MICROCHIP LASER RIN SUPPRESSION FOR FIBER RADIO APPLICATIONS

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ABSTRACT

This paper is about the suppression of the relative intensity noise (RIN) peak and phase noise of a diode pumped Neodymium-doped Lithium Niobate (Nd:$LiNbO_3$) microchip laser. Relaxation oscillations result in about 15-20 dB noise peak above the flat noise at 350 kHz offset frequency. In case of high quality requirements this noise peak is significantly disturbing. In this paper a new approach is presented for the suppression of the RIN peak and phase noise in microchip lasers.

INTRODUCTION

Laser noise is a crucial parameter in many applications, like fiber radio systems, optically fed mobile radio base stations, high speed optical links, etc. Therefore significant effort is done to reduce the noise of lasers. The microchip laser exhibits a very low phase noise. However, it suffers from the relaxation resonance as every laser. At the relaxation resonance the noise has a high peak, 15-20 dB higher than that outside of the resonance region.
There have recently been a number of publications on the design and analysis of fiber radio systems using solid state microchip lasers. Herczfeld [1], Jemison et al. [2] have examined the applications of a Nd:$LiNbO_3$ mode locked laser in an LMDS system. Because of the good phase noise characteristics the optical generation of the local oscillator signal is feasible. However, the suppression of the close to carrier relaxation oscillations can improve the quality of the whole system. A number of feedback loops for different types of lasers have been evaluated and their corresponding advantages discussed. Kane [3] and Harb [4] have designed an electronic feedback for the reduction of intensity noise in a diode pumped Nd:YAG laser. Similarly, Geronimo [5] and Taccheo [6] have investigated the intensity noise reduction in an ytterbium-codoped erbium glass laser. In addition, the noise suppression with an external feedback was studied by Tsang-Der Ni [7]. Another possible way of RIN cancellation was presented by Madjar et al. [8] using balanced fiber-optic communication link. In this paper a new approach is presented for the suppression of the RIN peak and phase noise in microchip lasers.

THEORY AND SIMULATION

The noise peak of the microchip laser at 350kHz is reduced by using negative feedback. The laser transmitter system, which consists of the pumping laser diode, the Nd:$LiNbO_3$ microchip laser, an optical beam splitter and the control circuits is depicted in Fig. 1.

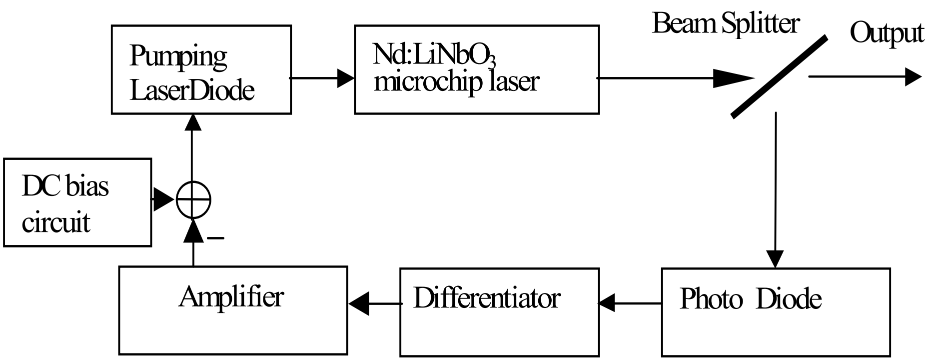

Fig. 1. Block diagram of the optoelectronic feedback-loop. The suppression of the relative intensity noise peak is performed by the differentiating control loop.

A part of the laser output signal is detected, amplified, differentiated and phase shifted and this signal controls the power of the pump diode. As the transfer function of the laser transmitter has a phase shift of almost -180° near the frequency where the gain of the open loop goes below unity, we have to realize positive phase shift in the amplifier following the low noise photodiode. To increase the phase noise sensitivity of the loop we use a differentiator circuit (phase shift +90°) with a zero near to the relaxation oscillation frequency and a pole at *f*=10MHz. The zero of the differentiator in the feedback circuit can compensate the effect of the complex conjugate poles of the microchip laser transfer function, which are responsible for the high noise peak. The additional pole at a higher frequency (10MHz) is only needed because of the stability of the differentiator circuit and does not have any effect in the frequency range of the peak. After the differentiation the phase shifted and amplified signal is added to the bias current of the pump diode.

