CHARACTERIZATION OF EXCESS NOISE INDUCED BY EXTERNAL REFLECTION IN 1.55 μm GAIN-COUPLED DFB LASERS OF ABSORPTIVE GRATING TYPE

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Abstract

We have fabricated 1.55 μm InGaAsP/InP strained multiple-quantum-well gain-coupled DFB lasers of absorptive grating type, and characterized their excess noise induced by external reflection from several meters. Coupling coefficient dependence of the critical feedback level is discussed.

I. Introduction

Since the single-longitudinal-mode (SLM) property of gain-coupled (GC) distributed feedback (DFB) semiconductor lasers is hardly affected by facet reflection [1], GC DFB lasers in general have higher SLM yield than conventional index-coupled (IC) DFB lasers. As an extrapolation of this facet reflection immunity, one may expect lower sensitivity also to external reflection if the reflecting point is not far (in the order of centimeters). In fact, smaller external reflection sensitivity in GaAlAs/GaAs GC DFB lasers of amplifying grating type was reported previously [2].

However, external reflection in optical fiber communications commonly comes from distance of a few meters where most fiber connectors exist. In addition, at the fiber communication wavelength range of 1.55 μm, InGaAsP/InP GC DFB lasers of absorptive grating type are mostly used. Therefore, it is important to characterize excess noise properties in this type of lasers under external optical feedback from a relatively remote reflection plane.

II. Device Structure

Illustrated in Fig. 1 is the schematic of the InGaAsP/InP GC DFB laser with InGaAs absorptive grating used in this paper. Its undoped active layer is composed of five compressively-strained (0.7%) InGaAsP 10 nm-thick quantum wells and 10 nm InGaAsP (1.25 μm) barriers sandwiched between 120 nm InGaAsP (1.25 μm) separate-confinement heterostruc-turre (SCH) layers. In the p-doped cladding region above the active layer, there are absorptive grating wires of n-type (conduction-type inverted) InGaAs embedded, whose pitch, thickness, and duty cycle is 238 nm, 30 nm, and 30~40%, respectively.

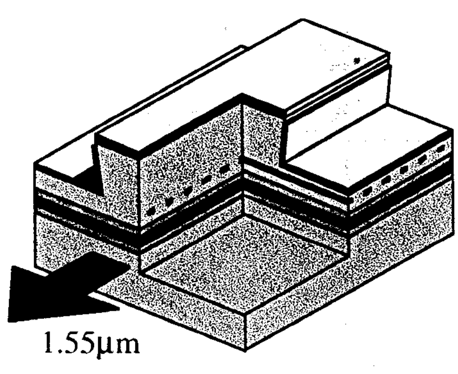

Fig. 1. Structure of the InGaAsP/InP GC DFB laser with InGaAs absorptive grating fabricated.

These layers were grown by two-step metal-organic vapor phase epitaxy (MOVPE, AIX200/4), and the grat-

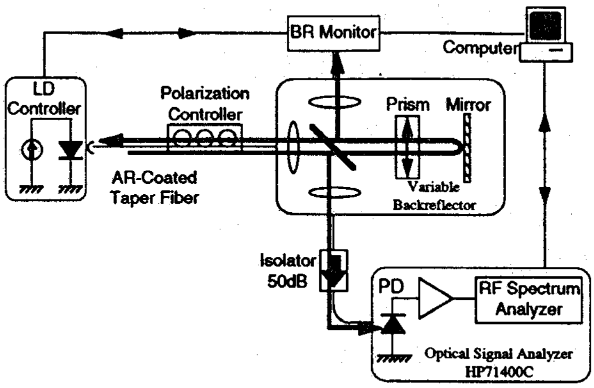

Fig. 2. Experimental setup for the measurement of excess noise induced by external optical reflection.

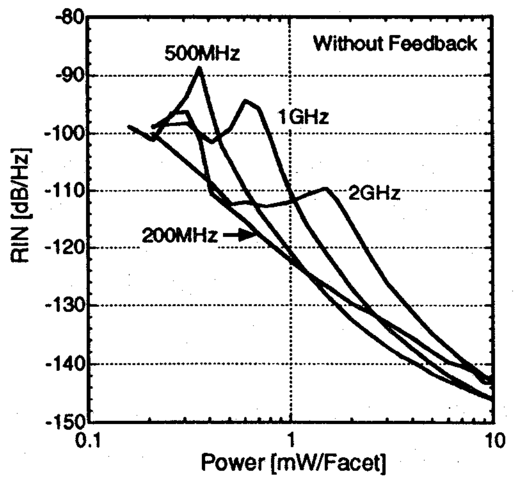

Fig. 3. RIN characteristics without external reflection.

