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Polarization coupling effects in transversely excited atmospheric CO_2 lasers: Application to single axial mode operation

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(Received 30 June 1982; accepted for publication 12 October 1982)

We report the observation of anomalous polarization coupling effects occurring in injection-locked transversely excited atmospheric (TEA) CO_2 lasers, deduced from studies of the injection detuning parameter under varying conditions of polarization and injection power. For the special case of injection with orthogonally polarized radiation we have determined the existence of an optimum operation point, exhibiting minimum sensitivity of single mode operation to the detuning parameter. Off-resonance injection locking of untuned TEA cavities is also discussed.

PACS numbers: 42.55.Dk, 42.60.By

The technique of injection locking is now established as one of great versatility and practical value[1] for inducing frequency stabilized single longitudinal mode (SLM) operation of transversely excited atmospheric (TEA) CO_2 lasers. To date, however, no studies have been carried out with regard to the effect of polarization coupling upon the injection-locking condition, although two previous reports[2,3] have described polarization slaving occurring when unpolarized TEA laser cavities are injected with a plane-polarized cw signal. In this work we have investigated the effect of varying the relative polarization angle between the TEA resonator and the injected beam. The output polarization of the TEA laser was under all conditions found to be independent of the injected polarization, being dictated solely by the intracavity Brewster window. Even in the extreme case of mutually orthogonal polarizations stable SLM operation was obtained. This was characterized by a behavior at variance with that obtained for all nonorthogonal configurations, indicative of an anomalous polarization coupling process.

The injection geometry employed for the study is as shown in Fig. 1 and consists basically of a ZnSe Brewster plate positioned external to the TEA cavity. The master oscillator signal is coupled coaxially into the TEA cavity after reflection off the Brewster plate. The TEA section consisted of matched uniform-field profile electrodes defining an active volume of $12 \times 12 \times 110$ mm^3. The cavity optics were comprised of a concave gold mirror of 3-m radius of curvature and a 95% reflecting plane germanium output coupler apertured internally to 8 mm for TEM_{00} operation. The cavity length was fixed at 46 cm and could be piezoelectrically fine tuned.

In quantifying the operational dependence of SLM on injected polarization, the frequency detuning range between the injection and TEA cavities over which SLM prevails was monitored as a function of injected power for a range of polarizations of the injection beam relative to that of the TEA output. This was accomplished by rotating the intracavity Brewster in the TEA section by a known amount relative to the plane of polarization of the injection signal. Cavity detuning parameters were calculated from a knowledge of the fine adjustment provided by the piezotransducer facility. The output signal, recorded by a photon drag detector and displayed on a Tektronix 7104 oscilloscope, was observed through the external Brewster plate, the transmission of which was never less than ~30%.

The expected dependence of the TEA output polarization upon the angular orientation of the intracavity Brewster was verified to be the same for both SLM and multimode operation by means of a rotatable KRS-5 polarizer positioned beyond the external Brewster plate. An identical polarizer was also used to attenuate the injection beam.

As is well known, the polarization discriminatory properties of an intracavity Brewster element are greatly enhanced in the multipass regime due to the dependence of the mean passive cavity photon lifetime τ upon the cavity losses, given by $\tau = 2L/c \ln[1/RT_0]$,[4] where L is the cavity length, R is the coupler reflectance, and T_0 is the empty cavity power transmission factor. The single surface transmission coefficient of the Brewster element is given by $T = 1 - \cos^2 2\theta \sin^2 \alpha$, where θ is the Brewster angle and α is the difference in polarization angle of some arbitrary incident ray referred to the plane of maximum transmission. Thus, the time evolution of the passive cavity internal field P described by

$$P = P_0(RT^4)^{N/2},$$

where N is the number of cavity traversals and P_0 is the initial power level, may be determined by substituting into this equation the above expression for T. This function is plotted for several different values of α in Fig. 2, compiled from the parameters pertaining to the TEA resonator used for this study and with P_0 normalized to unity. The predicted very strong polarization discriminatory capability of the Brewster plate when used in this multipass configuration is clearly evident.

Both the slaved and the master oscillator employed for

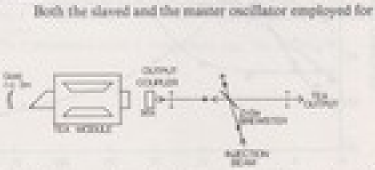

FIG. 1. Injection configuration. Polarizations indicated refer to the specific case of orthogonal injection.

