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Long Cavity DFB Laser for Linewidth Narrowing

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We developed the long cavity DFB laser to obtain the narrow linewidth taking account the effect of the mode coupling. To obtain narrow linewidth, we must make the long cavity DFB laser keeping κL at an small value. With a corrugation depth of 15 nm and a cavity length of 1200 μm, a narrow linewidth of 1.7 MHz was obtained at 11 mW.

1. Introduction

Narrow linewidth laser diodes are key devices in constructing coherent optical communication systems. The long cavity DFB laser is an attractive laser diode for reducing spectral linewidth[1),2)]. However, in the long cavity DFB laser, the mode coupling between the forward and the backward propagating waves is often very strong, causing spatial hole burning[3)], and then multi-longitudinal-mode operation sometimes occurs at a high injection level.

In this paper, we developed the long cavity DFB laser to obtain the narrow linewidth taking account the effect of the mode coupling. We investigated experimentally the dependence of the spectral linewidth on cavity length and coupling coefficient, and obtained the optimum condition of the cavity length and the coupling coefficient for the realization of the narrower spectral linewidth.

2. Experiment and discussion

The spectral linewidth of a DFB laser can be estimated by calculating the equivalent mirror loss using coupled wave theory[4)-6)]. When the coupling coefficient $\kappa L >> 1$,

$$\Delta\nu \propto \frac{1}{(\kappa L)^2 L} \qquad (1)$$

From eq. 1, a long cavity length L and large κL are very effective at reducing the spectral linewidth.

We fabricated the DFB lasers with different cavity lengths and measured their spectral linewidths. The laser under the test was a GaInAsP/InP FBH-DFB laser with first-order corrugation

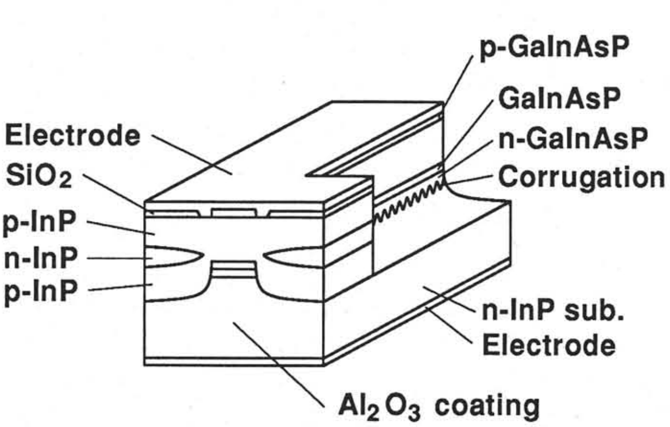

Fig. 1 Schematic structure of FBH-DFB laser

emitting at 1.55 μm wavelength[7]. Fig. 1 shows the schematic sturcture of this laser. The front facet was coated with the Al_2O_3 film to obtain the reflectivity of about 5%[8], and the rear facet was as-cleaved.

Fig. 2 shows the dependence of spectral linewidth on the cavity length. The ordinate shows the spectral linewidth at 5mW output power. The spectral linewidth of the DFB laser also depends on the wavelength difference between the lasing mode and the gain peak[9]. In Fig. 2, we selected the samples whose lasing wavelength was on the longer-wavelength side of the gain peak by about 5 nm to avoid the extra linewidth narrowing due to the detunig effect. The coupling coefficient κ was kept to be around 30 cm^{-1}. From eqn. 1, the spectral linewidth in inversely proportional to the cube of cavity length. However, in Fig.1, the spectral linewidth decreased inversely proportionally to the cavity length. This means that there exists some factor that prevents reduction of the spectral linewidth for large κL. This factor could be nonuniform field distribution in the strong coupling case that enhances the carrier fluctuation.

To estimate the effect of large κL, we measured the spectral linewidth of a DFB laser with large κ keeping L at a constant value of 300 μm. In this measurement, the lasing wavelength was 1.3 μm. The measured spectral linewidth is shown in Fig. 3. To show the difference between the effect of the detunig and that of the large κ clearly, the abscissa is the wavelength difference $\Delta\lambda = \lambda_{DFB} - \lambda_{peak}$, where λ_{DFB} is the lasing wavelength and λ_{peak} is the gain peak wavelength. The open circles show the κ of 30 cm^{-1} (κL=1.0), and the closed triangles show that of 85 cm^{-1} (κL=2.5). The large κ was obtained by making the corrugation deep. From Fig. 3, we can see that there is a tendency for the linewidth to narrow when the lasing wavelength is on the shorter wavelength side of the gain peak. This result clearly shows the linewidth reduction due to the detuning effect. However,

