milliwatts might be enough to alter the characteristics of a few-μm depth waveguide.

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[5]The optical deflection due to the thermal expansion is given by $g \sim (n - 1)\alpha/\lambda$ and that due to the elasto-optic effect is given by $g \sim n^4 p\alpha/2\lambda$, where α is the coefficient of linear thermal expansion and p is the elasto-optic constant. If the crystal is assumed to be completely clamped only along electrodes, the relevant component is p_{31} for the extraordinary ray and p_{21} for the ordinary one. In TiO_2 crystal, the thermal expansion gives 6–10% modification and the elasto-optic effect gives 9–25% modification to g in Eq. (3) with both positive signs.
[6]The time constant was estimated by the relation $t \sim D_0^2 wc/(2.4)^2 \lambda$, where w is the density and c is the heat capacity. For TiO_2 crystal $w \sim 4.2$ g/cm^3 and $c \sim 0.23$ J/gK at room temperature.

Laser with dynamic holographic intracavity distortion correction capability

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We report here a novel laser resonator with the ability to correct for intracavity phase distortions. The optical cavity employs a passive (self-pumped) phase conjugate reflector to provide this capability.

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In this letter we report on the operation of a laser oscillator in which one reflector is a passive (self-pumped) phase conjugate mirror (PPCM).[1] In contrast to conventional phase conjugate resonator (PCR) lasers,[2–8] it requires no external pumping beams, thus potentially removing one of the main disadvantages of PCR lasers.

The main optical component of the new laser is the PPCM, a phase conjugate mirror whose pumping beams are generated via optical interactions in the nonlinear medium by the input beam to be conjugated. The experimental arrangement is shown in Fig. 1. The laser gain medium is that of a Spectra Physics Model 171 argon ion laser. Figure 1(a) shows the starting arrangement of the PCR laser. Lasing is initially induced at the high gain line, 488 nm, between mirror M_1 and beam splitter BS. Light transmitted through the beam splitter causes oscillation in the PPCM, the resonator consisting of a barium titanate crystal and mirrors M_3 and M_4. This is oscillation of the type described in Ref. 1. Reflecting mirror M_2 is used to assist in the buildup of oscillation. With oscillation established between M_3 and M_4, the beam splitter and the retroreflecting mirror M_2 are removed, as shown in Fig. 1(b). We note that the starting procedure described above is required since the coherence of the flourescence is insufficient to allow the formation of the required refractive index grating in the crystal. Once the grating is established, the configuration of Fig. 1(b) corresponds to an equilibrium state, and the grating in the crystal is continuously maintained by the very beams which it couples together.

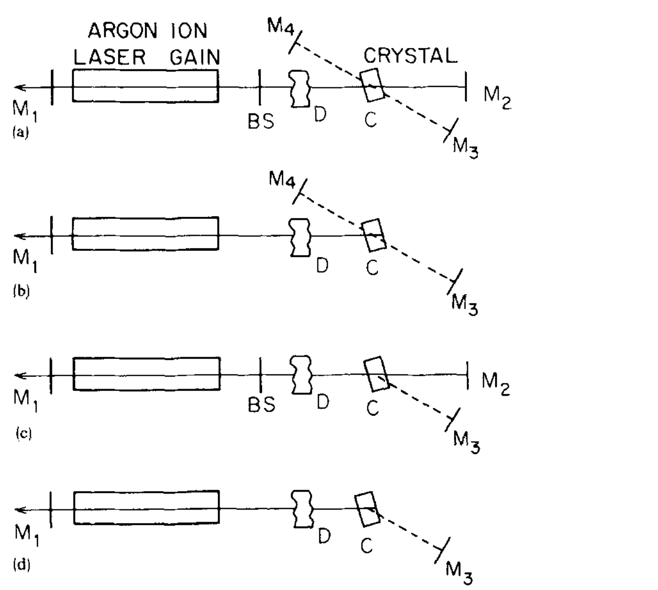

FIG. 1. Passive phase conjugate resonator laser. (a) Starting configuration. Mirror M_1 was the standard high radius of curvature output mirror of the Spectra Physics argon ion laser. The distance from it to the barium titanate crystal C was 220 cm. Mirror M_4 was flat and 50% reflecting, and mirror M_3 was concave 5-cm radius of curvature and highly reflecting. The distances between mirror M_3 and the crystal, and mirror M_4 and the crystal were both 4.5 cm. None of these parameters was critical to the operation of the laser, for example, M_3 could be replaced at the same location by a 50-cm concave mirror. The position of the intracavity distortion D is indicated on the figure. (b) Operating configuration. The crystal is pumped as a phase conjugate mirror by the beams shown dashed in the M_3-M_4 cavity. (c) Starting configuration for laser without mirror M_4. (d) Operating configuration for laser without mirror M_4.

