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CONSERVATION OF WAVE FRONT IN STRONGLY DEFORMED SOLID MEDIA

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It is known that optical pumping of laser media cause thermo-optical strains that disturb the homogeneity of the medium. These strains give rise to many phenomena (thermal lens, birefringence, rotation of the plane of polarization) that distort the field inside an optical resonator and disturb the coherence of the laser emission.

We consider here optical resonators in which oscillations that conserve the shape of the wave front can exist in active media that are strongly and uniformly deformed over their entire length.

The simplest variants of such resonators, which we shall call "waveguide resonators," are shown in Fig. 1. The active element, in the form of a flat plate, has polished side faces. The light enters the active element through the end face at a certain angle, experiences total reflection from the side faces, and emerges through the other end face. These oscillation modes can be classified in accordance with the number of reflections from the side faces and in accordance with the sign of the angle at which the beam is incident on the end face. For example, mode "0" corresponds to the lowest mode of the ordinary Fabry-Perot resonator.

The individual modes are separated by rough-grinding definite sections of the side faces, which do not take part in the reflection (the dull ground sections are shown in Fig. 1 by the wavy lines).

The light beam can pass not only parallel to the side faces, but also at an arbitrary angle. In this case all four side faces must be polished, since the beam can experience multiple reflection from all faces before emerging from the second end face. Such modes must be designated by two indices (±1/±1, ±1/±2, ±2/±2, etc.).

It is possible to consider in similar fashion more complicated resonators of the waveguide type, with the sample made in the form of a polyhedron that is developable into a surface.

To confirm the properties of the indicated oscillation modes, we investigated the front of a wave passing through a neodymium-glass or garnet plate of rectangular cross section located in the arm of a Mach-Zender interferrometer. The sample was flushed alternately on both sides with cold and hot water, using the method described in [1]; the temperature difference was 30°C. A comparison of the interference pattern for an ordinary resonator and a resonator of waveguide type (Fig. 2) shows that in the latter case the thermal-lens effect does not appear at all. The reason is that in the case of the ordinary resonator the refractive index n(x) in the sample cross section depends on the thermo-optical constants P and Q [2, 3]

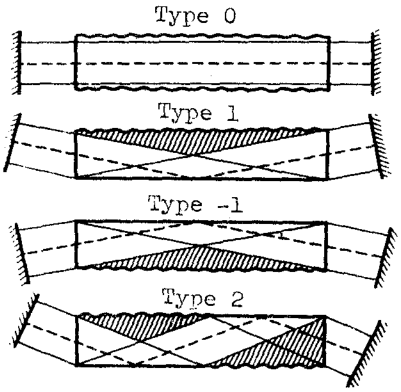

Fig. 1 Simplest types of "waveguide" resonators.

$$n_{1,2}(x) = n_0 + (P \pm Q)[T(x) - T_0],$$

where T_0 and n_0 are the temperature and the refractive index corresponding to it, averaged over the sample, and the subscripts 1 and 2 correspond to the two polarizations.

In the case of waveguide resonators, it can be shown that

$$n_{1,2}(x, L) = n_0 + (P \pm Q)[\overline{T(x, L)} - T_0].$$

Inasmuch as for symmetrical pumping the average temperature $\overline{T(x, L)}$ in the active sample is always equal to T_0 along the entire zigzag path L, we have $n_{1,2}(x, L) = n_0$ regardless of the values of P and Q.

In the next experiment, the sample was strongly deformed also in the transverse direction (the sample was clamped at the end faces, and was compressed at the center with a screw, or else was flushed with hot water on one side only). Unlike the case of uniform pumping, the wave front was conserved in the case of asymmetrical pumping only for the even modes, starting with the second; this phenomenon was observed at arbitrarily large deformations, until failure set in. It should be noted that on emerging from the sample the wave direction shifts by an angle $\alpha/2$, where α is the deflection of the beam for the first even mode at the same value of the deformation.

For odd oscillation modes, the transverse deformations do not influence the direction of wave propagation, and the distortion of the wave front, which is proportional to the produced deformation, decreases with increasing number of the odd mode.

