the elimination of undesirable fundamental TEM_{00q} modes entails great difficulties. We describe in this note a method of separating one TEM_{00q} mode with the aid of a thin absorbing film.

The proposed configuration is shown in Fig. 1, and is extremely simple. Here 1 and 2 are the mirrors making up the optical standing-wave resonator, 3 the active medium, and 4 is a plate of transparent material. One face (A) of this material is left clear, and the other (B) is covered with a thin absorbing layer of optical thickness much smaller (say by a factor of several times 10) than the wavelength. The surface of the film should coincide with the equal-phase surface for the mode that is to be separated. The plate can be displaced slightly along the axis. When the film is located in a node of the standing wave, where the electric field is zero, the loss introduced by the film is very small. At that instant, the film produces a large attenuation of other modes (longitudinal and transverse) whose node surfaces do not coincide with the surface of the absorbing film. If the absorption is sufficiently large, then the laser generates only the mode in whose node the film is located.

A successful application of this method depends on the possibility of producing very thin films with appreciable attenuation, and its experimental verification is therefore of interest. In the experiment we used a helium-neon laser operating at 6328 Å, and the experimental setup was as in Fig. 1. A discharge tube 3 with a discharge length 55 mm and an inside diameter 2.3 mm was filled with a mixture of neon and He^3. The tube was sealed with Brewster windows, and a dc discharge was excited in it. Mirrors 1 and 2 were located 101.6 cm apart and had curvature radii 106 and 136 cm.

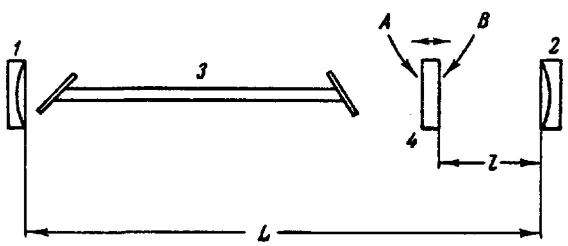

Fig. 1

At these mirror parameters, the equal-phase surfaces were planes at a distance l = 12 cm from mirror 2 [4]. A quartz plate 4, on which a thin film of nickel was deposited, was placed at this point. Both surfaces A and B were clear. The plate was mounted on a piezoceramic, which made it possible to move it along the axis. The transmission coefficient of the wave for the traveling wave was 0.84, and the absorption coefficient 0.14. Measurements of the Q of the passive resonator in which the plate with the film was placed have shown that when the film is placed in the node of the standing wave it introduces in the resonator a loss not exceeding 0.2 - 0.3% per pass, but when the film is shifted slightly from this position the loss increases sharply. Thus, when the film is moved a distance $\lambda/40$ from the node, the loss already amounts to 1.7 - 1.8% per pass, and when the film is placed in the antinode the loss is not less than 25%. These characteristics favor the separation of one of a large number of closely-lying modes.

