

Optimization of Dynamic Properties and Link Performance for Directly-Modulated Gain-Coupled DFB Lasers

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Abstract: This paper demonstrates the respective roles that combined gain- and index-coupling play in the dynamic properties and overall link performance of DFB lasers. It is shown that for datacommunication applications, modest gain-coupling enables optimum transmission at 10Gbit/s.

Introduction

In recent years there has been much interest in the relative merits of gain- and index-coupled DFB lasers. Gain-coupled DFB (GC-DFB) lasers have demonstrated advantages over conventional index-coupled devices in terms of bandwidth and chirp [1,2]. However excellent link performance has also been demonstrated using index-coupled devices and they remain heavily used in system applications. Although a large number of studies have been carried out concerning the bandwidth, chirp and damping performance of both classes of lasers, little has been reported in showing how these complex gain- and index-coupled devices can combine to enable enhanced overall link performance under high-speed direct modulation. This paper therefore seeks to assess for the first time the relative importance of gain- and index-coupling in DFB lasers for high performance optical links. It is shown that for links operating at 10Gbit/s, a transmission-oriented optimum complex-coupled DFB design can be realized.

In order to assess the relative merits of gain and index gratings, DFB lasers with uniform gratings and HR-AR (95%, 5%) facet coatings are modeled, with the aid of a transmission line laser model (TLLM). The model assumes an emission wavelength of 1550nm and a fixed cavity length L of 300 μ m. A complex kappa-length product $\kappa L = \kappa_{index}L + j\kappa_{gain}L$ is used and varied so that a full range of complex-coupled lasers are assessed in terms of bandwidth, chirp and damping performance. A system model, VPItransmissionMakerTM, is used to evaluate the transmission penalty of a link using the lasers. Our simulations of the lasers reported in [3] indicate high damping rate of about 44GHz and resonance frequency of around 12GHz, showing good agreements with experimental data.

Results and Discussion

Initial simulations at a data rate of 10Gbit/s show that for a complex-coupled DFB laser, a large $\kappa_{index}L$ component helps enhance the damping rate γ . This is due to the enhancement of damping factor K . High γ provides clearly open eye diagrams, whereas under-damped operation can lead to ringing and distortions. This can be observed by studying the eye diagrams of two lasers with different κ_{index} but otherwise identical parameters, as shown in Fig. 1. Furthermore, a more comprehensive study is carried out by plotting the damping rate γ , resonance frequency f_r and chirp against the 2-D complex plane of $\kappa_{index}L$ and $\kappa_{gain}L$ as shown in Fig. 2. It is stressed that here we assume a cavity length L of 300 μ m, for shorter cavity, realistic range of κL values may vary. It is shown in Fig. 2(a) that, together with a large $\kappa_{index}L$, $\kappa_{gain}L$ enhances f_r , which is in good agreement with previous experimental work [1]. Nevertheless, as f_r increases due to an increased κ_{gain} , γ decreases, which is undesired. A large $\kappa_{index}L$ together with $\kappa_{gain}L$, however, helps enhance the damping rate as shown in Fig. 2(b). This is largely because the damping factor K is affected by the variation of $\kappa_{index}L$ and $\kappa_{gain}L$. Note that in Fig. 2 for κL values approaching 0+j0 region (Fabry-Perot), the actual data is not shown, in order to display other data in a proper scale. Fig. 2(c) indicates that a properly increased $\kappa_{gain}L$ suppresses the chirp, while a large $\kappa_{gain}L$ leads to increased chirp together with distortion of the eye diagram due to reduced damping. So there is clearly a design trade-off among f_r , γ and chirp, and some optimum region may exist where they together offer optimized transmission performance with appropriate $\kappa_{index}L$ and $\kappa_{gain}L$. Transmission penalties are hence plotted in Fig. 2(d). A 20 km single mode fiber (SMF) (17ps/km/nm dispersion, 0.2dB/km attenuation) and a 3-order Bessel low pass filter (LPF) are assumed, penalties are measured at a BER of 10^{-9} . A constant extinction ratio of 6dB is maintained by adjusting the bias and drive current. An optimum region centered around κL of 5.0+j0.2 is identified, with minimum transmission penalty demonstrated.

Conclusion

It is shown that DFB laser design can be optimized aiming at the best transmission performance. High damping rate, high resonance frequency and low chirp are achievable with appropriate combination of $\kappa_{index}L$ and $\kappa_{gain}L$.

