Ultra-narrow (sub-MHz) Linewidth Emission from Discrete Mode Laser Diodes

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A new class of semiconductor laser, termed Discrete Mode (DM) laser, has been introduced [1] which provides a low-cost manufacturable technology for high speed stable single mode communications without optical isolation, and which can achieve wide wavelength tunability [2]. Here we demonstrate that, in addition, this class of laser exhibits ultra-narrow sub MHz linewidth emission such as is necessary for numerous applications in optical communications and sensors, without introducing severe levels of complexity into the laser design which is of paramount importance for devices to be of practical commercial use. We also compare the spectral performance of commercial DM and DFB lasers.

Distributed feedback (DFB) lasers and vertical cavity surface emitting lasers (VCSELs) require very stringent fabrication conditions for narrow linewidth operation and neither device is readily able to achieve linewidths below 1 MHz. DM lasers are obtained by etching small numbers of index perturbing slot features into otherwise conventional ridge waveguide FP lasers in order emit light in a single mode at a predetermined wavelength [1]. In these lasers the optical feedback is provided mainly by the facets of the device with the allowed longitudinal modes being determined by the distance between the facets and the average refractive index of the cavity. The slot features physically introduce a spatially varying effective index perturbation on top of the constant average effective index of the unperturbed cavity. This manifests itself in the Fourier domain as a wavelength selective loss spectrum. Suitable positioning of these slots therefore allows the mirror loss spectrum of an FP laser to be manipulated in order to achieve stable single longitudinal mode emission by reducing the threshold gain of an individual cavity mode below that of all other cavity modes [1].

The devices used in this work were asymmetrically coated ridge waveguide Fabry Perot lasers which incorporated etched slot features and emitting around $\lambda = 1.55$ μm. The asymmetric coating serves to redirect light that would normally exit from the rear facet of the laser to the front facet as is common in FP laser design. The active region of the devices consisted of a strained compensated InAlGaAs MQW structure. The ridge waveguide and slot features were made using only a combination of conventional dry and wet etching surface processing techniques. Regrowth was not used in any stage of device fabrication. Additionally, the slot features do not impinge on the active region [1]. The cavity length of the devices was 350μm and the ridge width was approximately 2.5μm. To achieve the desired spectrum the positions of the etched slot features were generated using an analytical procedure.

Fig. 1(inset) shows a SMSR > 40 dB single-mode DM laser emission spectrum biased at 60 mA. To resolve the linewidth of these devices we used a commercial self-heterodyne detection system with a frequency resolution of 20 kHz (Advantest Q73321). In Figure 1 we plot the spectral linewidth (Δv) versus the inverse optical output power for this DM laser and also for a standard commercial DFB laser. The optical power levels are measured after coupling light from the devices into single-mode fibre, and coupling losses for both devices is around 3 dB. Both devices follow the well-known modified Schalow-Townes relationship. The measured linewidth of the DM laser decreases from about 400 KHz to 200 kHz with slight fluctuations whereas the DFB linewidth varies from 17 to 7 MHz. Remarkably, at equivalent emission powers, the DM laser linewidth is up to 200x narrower than the DFB device with similar results being obtained with other randomly chosen DM devices. Currently we are reconciling this record-breaking performance with theory. Nonetheless this performance represents a significant improvement in linewidth when compared with other semiconductor single-mode laser chips.

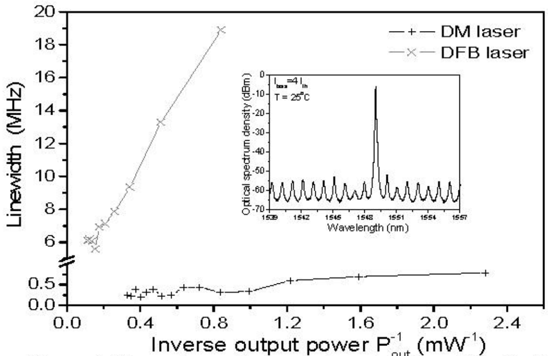

Figure 1. Comparison of measured spectral linewidths for DFB and DM lasers. Inset shows the DM lasing spectrum.

References

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