COMMENTS AND ADDENDA

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Magnetic Field Shift of Optically Pumped Stimulated Emission in High-Purity GaAs

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Optically pumped stimulated emission in high-purity GaAs shifts toward the blue with magnetic field as $\frac{1}{2}\hbar(\omega_p^2+\omega_c^2)^{1/2}$, where ω_p is the plasma frequency $(4\pi ne^2/\epsilon m^*)^{1/2}$ and ω_c the cyclotron frequency eB/m^*c. The possibility of exciton-exciton recombination is thus excluded. The quantitative agreement between the experimental shift toward the blue and the increase in the zero-point energy of the dominant hybrid plasmon mode confirms the importance of plasmaron coupling in this common laser material.

Recently the shift toward the blue with magnetic field of the stimulated emission in optically excited $CdSnP_2$ was described and interpreted in terms of plasmaron coupling and band-to-band recombination in a many-body regime.[1,2] A similar effect would be expected in the more familiar materials GaAs and InP owing to the similar values of dielectric constant and electron and hole effective masses. We have observed this to be the case, indeed, as shown in Figs. 1 and 2, for an ultra-high-purity epitaxial sample ($n\sim 10^{14}$ cm^{-3}) of GaAs.

The experimental[1,2] and theoretical[1,3] details have been given elsewhere. We wish to emphasize only that exciton-exciton Auger recombination, which has been suggested as a stimulated-emission mechanism in both GaAs[4] and InP,[5] would shift toward the *red* with increasing magnetic field. Such a mechanism is thus excluded for our high-purity sample of GaAs. It is apparent from Fig. 2, however, that the magnitude of the observed shift toward the blue is considerably less than expected for band-to-band recombination, which should follow the lowest Landau level, shifting as $\frac{1}{2}\hbar\omega_c$. We have shown elsewhere[1-3] that proper account of many-body correlation effects equivalent to electron-plasmon coupling leads to the prediction that the band-to-band recombination should shift approximately as the dominant hybrid plasmon mode $\frac{1}{2}\hbar(\omega_p^2+\omega_c^2)^{1/2}$. The solid curve in Fig. 2 is the resulting theoretical shift for a steady-state electron concentration $n=3.7\times10^{16}$ cm^{-3} determined from the energy of the zero-field stimulated emission in Fig. 1 using the theory described in Ref. 3.

We conclude that the Coulomb interaction is, indeed, important in stimulated emission in GaAs, but not as a source of stable hydrogenic excitons.

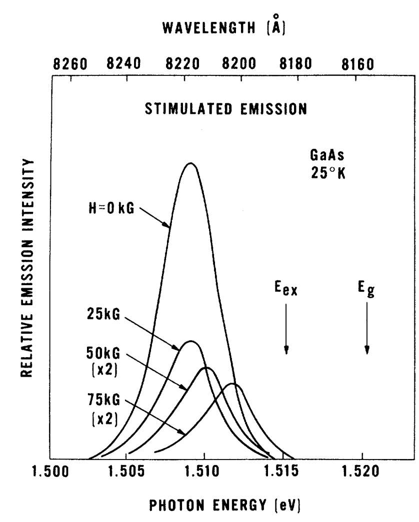

FIG. 1. Stimulated-emission intensity vs wavelength at different values of magnetic field, for ultra-high-purity GaAs at 25 °K. E_g and E_{ex} indicate, respectively, the energies of the energy gap and the free exciton in pure unexcited material.

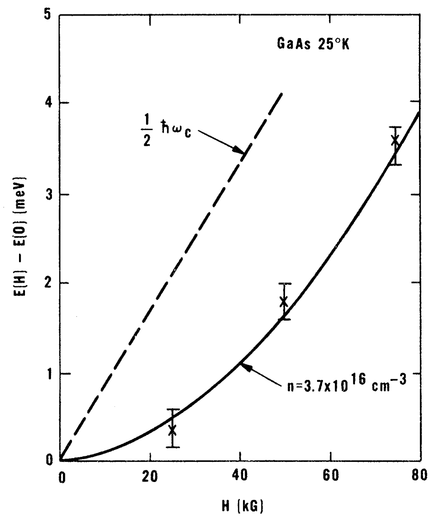

FIG. 2. Shift of maximum of stimulated emission vs magnetic field for the sample in Fig. 1. The solid curve corresponds to $\frac{1}{2}\hbar(\omega_p^2+\omega_c^2)^{1/2}$ for $n=3.7\times10^{16}$ cm^{-3}, with ω_p and ω_c the plasma and cyclotron frequencies, respectively.

The essential features of the stimulated-emission spectra in GaAs are determined principally by many-body correlation effects equivalent to electron-plasmon coupling. Proper inclusion thereof predicts the observed magnetic field shift and also the "red shift" of the stimulated emission below the energy of the band gap of pure unexcited material.[1-3] The concept of excitons is quite irrelevant to the discussion of stimulated recombination in optically excited GaAs. We thus confirm the position taken initially by Basov *et al.*[6] and reinforced by Holonyak and his co-workers.[7] Measurements of this kind in other materials (II-VI compounds in particular) are difficult owing to typically wider emission bands and smaller expected magnetic shifts. Indirect arguments that exciton processes are generally irrelevant to the stimulated-emission mechanism in most semiconductors under optical excitation have been given in Ref. 3.

In conclusion, we find that the essential features of the shift of optically excited stimulated emission with magnetic field in ultra-high-purity GaAs are the same as previously reported for $CdSnP_2$. The possibility of the exciton-exciton recombination mechanism is therefore excluded. Electron exchange and correlation effects equivalent to electron-plasmon coupling are the manifestations of the intercarrier Coulomb interaction appropriate for description of the stimulated recombination in GaAs just as in $CdSnP_2$.

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