10:45am - 11:00am
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Room 203

Stabilization of Passively Mode-Locked Semiconductor Laser Repetition Frequency

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Passively mode-locked semiconductor diode lasers have demonstrated repetition frequencies up to 350 GHz [1]. However, most applications for optical pulses with a millimeter-wave repetition frequency require that the repetition frequency be stable, and synchronized to a low frequency reference. This stabilization can be provided by hybrid mode-locking, where current injection is used for gain modulation. However current injection is limited by the electrical parasitics of the contacts.

We demonstrate for the first time feedback stabilization of passively mode-locked semiconductor diode lasers. This technique is useful for stabilizing millimeter-wave repetition frequency mode-locked devices as it is not limited by the laser contact electrical parasitics. Electrical feedback has previously been used to stabilize a mode-locked dye laser and color center laser using a piezoelectric tuning element to adjust the cavity length [2]. This stabilization technique is unique in that the photodetection and frequency tuning functions are monolithically integrated into the laser structure.

The experimental mode-locking configuration is shown in Figure 1. The active device was a 360 μm long GaAs/AlGaAs bulk active region laser fabricated using impurity induced disordering [3]. The laser was antireflection (AR) coated on one facet and coupled to a 5 GHz external cavity. A reversed biased 8 μm long absorber was used as a saturable absorber to produce passive mode-locking. The absorber was also used as a photodetector to generate an electrical output at the pulse repetition frequency.

Feedback stabilization requires control of the repetition frequency by a DC signal. Previously we demonstrated repetition frequency tuning by current injection of a short segment [4]. The two parameters that can be used for repetition frequency tuning of a semiconductor laser are forward current for gain sections and reverse voltage for absorbing sections. The repetition frequency and power dependence on gain and absorber bias is shown in Figure 2. The repetition frequency can be tuned with very little power variation using the absorber voltage, which reduces AM noise to FM noise conversion in the stabilization process. In contrast, varying the gain segment current causes a much larger change in output power and a smaller repetition frequency tuning range.

Several mechanisms can vary the pulse repetition frequency as a function of bias. One is carrier dependent changes in group velocity, which determines the pulse transit time through the laser. Another mechanism is a change in the gain or absorption saturation. Saturable gain and absorption changes cause a shift in the pulse center and therefore the effective cavity round trip time.

The electrical network for feedback stabilization is shown in Figure 1. The short segment is used as a saturable absorber, photodetector, and a repetition frequency tuning element. The resulting phase noise shown in Figure 3 was measured using an external high speed photodetector. The phase noise after stabilization was unchanged at carrier offsets much greater than the feedback loop bandwidth of 30 kHz. For carrier offsets below the stabilization loop bandwidth, the optical output tracks the electrical reference. The unstabilized phase noise has a slope of 20dB/decade, which is a result of frequency modulation by a white noise source.

This electrical feedback technique can be extended into the millimeter-wave band using monolithic cavity devices. A low frequency reference signal can be used together with a sampling mixer to allow stabilization of an optically generated millimeter-wave signal.

This research was supported by a National Science Foundation Presidential Young Investigator award. R. Helkey was supported by a Newport Research Fellowship.

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[2] D.R. Walker, D.W. Crust, W.E. Sleat, and W. Sibbett, "Reduction of Phase Noise in Passively Mode-Locked Lasers", IEEE J. Quantum. Electron., JQE-28, 289 (1992).

[3] R.L. Thornton, W.J. Mosby, T.J. Paoli, IEEE J. Lightwave Technology 6, 786 (1988).

[4] D.J. Derickson, R.J. Helkey, A. Mar, J.G. Wasserbauer, J.E. Bowers, "Microwave and Millimeter Wave Signal Generation Using Mode-Locked Semiconductor Lasers with Intra-Waveguide Saturable Absorbers", IEEE MTT International Microwave Symposium, V-2, Albuquerque New Mexico, June (1992).