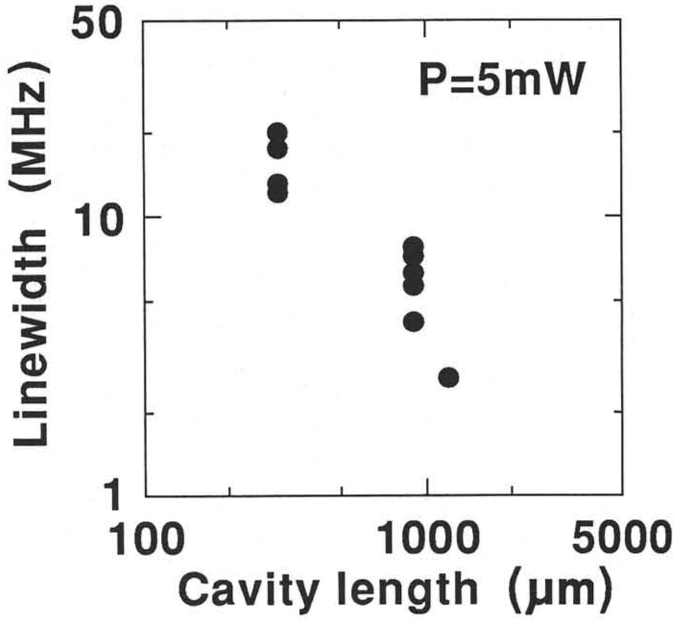

Fig. 2 Dependence of spectral linewidth on cavity length in 1.55 μm FBH-DFB laser

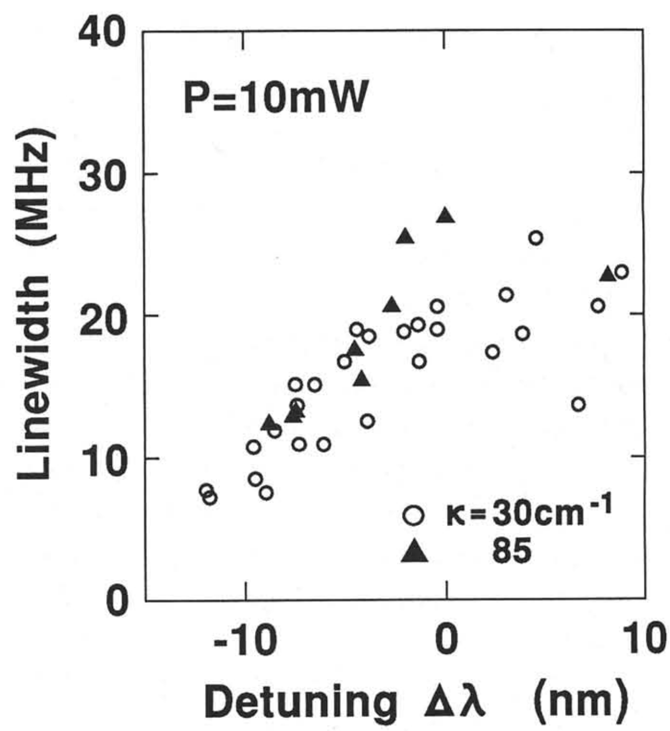

Fig. 3 Measured spectral linewidth of 1.3μm FBH-DFB laser as function of wavelength difference $\Delta\lambda = \lambda_{DFB} - \lambda_{peak}$. λ_{DFB} is lasing wavelength. λ_{peak} is gain peak wavelength.

there was no difference in the spectral linewidth between the samples with large κ and the conventional κ. Therefore, we can conclude that it is not effective to make κL large keeping L constant for the reduction of linewidth.

