Oscillation frequency narrowing and stabilization of a diode laser by using an external cavity

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1. Introduction

Semiconductor lasers have prominent characteristics over their competition; lower cost, greater efficiency and durability. While Semiconductor lasers are expected to next-generation optical communications- and measurement- applications, their spectra are not stable or pure as the other lasers. So, the only obstacles to their use in these areas appear to be the susceptibility of their oscillation frequencies to fluctuations in its driving current and ambient temperature; issues that have confronted researchers from the start. The experiments now underway in our facility involve the stabilization of a temperature-controlled diode laser's oscillation frequency, through the management of its driving current.

External cavity diode laser (ECDL) systems are presently experiencing a surge in popularity as laser light-sources, in advanced optical communications- and measurement-applications. This technique brings the added advantages of a narrower linewidth. However, the ECDL's oscillation frequency is susceptible to the influences of the driving current, changes in the refractive index, and changes in external-cavity length that result from fluctuations in atmospheric temperature. I made every effort to maintain the length of the ECDL cavity, while evaluating oscillation-frequency stability.

The vertical cavity surface emitting laser (VCSEL) is now commercially available, and the ECDL systems using them are expected to improve their frequency stability. The VCSEL's oscillation linewidth is, however, originally very wide, so we expect that the VCSELs with our double optical feedback system will make their oscillation frequency narrow and stable.

2. Experiment

Fig.1 shows optical setup used in this study. We introduced VCSEL as the diode laser in our external cavity system. The VCSEL has low threshold current, single-longitudinal-mode operation, a circular output beam, wafer-scale integration and less mode hopping characteristics by the temperature change than the other semiconductor lasers.

Beam splitters (BS1) divide the output beams of VCSEL1 and VCSEL2. The resulting beams are further divided by beam splitters (BS2), and fed back to the diode lasers from mirrors of Littrow arrangements. In constructing our ECDL systems, we mount two systems on a 400mm×400mm, iron/nickel alloy, super-invar "breadboard", to eliminate the influence of atmospheric temperature on resonator-length.

The ECDL diode laser systems are temperature controlled within 1/100K variation. We measured a beat-note output between two ECDL systems from APD and evaluated the relative frequency stability of two ECDL systems.

3. Result and Examination

We used the square root of the Allan variance, when evaluating oscillation frequency stability, and confirmed that the double optical feedback method improved stability by about one order of magnitude, and narrower the oscillation linewidth down to 3MHz from 150MHz as shown in Fig. 2. Next, we will incorporate a Fabry-Perot type laser diode in place of VCSEL2, because the oscillation linewidth of this type laser is narrower than VCSEL's one. So we think we get the better resolving power and stability.

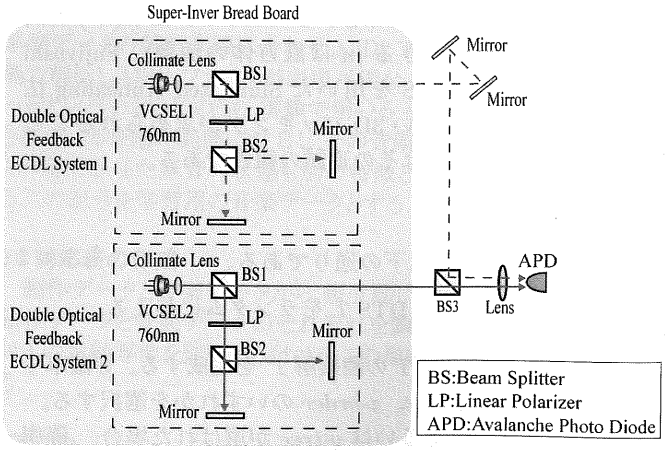

Fig.1 Optical Setup

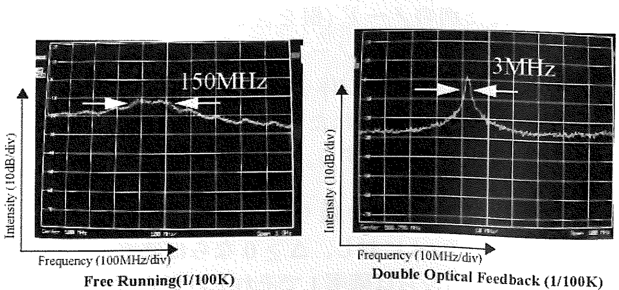

Fig.2 Comparison of oscillation spectra