Simulation

During the computer simulations the RIN peak of the solid state laser was modeled by the simple transfer function G(s)

$$G(s) = \frac{1}{1 + 2dTs + T^2 s^2} = \frac{1}{1 + 2 \cdot 10^{-8} s + 2.06116 \cdot 10^{-13} s^2} \qquad (1)$$

The parameter d defines the value of the complex conjugate poles and so the height of the noise peak, and T determines the resonance frequency. Bode plot of the RIN model used in the calculations is shown in Fig. 2. Using the transfer function G(s) of the RIN model the transfer function of the closed feedback loop is shown in (2), where β(s) is the transfer function of the feedback system.

$$F(s) = \frac{G(s)}{1 + G(s)\beta(s)} \qquad (2)$$

The results of the computer simulations are shown in Fig. 3. The real disturbing resonance term (open loop) stands out by 15-20 dB from the outside region.
The simulation results show an intensity noise suppression of ~20dB at the resonant frequency and a slight increase in noise at higher frequencies. These frequencies are within the circle of radius 1 around the point (-1,0) in the Nyquist diagram of the open loop transfer function. Resetting the phase shift and the gain of the differentiator circuit in the feedback loop it is possible to tailor the noise suppression to the specific application, Fig. 4.

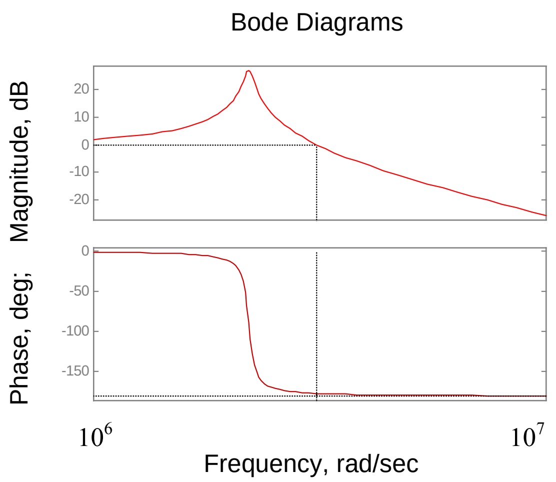

Fig. 2. Bode plot of the RIN model

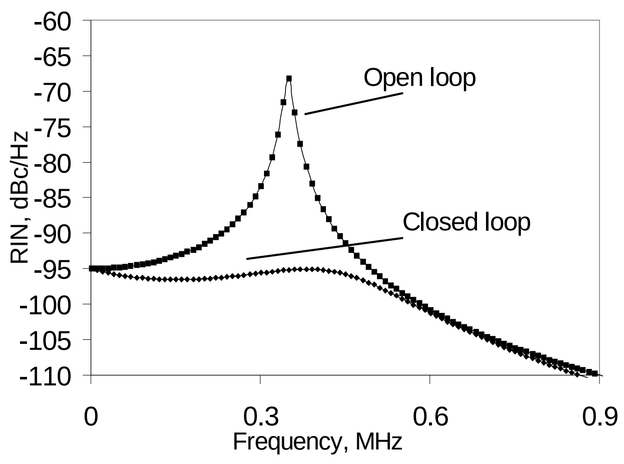

Fig. 3. Simulation results of RIN suppression

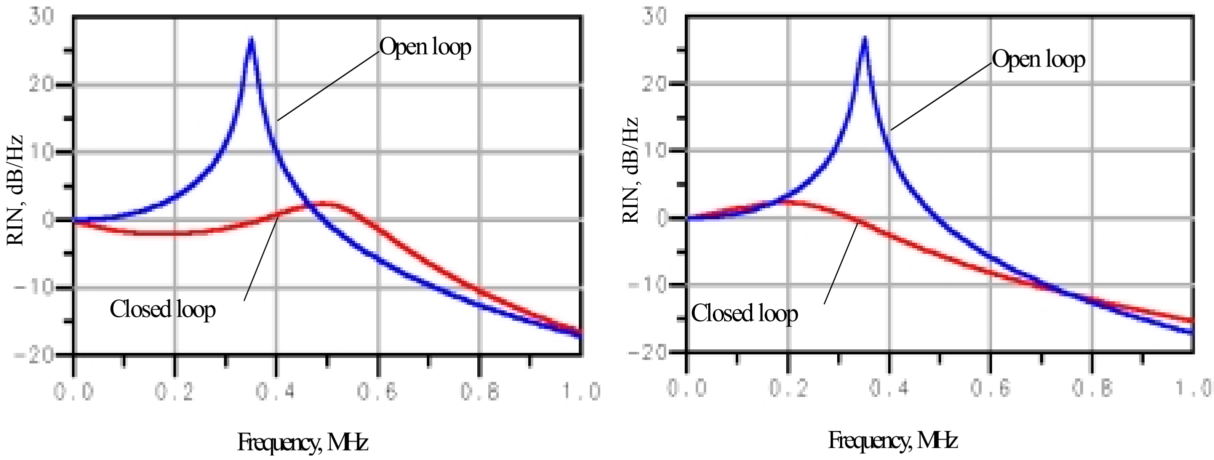

Fig. 4. The frequency of the noise suppression can be shifted by adjusting the parameters of the feedback loop.