References

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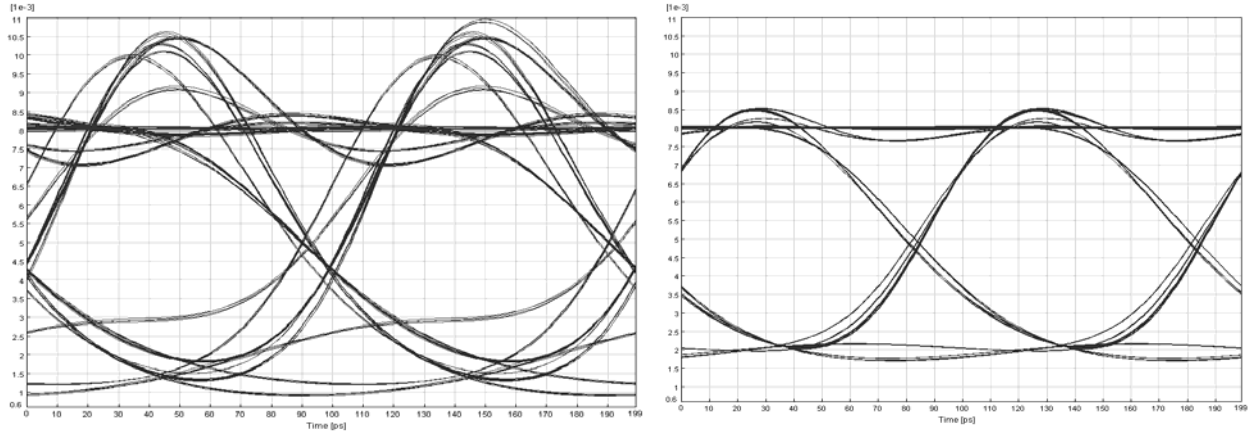


Fig. 1. 10Gbit/s back-back filtered eye diagrams of lasers with $\kappa L = 2 + j0.15$ (left) and $\kappa L = 6 + j0.15$ (right), with time base of 10ps/div

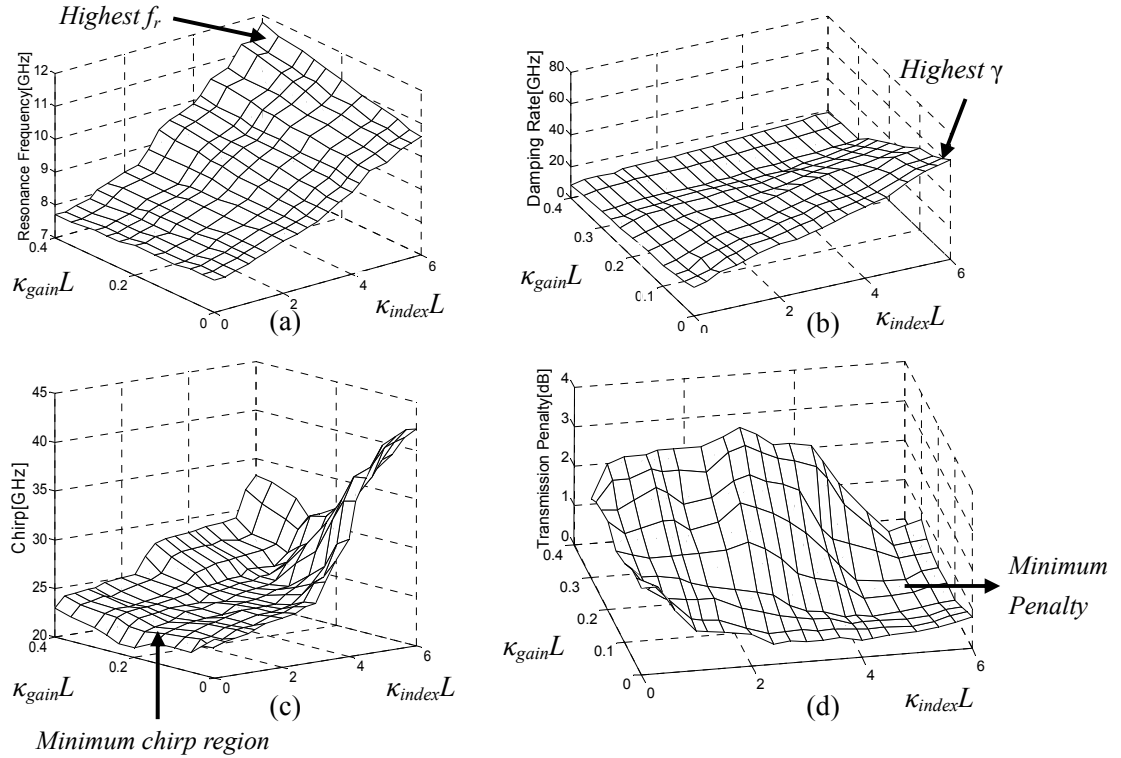


Fig. 2. Plot of (a) resonance frequency f_r , (b) damping rate γ , (c) chirp and (d) transmission penalty for a 20-km SMF link at 10 Gb/s vs. index-coupling ($\kappa_{index}L$) and gain-coupling ($\kappa_{gain}L$) components of the complex coupling κL .