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Investigation of the Linewidth of a Tunable Laser Integrated with DFB Lasers and a Semiconductor Optical Amplifier

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Abstract

Semiconductor laser linewidth with a semiconductor optical amplifier was experimentally investigated. The apparent linewidth increases with increased SOA current, which can be attributed to the gradual increase of the intrinsic white FM noise and the 1/f noise.

1. Introduction

A tunable laser is a key component for coherent optical transmission systems. Among the several different types of tunable lasers[1-3], a tunable laser integrated with a laser consists of 16-channel distributed feedback (DFB) laser array, a beam combiner, and a semiconductor optical amplifier (SOA), is attractive for its high reliability and stable wavelength stability[4-7]. Its wavelength can be tuned by selecting the appropriate DFB laser element and by controlling the chip temperature. Even though there were some reports on the linewidth of these types of devices[4-6], there has not been systematic study of the effect of the SOA.

For coherent optical communications, we need to separate the effects between the intrinsic linewidth (white FM noise) and low frequency noise (typically characterised as 1/f noise). In this paper, by measuring the frequency modulation (FM) noise spectrum of the tunable laser with varying the laser and the SOA current, we show that the intrinsic white FM noise and 1/f noise increases with increasing the SOA current.

2. Device structure

Figure 1 is a schematic diagram of a monolithi-cally integrated tunable laser on an InP substrate[7]. The total chip size is 4.8 x 0.5 x 0.1 mm^3. The tunable laser consists of 16-channel DFB lasers, S-bend passive waveguides, a multi-mode interferometer (MMI) coupler, and an SOA. The DFB laser cavity is 1200 μm long to achieve narrow linewidth. The DFB laser array is designed to cover a wide tuning range of more than 37 nm, which corresponds to 88 channels on the 50 GHz grid in the L-band. The wavelength of each DFB can be lineally changed by about 2.5 nm by means of changing the chip temperature from 25 to 55 °C. The output light from DFB laser is guided into the 16 × MMI coupler through the S-bend passive waveguide. The output power from the MMI coupler is amplified by SOA. The optical output power is controlled by adjusting the SOA current.

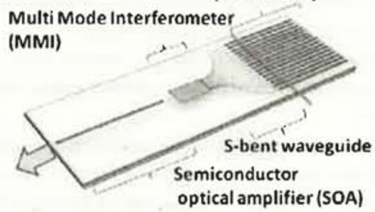

Fig. 1 A schematic of the tunable laser used in the measurement[7]

3.Measurement

We first used the conventional DSHI[8] with a delay fibre length of 10 km, and compared the linewidth measured from the front-side (through SOA) and the back-side (directly from the DFB laser). The ratio of the linewidth measured from the front side to that from the back side. If amplified spontaneous emission (ASE) noise from the SOA directly added to the laser light had influenced the linewidth measurement, the ratio should have increased systematically with the SOA current. However, it could not be observed. With this above information, we concluded that the linewidth measurement was not affected by the added ASE noise from the SOA directly coupled into the fibre. In the following experiment, we use the light from the front side through the SOA.,

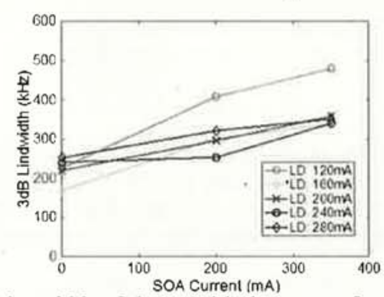

Fig. 2 Linewidth of the tunable laser as a function of the SOA current measured by the DSHI.

Figure 2 shows the measured 3dB linewidth when the laser diode (LD) current and SOA current were changed. The minimum linewidth was 200 kHz when SOA was turned off. It is clearly seen that SOA current affects the tunable laser linewidth, and it is important to determine whether the broadening comes from the white FM noise which directly affects the coherent transmission characteristics, or from a low frequency noise which can mostly be compensated by digital signal processing (DSP)[9].

We then measured the FM noise spectra of the tunable laser with various LD and SOA current by using commercial equipment[10]. Figure 3 show the measured FM noise spectrum when the LD current is fixed and the SOA current is changed. Low frequency FM noise is apparent in all cases, but is most prominent at higher frequency when the SOA current is highest.

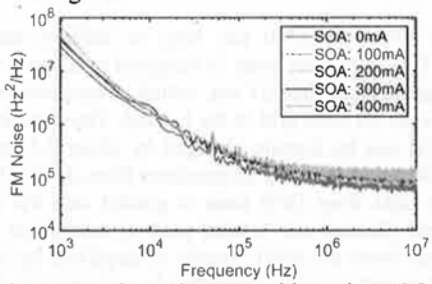

Fig. 3 Measured RF Spectra with various SOA current, with LD current at 300 mA

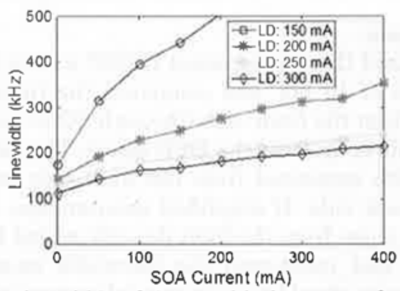

Fig. 4 Linewidth of the tunable laser as a function of the SOA current, measured from the FM Noise Spectrum

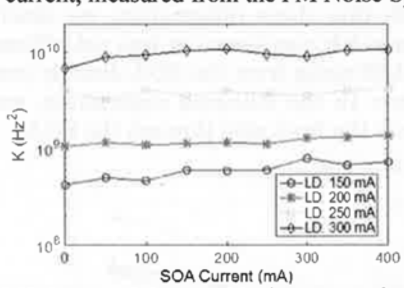

Fig. 5 K factor of the tunable laser as a function of the SOA current, measured from the FM Noise Spectrum

Each FM noise spectrum was fitted with the combination of the white noise component and the 1/f noise component

$$S(f) = 2(\Delta\nu/\pi + K/f),$$

[11,12],where $\Delta\nu$ is the intrinsic linewidth, and K is a constant representing the 1/f noise. Frequency components below 3 x 10^3 Hz was omitted for fitting to avoid fitting error. The intrinsic linewidth $\Delta\nu$ as a function of the SOA current is shown in Fig.4. It is shown that the intrinsic linewidth increases fast with SOA when the LD current is smaller (150 mA), while it increases more slowly when LD current is larger (200 - 300 mA). The minimum $\Delta\nu$ was 110 kHz when the SOA is turned off, and it stayed below 200 kHz for most of the SOA currents while LD current was 300 mA.

K is plotted in Fig.5 as a function of the SOA current. K increases slowly by increasing the SOA current (the log plot of Fig.5 makes the increase look smaller), but also increases with increasing the LD current. Note that increase in K does not affect the coherent optical system performance[9].

The mechanism of the linewidth broadening with the SOA current is not known at this moment, but we have shown that this is not a measurement artifact. One possibility is that small amount of the spontaneous emission from the SOA couples back into the DFB laser and broadens the linewidth. Further experiment to verify the cause will be necessary.

4. Conclusions

We have measured the linewidth of the tunable laser consisting of 16-element DFB laser array and an SOA, as a function of the LD and SOA current. The linewidth increased with increasing the SOA current, which was attributed to the gradual increase both in the white FM noise and the 1/f noise component. The intrinsic linewidth stayed below 200 kHz at most SOA current levels when the LD current was highest.

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