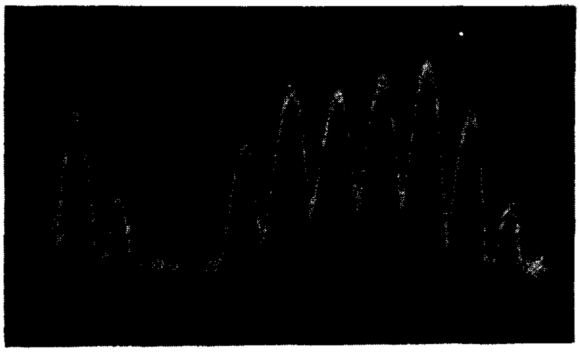

Fig. 2a

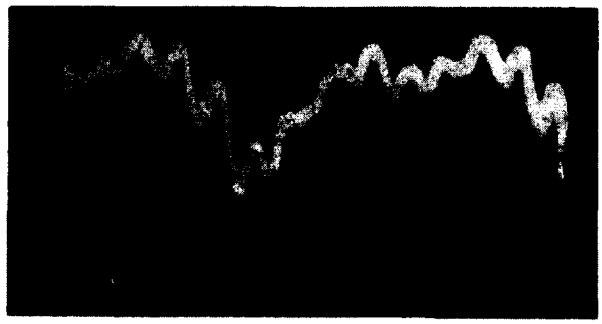

Fig. 2b

Figure 2 shows a plot of the laser emission power against the film displacement. Fig. 2a was obtained with the resonator diaphragmed and the laser capable of generating only at axial modes. Each maximum corresponds to generation at one mode only, and a total of 8 TEM_{00q} modes differing only in their longitudinal indices generate in succession in this case. The maxima repeat periodically, with a period $\lambda/2$ (almost 2 periods are shown in the figure). Figure 2b was obtained with the diaphragm fully open. In this regime, TEM_{00q} modes are excited as before, but TEM_{01q} modes having a somewhat smaller power arise in the intervals between them, causing the dependence of the power on the displacement to become "equalized." In this case the generation also takes place, in the main, at one mode and at one frequency, but at certain instants, in boundary regimes, two modes with different transverse indices can also be excited.

The mode composition of the radiation was monitored with the aid of a 10-cm Fabry-Perot interferometer.

The maximum emission power of the laser described above, when operating at one longitudinal mode (the "single-frequency" regime) was about 3 MW, which is equal to two-thirds of the total power of the laser prior to insertion of the plate with the film in the resonator, and approximately equal to the laser power without the film, but with a diaphragm eliminating the transverse modes (in the latter case five TEM_{00q} modes are generated).

Thus, the introduction of an absorbing film makes it easy to obtain discrimination of modes with different longitudinal and transverse indices and to realize a single-mode laser. This method differs from the Michelson interferometer method in that it is simpler, is insensitive to polarization, and has lower initial losses.

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ADDITIONAL RADIATION CONES OF ANTI-STOKES SRS COMPONENTS IN CALCITE

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The experimental investigation of the angular distribution of the anti-Stokes components of stimulated Raman scattering (SRS) in liquids has been reported in a number of papers (see [1,2]). It was established in these investigations that all the anti-Stokes components are emitted essentially in cones whose axes coincide with the axis of the scattered beam incident on the medium (pump). Concentric circles of various anti-Stokes components are obtained in this case on a photographic film placed behind the sample perpendicular to the pump beam. At the same time it was theoretically predicted in [3] that additional radiation of anti-Stokes components is possible in crystals, and should propagate at a different angle (which in general is variable) to the pump-beam direction. In the same paper, equations were obtained determining the direction of its propagation. These equations are solved in the present paper for the case of uniaxial crystals, and we have observed the additional radiation of the anti-Stokes components experimentally in a uniaxial $CaCO_3$ crystal. The comparison presented below shows good agreement between the obtained experimental data and the results of the theory.

In the case when the pump and the first Stokes component (in the wave zone) constitute an ordinary wave, the angle θ_m^{12} of the additional radiation of the anti-Stokes component of order m is determined by the following relations [3]:

$$2\sin\frac{\theta_m^{12}}{2} = \left\{\frac{[k_{m2}(\theta_m^{12}) + mk_{-11} - (m+1)k_{01}][mk_{-11} + (m+1)k_{01} - k_{m2}(\theta_m^{12})]}{(m+1)k_{01}k_{m2}(\theta_m^{12})}\right\}^{1/2}$$

$$k_{e\alpha}(\theta) = \frac{\omega_e}{c} n_\alpha(\omega_e, \Theta), \quad \Theta^2 = \nu^2 + \theta^2 + 2\nu\theta\cos\phi, \quad n_1(\omega, \Theta) \equiv \sqrt{\epsilon^{(y)}(\omega)} \qquad (1)$$

$$n_2(\omega, \Theta) = \left\{\frac{\sin^2\Theta}{\epsilon^{(x)}(\omega)} + \frac{\cos^2\Theta}{\epsilon^{(z)}(\omega)}\right\}^{-1/2},$$