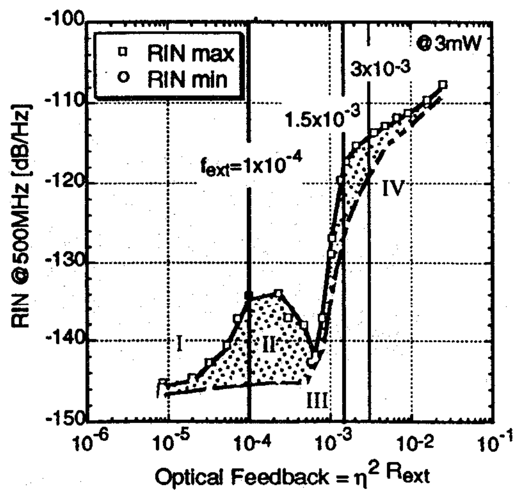

Fig. 4. General RIN characteristics with external reflection.

ing was made by holographic exposure and wet chemical etching. Ridge waveguides with 4 μm width were fabricated on the epitaxial wafer, which was then cleaved into individual laser chips with cavity length of ~400 μm. The facets of the lasers were left uncoated. For comparison's sake, IC DFB lasers having the identical structure except their transparent grating were fabricated concurrently.

CW threshold currents of these lasers were ~20 mA. The GC DFB laser had side mode suppression ratio (SMSR) of ~50 dB even with the cleaved facet reflection whereas the IC DFB laser had SMSR of ~40 dB.

III. Excess Noise Characteristics

Figure 2 shows the experimental setup for the excess noise measurement by external reflection. The variable back reflector (VBR) was used to generate the reflection. The distance between the laser and the VBR was ~6 m. The polarization controller inserted was adjusted so as to maximize the excess noise due to the reflection. The relative intensity noise (RIN) was characterized by the optical signal analyzer (HP71400C).

First of all, RIN behavior without external reflection was observed, the result of which is shown in Fig. 3. As the standard theory predicts, RIN is inversely proportional to the cube of output optical power after the resonance frequency passes the noise measurement frequency. The magnitude of RIN as well as the power and frequency dependences were almost the same for both GC and IC DFB lasers.

When external reflection exists, it causes excess noise whose general behavior is like the one shown in Fig. 4. The upper and lower traces correspond to the peak and bottom values of the noise spikes in the microwave spectra. Since the peak value depends very much on the phase of the reflected light and its measurement is not very accurate, we here use the lower trace as the measure of the feedback sensitivity. The

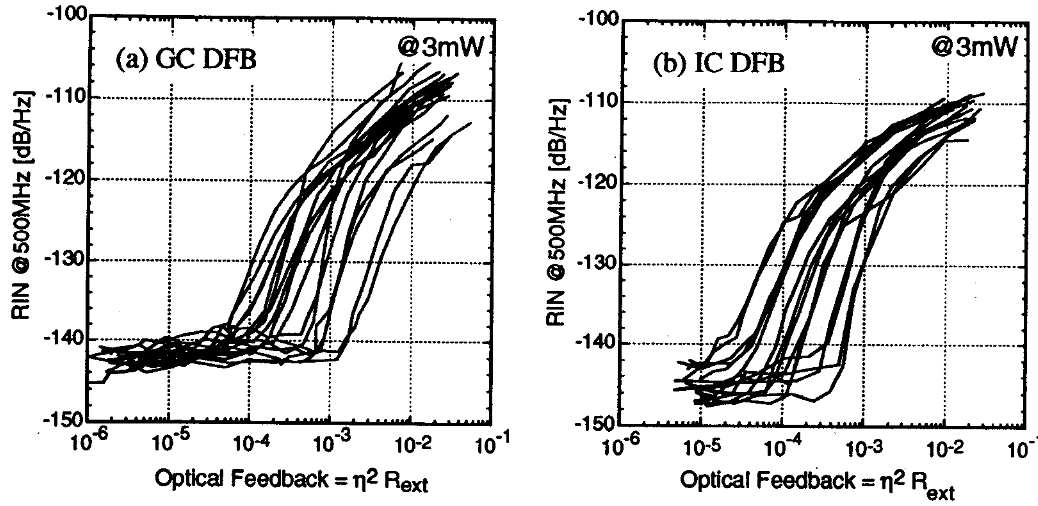

Fig. 5. RIN characteristics with external optical feedback for the GC (a) and IC (b) DFB lasers.

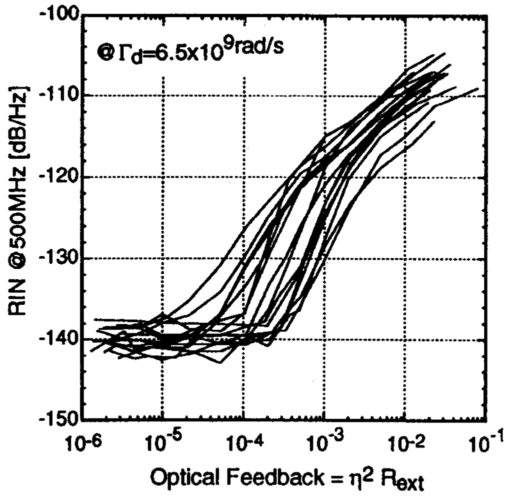

Fig. 6. RIN characteristics with external reflection at a constant damping factor for the GC DFB lasers.