The Nyquist diagram of the simulated control loop is shown in Fig. 5. The instability point (-1,0) is not encompassed by the loop, so the loop is stable and has a maximum suppression at the relaxation oscillation frequency

MEASUREMENT RESULTS

The measured relative intensity noise spectrum with and without the feedback loop was detected after the polarizing beam splitter by an out-of-loop photodetector, which was followed by a low noise transimpedance amplifier. Fig.6. shows the results, which were recorded by a HP8593E Spectrum Analyzer. The noise peak is reduced by 13 dB due to the feedback loop. The noise level of the microchip laser can be further reduced, it is only limited by the noise of the measuring photoreceiver. When using low noise photodiodes the suppression at the relaxation oscillation can be increased.
The RIN suppression can be employed in case of other lasers too, such as pump laser diodes in Erbium-Doped Fiber Amplifiers (EDFA), in optical transmitters or in optical local oscillators.

CONCLUSIONS

A system with capabilities both suppressing the RIN peak and reducing the phase noise of a Nd:LiNbO$_3$ microchip laser was demonstrated in this paper.
This approach applied a feedback loop sensitive to the phase noise. Special attention had to be given to the stability and the noise of control system. It is worth noting that our measurements showed it is possible to suppress all classical intensity noise.

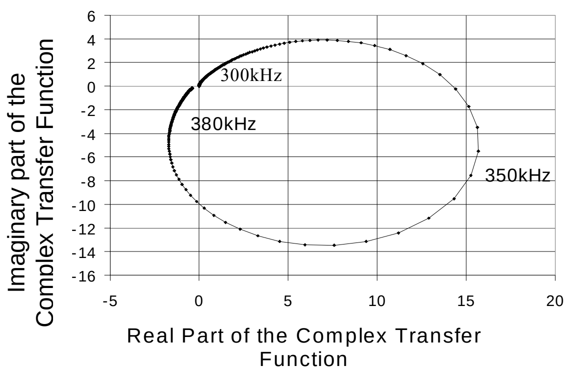

Fig. 5. The Nyquist diagram of the control loop. Maximum is at 350kHz in the pos.-neg. quadrant of the diagram. The instability point is not encompassed by the curve, hence the loop is stable.

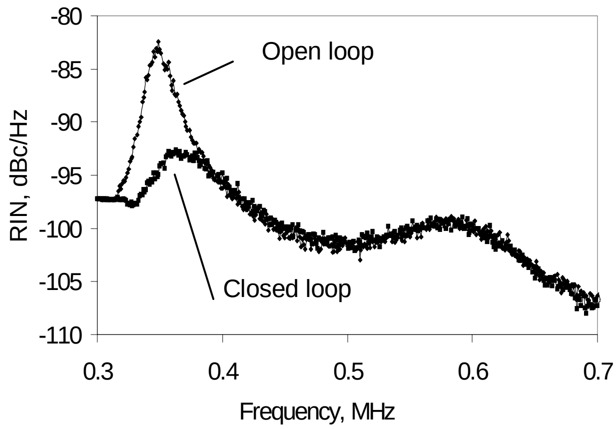

Fig. 6. The measured RIN suppression

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