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Narrow Linewidth Phase-Lockable High Power α-DFB Laser

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Abstract

The free running spectral linewidth of a high-power α-DFB laser at 1064nm is measured to be less than 100 kHz. Electronic feedback to the injection current is used to phase-lock the α-DFB laser to a diode pumped Nd-YAG laser.

The α-DFB (angled-grating distributed-feedback) laser structure provides a unique combination of high output power and single-frequency single spatial-mode operation.[1] In the work reported here we find that these lasers also have an exceptionally narrow spectral linewidth for a semiconductor laser. Many scientific and technical applications such as spectroscopy, laser cooling and trapping of atoms, holography, remote sensing, and wavelength conversion in nonlinear materials require single-frequency narrow linewidth sources. Some special applications such as length metrology, laser ranging, optical frequency synthesis and coherent communications also require phase-coherence between two lasers.

We measured the spectral characteristics of a 1064 nm α-DFB laser by making a beatnote with a narrow linewidth (~1 kHz) Nd-YAG laser that served as a reference oscillator. The α-DFB laser had a threshold of 450 mA and operated single frequency up to an output power of 650 mW at 2 A of injection current. Its output beam was collimated, passed through an optical isolator and combined with the Nd-YAG laser on a fast photodiode. The resulting beatnote between the lasers was analyzed in the time and frequency domains. An RF spectrum analyzer display of the beatnote is shown in Fig.1. We measured a free-running fast-linewidth of ~80 kHz full width at -3dB$_c$ and ~800 kHz full width at -25 dB. This is a remarkably narrow linewidth for a semiconductor laser, particularly such a high power device, and is more than adequate for most applications. The longer term frequency jitter and drift amounted to ~12 MHz in one minute, apparently limited by current and temperature fluctuations, and possibly small amounts of optical feedback from the collimating optics.

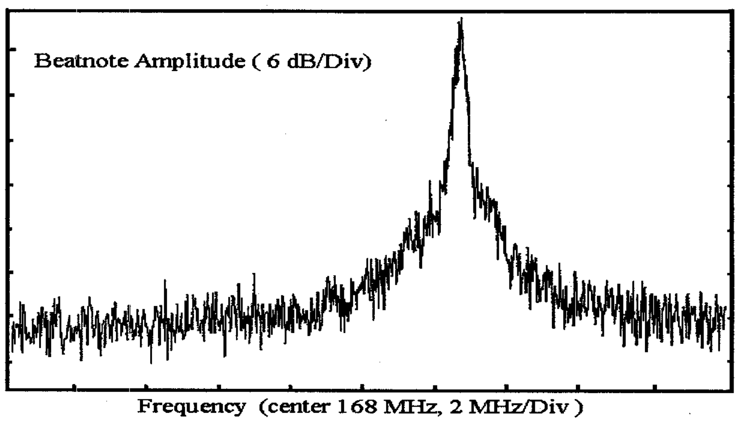

Fig. 1 An RF spectrum analyzer display of the beatnote between an α-DFB laser and a diode-pumped Nd-YAG laser. Fast linewidth for the α-DFB laser is about 80 kHz full width at -3dB$_c$. The Spectrum analyzer resolution bandwidth and video bandwidth were 30 kHz and the measurement time was ~100 ms.

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Encouraged by the narrow linewidth of the free-running laser, and the rule-of-thumb that to phase-lock an oscillator usually requires a servo-loop bandwidth equal to an oscillator's linewidth, we anticipated that it would be possible to phase-lock the α-DFB to the Nd-YAG laser. Indeed, a phase-lock loop circuit feeding back to the injection current (with a bandwidth as low as 300 kHz) was sufficient to capture the phase of the α-DFB laser. This means that relatively simple servo electronics can be used to further narrow the linewidth without having to resort to the very fast, minimal-time-delay electronics that are usually required with monolithic diode lasers. Figure 2 shows the beatnote spectrum that is obtained with the phase-locked loop activated. Even with this nonoptimal servo system most of the α-DFB's power is contained in the narrow central spike. Using smaller spectrum analyzer spans and a 100 Hz resolution bandwidth, we measure a signal-to-noise ratio of the carrier to background of about 60 dB. Because of the relatively small amount of frequency jitter on the laser, the phase-lock was robust and was not prone to unlocking in a usual laboratory environment. The spectral density of the frequency noise is much less than is typically found on diode lasers. However, it's broadband nature prevented our first simple servo-loop from capturing all of the optical power into the narrow carrier. This resulted in the broad phase-noise pedestal below the central spike shown in Fig. 2. Nonetheless, our results show that most of the power is in the carrier, and the relative spectral width between the Nd-YAG and the α-DFB laser is less than 1 Hz.

High power and high spectral purity are not usually found in a single semiconductor device. The α-DFB laser is an exception to this rule, and simultaneously provides high power, high brightness and high spectral purity. With many obvious advantages, α-DFB lasers are the first to provide a viable alternative to external-cavity diode laser systems for high-coherence, high-spectral-resolution applications.

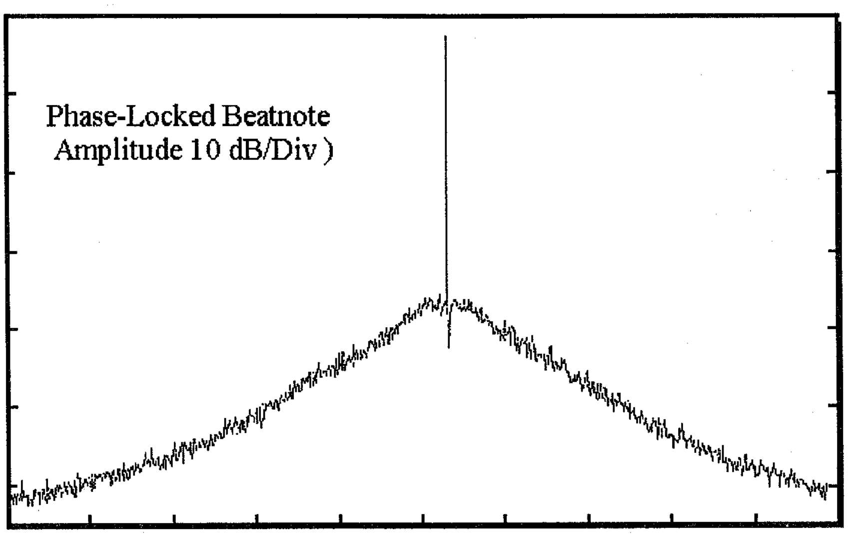

Fig. 2 A beatnote spectrum of the α-DFB laser phase-locked to the Nd-YAG laser. The very narrow spike at the center is the phase-locked carrier which stands on top of a residual phase-noise pedestal. This spectrum was taken with a 1 kHz resolution bandwidth and the spectrum analyzer sweep time was 100 seconds.

References

1. A. Schoenfelder, S.D. DeMars and R.J. Lang, Digest of IEEE/LEOS Summer Topical Meetings, Advanced Semiconductor Lasers and Applications, pg.72-73, Montreal Aug. 1997.