Homogeneous broadening in a 0.63 μm single mode He-Ne laser

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The expression for inversion density in a gas laser includes an additional term if one allows elastic and/or resonant collisions among the active atoms. This term is a function of the line parameters and describes the effect of homogeneous broadening on the saturated gain profile. Measurements of these parameters show that the homogeneous broadening in a 0.63 μm He-Ne laser plays an important role.

1. Introduction

For the case of simple inhomogeneous broadening in which the Doppler width is large compared to the line width, well pronounced holes are burned in the gain profile of a gas laser. Away from the hole-centre by more than the full hole width the gain profile remains unaffected. But if the motion of the atoms is also disturbed by velocity changing collisions during their life time, excited atoms can 'diffuse' into the holes and interact with the laser field. Excitation can be similarly exchanged among different velocity classes of active atoms by resonant collisions and resonance trapping so that the gain for the laser field can be increased by these effects also. Collisions of these types and the resonance trapping reduce the gain outside the holes more or less uniformly over the entire width of the gain profile so that in effect a partially homogeneous saturation takes place, as shown in Fig. 1. In gas lasers we can expect both inhomogeneous and homogeneous broadening if one or more of the mentioned processes becomes important.

2. Theory

Reference [1] gives the calculation of macroscopic electric polarization in the active medium by using the Boltzmann-kinetic equation system developed by Rautian [2] and not according to the treatment of Gyorffy, Borenstein and Lamb [3] (GBL). In these Boltzmann-kinetic equations different types of collisions in a gas laser can be taken into account by different types of collision integrals. Besides, a complicated time averaging procedure over the histories of velocity and transition frequency is avoided by the calculation of macroscopic electric polarization of active atoms. With Rautian's

*Our results (2) and (3) are similar to those of [7] and [8] which started from the rate equation approach. The parameter used here can be shown to be equivalent to the cross-relaxation parameter of [7] by the relation and to the mixed broadening parameter of [8] by the relation .

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Boltzmann-kinetic equation system we can give a multimode laser theory including the influence of following collision types: (1) phase interrupting collisions; (2) collisions which change simultaneously the phase and the velocity (using the 'strong collision' model of Rautian and Sobelman) and (3) resonant collisions (using Kasanzev's model). For single mode operation the inversion density (following Lamb's notation) becomes in the second order of perturbation theory:

\[
\rho^{(2)}(v, t) = \rho_{aa}^{(2)}(v, t) - \rho_{bb}^{(2)}(v, t) \\
= W(v) \overline{N}(t) \left\{ 1 - (\gamma'_{ab} p^2/4\hbar^2 \gamma_a \gamma'_{b} \gamma^{-1}_{ab}) (1 + \epsilon n^2) E^2(t) \right\} \\
\times \left[ \mathcal{L}_1(v - \omega + K\nu) + \mathcal{L}_2(v - \omega - K\nu) + \frac{1}{2}(\gamma_1/\gamma_2 - 1) \right] \\
\gamma_2 = \gamma_1 (1 + 2\theta)^{-1} ; \quad \gamma_1 \equiv \gamma_{ab}^{-1} , \\
(2) \\
\theta = 2Z_i(\omega - v) \gamma_1 \frac{1}{K\nu} \left[ (\gamma_a' \gamma_b' \gamma_{ab}/\gamma_a' \gamma_b' \gamma_{ab}' - 1) \right] , \\
(3) \\
\gamma_a' = \gamma_a + A(P) ; \quad \gamma_b' = \gamma_b + B(P) . \\
(4)
\]

In the Doppler limit \(Z_i(\omega - v)\) may be approximated: \(Z_i(\omega - v) \approx \pi^3/2(\gamma_1/K\nu)\). Equations 2, 3 and 4 are comparable to those obtained in the theory of GBL; see their Equations 128 and 130. In contrast to GBL, we have a factor of 2 in Equation 2 and a different meaning to \(\gamma_a'\) and \(\gamma_b'\) due to our more generally pressure dependent functions \(A(P)\) and \(B(P)\). The terms \(\mathcal{L}_1(v - \omega + K\nu)\) and \(\mathcal{L}_2(v - \omega - K\nu)\) in Equation 1 both describe Lorentzian holes which are burned into the gain profile, and consequently represent inhomogeneous broadening. The additional term \(1/2(\gamma_1/\gamma_2 - 1)\) decreases the...