Figure 1 shows the dynamics of laser emission and wavelength chirping of the QW, wire, and box DFB lasers at 2 K. The dynamic chirping up to total ~3 nm to long wavelength in the QW laser is due to carrier depletion in both the active and confinement regions during laser emission, which induces a dynamic increase of the refractive index. The same chirping behavior is observed in the wire lasers although the observed lasing duration is large as a result of a long effective carrier capture time and a low Γ. In contrast, we observed a quite abnormal dynamic wavelength chirping behavior for the box lasers. Figure 2 shows the results by time-integrated measurements.

As a result of a quite small Γ (~0.5%) for the investigated box lasers, the dynamic chirping behavior is considered to be mainly determined by the carrier dynamics in the confinement layers. It reflects that the observed chirping behavior is related to a different carrier injection mechanism in the 60-nm box lasers at 2 K.

The observed behavior can be understood in the following way: In the 60-nm quantum box system, carrier capture and relaxation processes are dominated by the Auger-like electron-electron interaction, which is different from the electron-phonon scattering relaxation mechanism in the QW system. The captured carriers transfer their kinetic energies to the remaining carriers in the barrier. This process heats the carriers in the barrier significantly. As a result, the transient refractive index of the confinement region is influenced by both the carrier density and temperature dynamics. The detailed theoretical calculation shows that a total of ~80–100 K carrier temperature change in barrier during lasing emission is needed to explain the observed behavior. Figure 3 shows the measured barrier luminescence spectra under different excitation density during cw laser operation. It supports the above consideration. The further experimental results and theoretical analysis will be discussed.

Investigation of squeezed states of light of semiconductor lasers with a classical corpuscular optical theory

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Semi-classical theory of semiconductor laser noise considers the spontaneous emission as the major noise source. For quiet pumping conditions, the addition of vacuum fluctuations permits the description of fluctuations below the shot noise level, usually referred to as squeezed, or nonclassical, states of light. A description of semiconductor laser noise without quantification of the optical field has been proposed recently. It points out that the fundamental noise source is the shot noise associated with the field to absorbing atoms conversion. Such a theory requires the existence of a feedback wave, similar to vacuum fluctuations, for transmission into the cavity of the fluctuations associated to the nonlocal, and sometimes far away, absorbing atoms.

In a classical corpuscular optical theory, we consider the photons as classical particles and describe the intrinsic field fluctuations at the shot noise associated with the photon generation and absorption. As a result of the stochastic characteristic of output coupling in corpuscular optical theory, the mirror loss noise is taken into account in the form of classical partition noise. Analysis shows that quiet pump conditions lead to a 3 dB internal noise reduction, while for high power and low frequency, the spectral photon noise density associated with an average photon emission is determined by the ratio between the overall photon lifetime and the mirror loss photon lifetime (Fig. 1). It can be reduced below the shot noise limit:

\[ S_{\text{ph}}(\omega) = \hat{\beta} \left( 1 - \frac{\tau_m}{\tau_{\text{ph}}} \right) \]

The propagation of laser fluctuations inside an absorbing medium is studied by use of the concept of optical partition noise and leads to the invariance of a suitably defined relative intensity noise (R.I.N.) that becomes negative for sub-Poissonian statistic:

\[ \text{R.I.N.}(\omega) = \frac{S_{\text{ph}}(\omega) - \hat{\beta}}{\hat{\beta}} \]

With this definition the R.I.N. of a semiconductor laser is derived:

\[ \frac{\text{R.I.N.}(\omega)}{2} = \frac{S_{\text{ph}}(\omega)}{\hat{\beta}} = \frac{4A}{\tau_{\text{ph}} |\Delta|^2}, \]

where \( S_{\text{ph}} \) is the internal photon noise spectral density, \( \hat{\beta} \) the average photon number inside the cavity, the differential gain \( A \), and \( \tau_{\text{ph}} \) the damping time associated with the relaxation frequency. The first term is the usual R.I.N. definition while the second expresses the difference between internal and external fluctuations, pointing out the possible reduction of the latter. Figure 2 shows the R.I.N. decreasing with \( \tau_{\text{ph}}^{-3} \) under normal pumping conditions in agreement with the theory. For high pumping rates, the R.I.N. increases drastically with the increasing of longitudinal side modes.
We investigate the squeezing potential of several 1.55 µm DFB lasers with different structures and parameters. Figure 2 presents the intensity fluctuations measurements of a 1.55 µm compressively strained MQW DFB laser with cleaved facets at room temperature under noise suppressed and shot-noise-limited current injection. The laser fluctuations in both cases exceed the shot-noise limit, but a decrease of 0.7 dB in the noise level is observed under quiet pumping conditions. The excess noise that degrades the squeezing is also examined and it appears that the source of most of this noise is associated with the presence of weak longitudinal side modes resulting from a low κ_s value.


**CWF21**

**Analysis of current self-distribution induced by self-focusing filamentation in laser diode**

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Optical filamentation is a nonlinear effect limiting the laser semiconductor performance in the high-power regime. In laser diodes it can be influenced by injection current self-distribution (CSD), which results from non-uniform stimulated recombination in the active region. We developed an approach for analysis of the CSD in the case of self-focusing filamentation (see Fig. 1 for the geometry). Depending on the resistivities and thicknesses of passive regions of the diode, the injection current can be crowded along the filament, and the additional current compensates the locally enhanced consumption rate of the excess carriers. A proper configuration of the diode and low series resistance (of both passive bulk regions and contacts) can provide suppression of spatial hole burning. A criterion is formulated to estimate the contribution of the CSD effect into the suppression of spatial hole-burning using a new parameter β defined as

$$\beta = \left(\tau / \epsilon\right) \left(\frac{dI}{dV}\right) \left(\frac{dV}{jdN}\right),$$

where τ is the carrier lifetime, d is the active region thickness, j is the current density, V is the voltage applied to the passive region, V_j is the junction voltage, and N is the carrier density. The local relative change of carrier density \( \Phi N \) induced by the stimulated recombination may be expressed as

$$\Delta N / N = (\Delta \tau / \tau) / \left(1 + \beta\right),$$

where \( \Delta \tau \) is the local decrease of carrier lifetime resulting from enhanced stimulated recombination. A relative measure of the CSD effect can be obtained as follows:

$$\Delta j / j = -\left(\Delta \tau / \tau\right) \beta / \left(1 + \beta\right),$$

where j is a local current density across the junction. Thus the criterion of strong CSD is

$$\beta \approx 1.$$