The existence of oscillation modes that are insensitive to inhomogeneous pumping makes it possible to maintain high radiation coherence at arbitrary

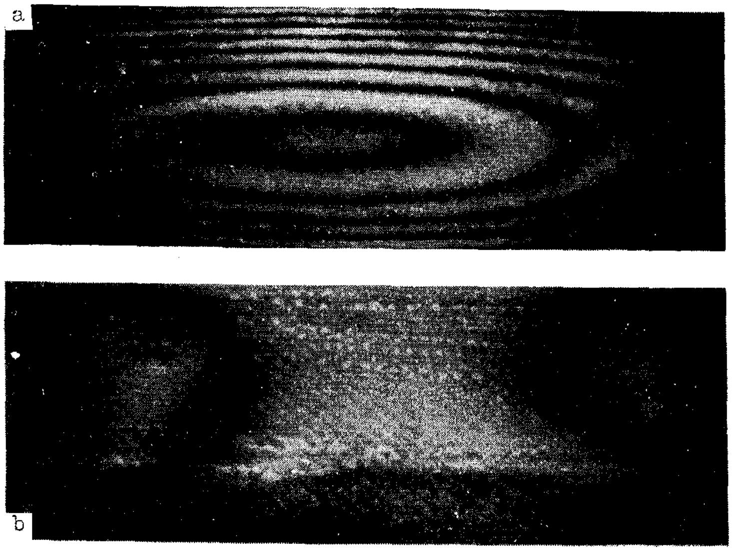

Fig. 2

Fig. 3

Fig. 2. Typical interference patterns of the investigated resonators: a - ordinary resonator, b - waveguide resonator, type 2, with near-maximum deformation in the sample.

Fig. 3. Far zone: a - for ordinary resonator, b - for the same crystal at the 2/2 mode.

pump-to-threshold ratios, even without using stable resonators [4]. All this pertains to pulsed operation, when the thermo-optical effects vary in time and ordinary compensation methods are difficult.

By way of an example, Fig. 3 shows photographs of the radiation in the far zone for an ordinary resonator and a waveguide resonator of type 2/2. The garnet crystal operated at a pump-to-threshold ratio of 100 and measured 3 × 6 × 90 mm. Photometry has shown that in the case of the waveguide resonator the divergence decreases greatly and is close to the diffraction limit.

An important property of such resonators is also the homogeneous distribution of the radiation density in the cross section; this increases the strength of the end faces and ensures a narrow directivity pattern.

This permits, for example, to maintain the single-mode regime for a cw garnet laser at large pumping, and by the same token increases appreciably the second-harmonic radiation power.

One more feature of a waveguide resonator, which makes it possible to narrow down the radiation spectrum, i.e., to stabilize the radiation frequency, is connected with the value of the third optical constant W [1], which depends in this case on the resonator parameters and can be compensated for in a sufficiently wide temperature range.

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POSSIBILITY OF ACCELERATING MANY-LEVEL SYSTEMS AND MULTIPOLE-MOMENT SYSTEMS MOVING IN AN INVERTED MEDIUM

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We consider the emission of a quantum $\hbar\omega$ by a system with natural frequencies ω_{ik} moving in a refractive medium with velocity $v = \beta c$. If the system velocity is lower than the phase velocity of the waves in this medium, then the system can emit a quantum only by going from an excited state of energy E_i to a lower state with energy $E_k = E_i - \hbar\omega_{ik}$, corresponding to the normal Doppler effect: $\beta n(\omega) \cos \theta < 1$, where θ is the angle at which the photon is emitted and $n(\omega)$ is the refractive index of the medium. The quantum radiation energy is drawn from the kinetic energy of the system and from the internal energy of the system. Superluminal motion of the system produces the so-called anomalous Doppler effect [1] ($\beta n(\omega) \cos \theta > 1$). The emission of the quantum is accompanied in this case by excitation of the system, and both the excitation energy and the radiation energy are drawn from the kinetic energy of the system. Thus, superluminal motion makes it possible to observe the system in all the states to which it can go over as a result of direct or cascade processes [2, 3].

We wish to call attention to the features of the mechanism whereby a superluminal system interacts with an inverted-population medium. These features