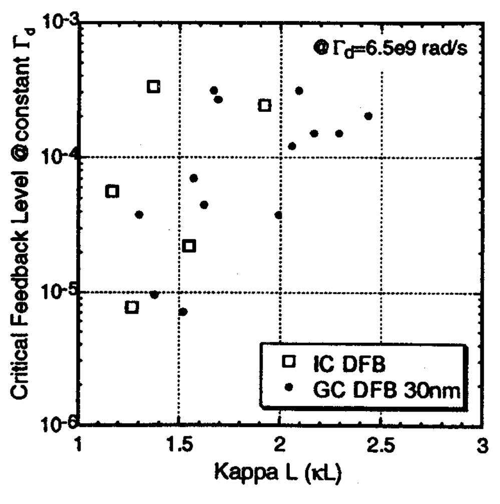

Fig. 7. Critical feedback levels as a function of the coupling coefficient for the GC (closed circles) and IC (open rectangles) DFB lasers.

threshold feedback level where the noise begins to increase abruptly is called "critical feedback." The feedback immunity can be said as high if this critical feedback level is high.

Figure 5 is collection of the lower traces for GC (a) and IC (b) DFB lasers at 3 mW of output power per facet. Although there is a tendency of obtaining higher critical feedback levels in the GC DFB lasers, the difference from chip to chip is too large to draw a general conclusion. Therefore, we next investigated the factors causing this variety.

One analytical expression for the critical feedback level is given as [3]

$$\frac{\tau_L^2}{16|C|^2}\Gamma_d{}^2\frac{1+\alpha^2}{\alpha^4},$$

where τ_L is the round trip time in laser cavity, C the suceptance to optical feedback, Γ_d the damping factor of the relaxation oscillation, and α the linewidth enhancement factor. Among these parameters, C and Γ_d are most likely to give rise to the variety in critical feedback level. Therefore, we measured RIN as functions of the feedback level under condition of constant Γ_d in the GC DFB lasers, whose result is shown in Fig. 6. Although the diversity became less as compared with Fig. 5 (a), it still remains probably due to the difference in the coupling coefficient κ from chip to chip that affected C.

In order to confirm this, we then measured the normalized coupling coefficient κL (κ here is

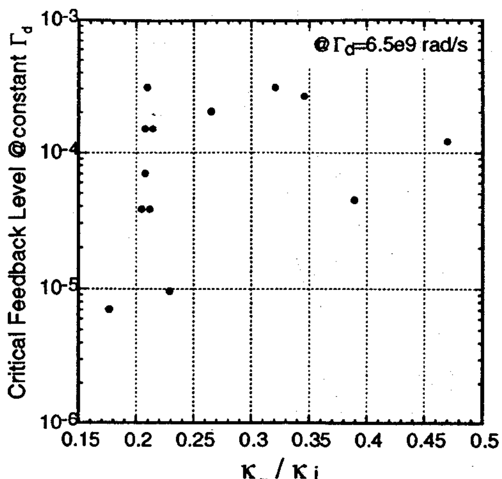

Fig. 8. Critical feedback levels versus ratio of gain- to index-coupling coefficients for the GC DFB lasers.

the vector summation of index- and gain-coupling coefficients, κ_i and κ_g) by using the parameter extraction program, LAPAREX [4], and plotted the critical feedback level in Fig. 6 as a functions of κL in Fig. 7. Positive correlation between the critical feedback level and κL is clearly seen. However, the coupling coefficient dependence of the critical feedback level is not much different between the GC and IC DFB lasers.

In addition, dependence of the critical feedback level on the ratio of κ_g to κ_i in the GC DFB lasers was examined and plotted in Fig. 8. The figure shows increasing tendency of the critical feedback level as the gain coupling component in the coupling coefficient increases. Consequently, having large gain coupling is advantageous for higher reflection immunity.

IV. Conclusions

We have fabricated 1.55 µm InGaAsP/InP strained multiple quantum well gain-coupled DFB lasers of absorptive grating type, and characterized their excess noise induced by external reflection from several meters. It has been experimentally shown that the critical feedback level has positive correlation with coupling coefficient as well as damping factor of relaxation oscillation. This behavior is consistent with existing theory for conventional lasers. As far as relatively long distance reflection of several meters is concerned, the GC DFB laser exhibited reflection sensitivity similar to IC DFB lasers. Nevertheless, the critical feedback level tended to become improved when the gain coupling component in the coupling coefficient was large.

Acknowledgment

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References

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