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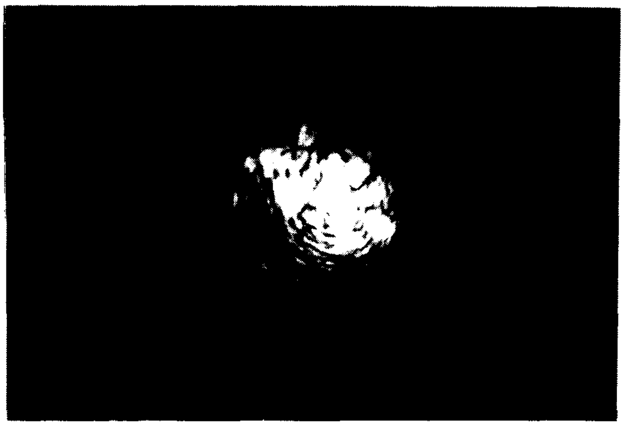
According to the theory of the passive phase conjugate mirror,[9] there is a certain two-beam coupling strength in the crystal, above which it is possible to maintain oscillation between the crystal and M_3 even in the absence of mirror M_4. We were able to demonstrate such oscillation in our resonator. Figure 1(c) depicts the starting arrangement. Once oscillation involving mirror M_3 was established, the beam splitter and mirror M_2 were removed and the laser continued to oscillate, as shown in Fig. 1(d).

To demonstrate the distortion correction capability of the laser with the PPCM, we operated it in the configuration of Fig. 1(d) with a severe distortion placed between the barium titanate crystal and the laser gain medium. Figure 2(b) shows a photograph of the intensity pattern of the beam exiting through mirror M_1. Operating the laser in a conventional fashion with the crystal replaced by a high reflectivity dielectric mirror and with the distortion in the beam path gave rise to the beam shown in Fig. 2(a). The compensation effect of the PPCM is evident.



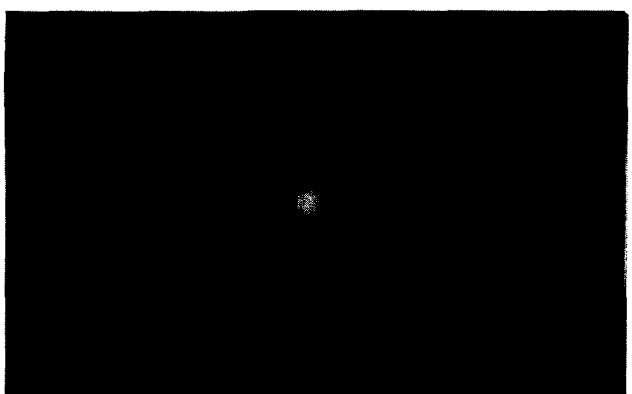


FIG. 2. (a) Photograph of the output of regular laser (i.e., crystal replaced by high reflectivity dielectric mirror) containing an intracavity distortion. The distance from the output mirror M_1 is 1 m. The laser intensity is 1 mW, obtained at 38 A laser tube current. (b) The output of the passive phase conjugate resonator laser containing the intracavity distortion. The distance from the output mirror M_1 is one meter. The laser intensity here is 3 mW, obtained at only 21 A laser tube current. The power output at 38 A is 500 mW.

In addition the power output at 38 A laser tube current in the conventional resonator with the distortion inside was about 1 mW compared to about 500 mW with the PPCM. This plus the distortion correction indicates that each of the oscillations—one in the M_1 crystal arm and the second in the M_3 crystal arm—is composed of two oppositely traveling waves which are phase conjugates of each other [Fig. 1(d)]. *The crystal thus acts simultaneously as a PCM to the two beams which are incident on it, coupling, in the process, the two arms to each other.* This mode of oscillation, where the counterpropagating beams in each arm are phase conjugate to each other, may not be the only allowed stable configuration but in the presence of spatial filters such as the plasma bore tube, it is the minimum diffraction loss configuration and thus the one surviving in a laser oscillator.

The loss of independence of the pump beams in our PPCM causes one difference from a regular PCM. Longitudinal modes are present in the cavity and correspond to the normal modes observed in a standing wave resonator. This has been observed by using an optical spectrum analyzer to analyze the output of the laser.

Finally, we note that in comparison with the light intensity (600 mW at 24-A tube current) inside the M_1 crystal cavity, the amount of light lost from the PCM both in the beam extending straight through the crystal from the laser gain (6 mW) and the beam extending straight through the crystal from the mirror M_3 (16 mW) is quite small.

In conclusion, we have demonstrated for the first time a cw laser with the ability to correct for intracavity phase distortions by utilizing a passive phase conjugate mirror as one of the end mirrors in the laser cavity. When the light beam coupling in the four-wave mixing crystal is sufficiently strong, the passive phase conjugate mirror can be constructed using the nonlinear crystal and only one external mirror. Experiments are currently in progress to investigate the longitudinal and transverse modes of this new laser.

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