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Numerical Analysis of Suppression Effects on Optical Feedback Noise by Superposition of High Frequency Current in Semiconductor Lasers

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Semiconductor lasers play a central role in the growing world of optoelectronic technologies. But they tend to be suffered by the optical feedback (OFB) noise caused by reflection of the output light at surface of the optical disc or the optical fiber.

Superposition of high frequency (HF) current is popularly used as a technique to suppress the OFB noise. But experiment revealed that the OFB noise is not suppressed when frequency of the superposed current coincides with a rational number of the round-trip time for the OFB [1]. Author's group gave a theoretical analysis on this problem based on mode competition phenomena among external cavity modes [1]. Since this analysis was based on small signal approximation, quantitative assessment for conditions unable to suppress OFB noise was difficult.

In this paper, we present a new model by which generation of the OFB noise and its suppression by the superposition of HF current can be numerically simulated. Conditions unable to suppress the OFB noise are evidently shown.

Mode dynamics of semiconductor lasers operating under external OFB with superposition of modulated HF current are governed by the following rate equations of the modal photon number $S_p(t)$, modal phase $\theta_p(t)$ and number of injected electrons $N(t)$.

$$\frac{dS_p}{dt} = \left(G_p - G_{tho} + \frac{c}{n_r L} \ln\left|U_p\right| \right) S_p + \frac{a\xi N/V}{\left[2\frac{(\lambda_p - \lambda_0)}{\delta\lambda} \right]^2 + 1} + F_{Sp}(t)$$

$$\frac{d\theta_p}{dt} = \frac{1}{2}\left[\frac{\alpha a \xi}{V}(N - \overline{N}) - \frac{c}{n_r L}\varphi \right] + F_{\theta_p}(t)$$

$$\frac{dN}{dt} = -\sum_p A_p S_p - \frac{N}{\tau_S} + \frac{I}{e} \quad \text{with } I = I_D + I_M \cos(2\pi f_M t)$$

Calculated examples of noise spectrum of the OFB noise and its suppression by superposition of HF current are shown in Fig. 1. Quantum noise spectra are also shown for comparison. Dependency of suppressed noise level with the modulation depth of HF current is shown in Fig. 2. Dependency of the modulation frequency (f_M) of the HF current for noise suppression is shown in Fig. 3. The noise was reduced in wide range of the f_M. But the RIN raised up when $nf_M = mf_{ex}$, where f_{ex} is the external round-trip time period of OFB. This phenomenon was also demonstrated by experimental data in [1].

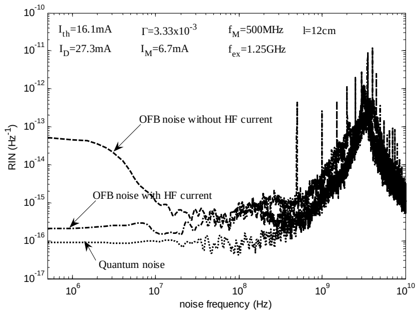

Fig. 1. Spectra of RIN profiles of OFB noise and suppressed noise by HF current.

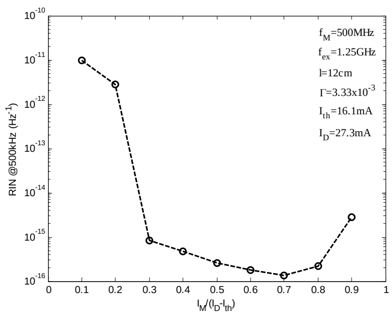

Fig. 2. Dependency of suppressed noise with modulation depth of HF current.

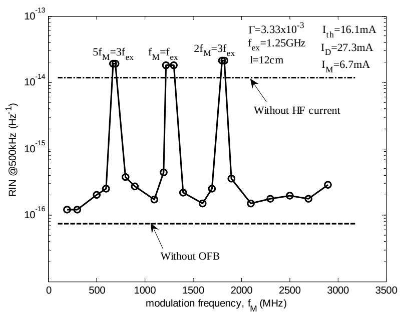

Fig. 3. Dependence of RIN on modulation frequency of the superposed HF current.

References:

[1] M. Yamada *et al.*, IEICE Trans. Electron., **E84-C**, 10, 1588-1596 (2001).