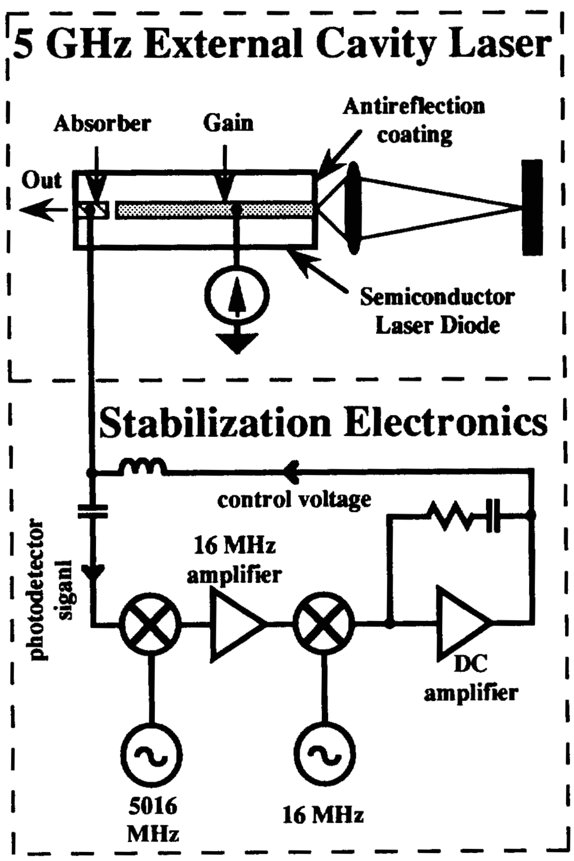

Figure 1. Experimental configuration for passive mode-locking and repetition rate stabilization.

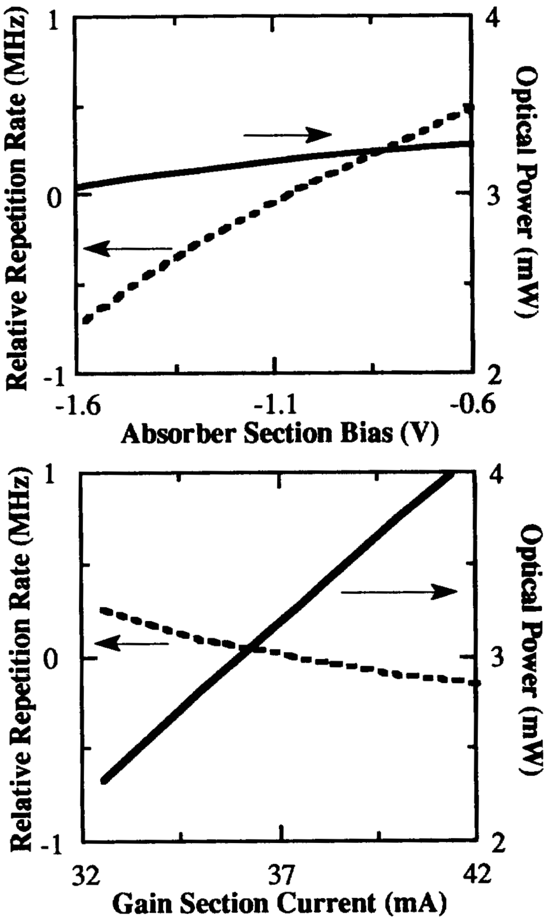

Figure 2. Measured repetition frequency tuning using control of gain section current and absorber section voltage.

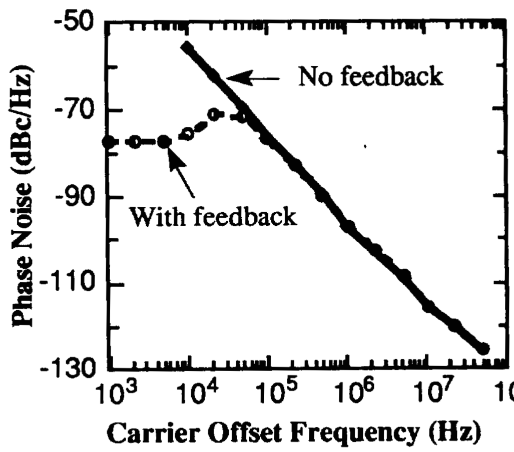

Figure 3. Single sideband phase noise with and without electrical stabilization.