From these two experiments, we confirm that the long cavity length is essential to reduce the spectral linewidth. However, the large L gives the large κL which results in the multi-longitudinal-mode operation due to the effect of the spatial hole burning[3]. Our experiment also showed that the large κL alone had little effect on the linewidth reduction. Then the most effective design for the reduction of the spectral linewidth is to make the cavity length long while keeping κL at a small value. Therefore, we fabricated the DFB laser with long cavity length of 1200 µm and shallow corrugation of 15 nm. Fig. 4 shows output power v.s. injection current characteristic of this sample. The threshold current was 24.3 mA, and the differential efficiency was 0.067 mW/mA. κL was estimated to be 1.6. The side-mode suppression ratio of more than 40 dB was obtained up to 13 mW without mode jump. This stable single-mode operation is due to a comparatively small κL. Fig. 5 shows power dependence of spectral linewidth of this sample. From Fig. 5, we can see that the linewidth was decreased continuously when the output power was increased, and minimum value of 1.7 MHz was obtained at 11 mW output power. This result shows that the narrow linewidth is obtained by making the cavity length large, while keeping the κL at a small value.

3. Conclusion

We developed the long cavity DFB laser to obtain the narrow linewidth taking account of the effect of the mode coupling. To reduce the spectral linewidth, the long cavity length was very effective, whereas the high coupling coefficient had little effect. Therefore, to reduce spectral linewidth, we must make the long cavity DFB laser

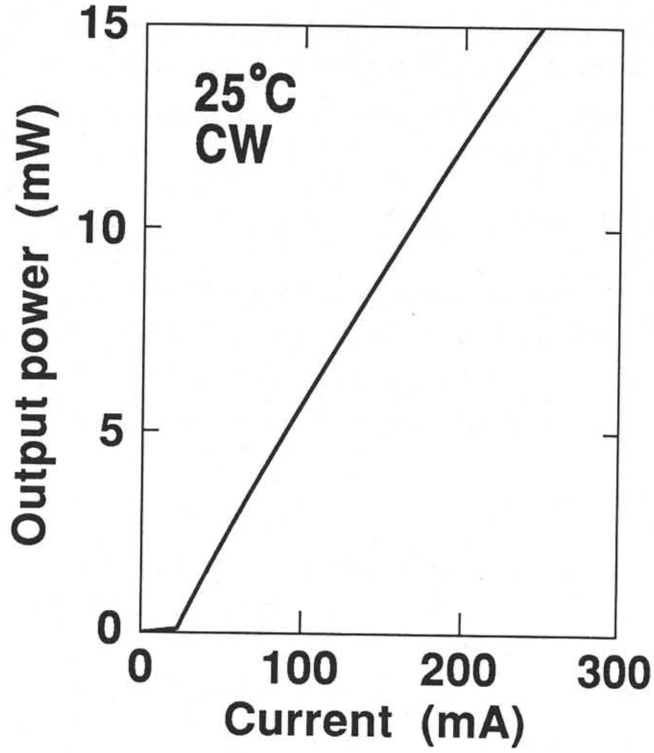

Fig. 4 Output power v.s. injection current characteristics of the DFB laser with cavity length of 1200 µm and corrugation depth of 15nm.

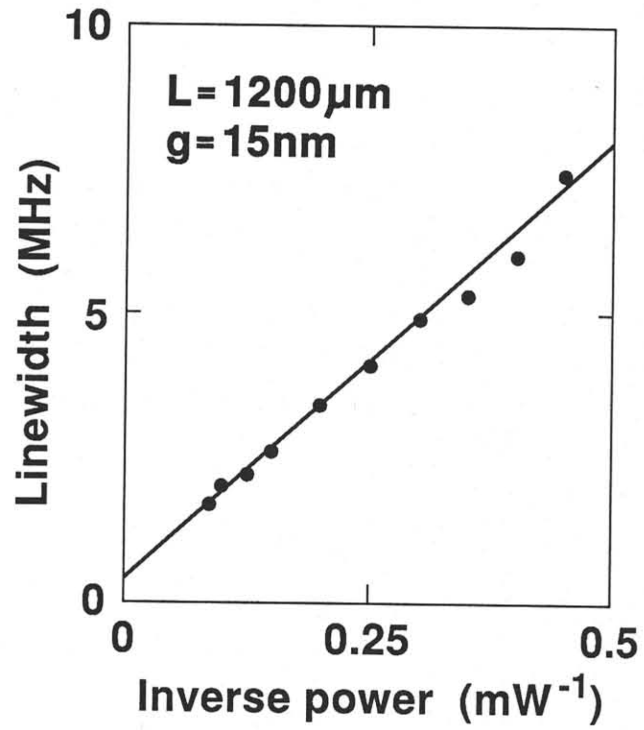

Fig. 5 Power dependence of spectral linewidth

keeping κL at a small value. The narrow spectral linewidth of 1.7 MHz was obtained at long cavity length of 1200 μm and the shallow corrugation depth of 15 nm.

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