ASEC 2024 Conference
The 5th International Electronic Conference on Applied Sciences
04–06 December 2024 | Online
MDPI

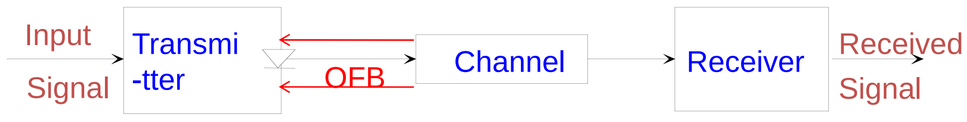
Dynamics and Phase Noise of Time Delayed Laser Diode with Non-Radiative Recombination Rate

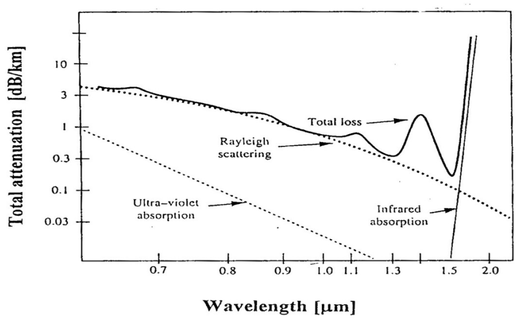
Salah Abdulrhmann, and Jabir Hakami
Jazan University, College of Science, Department of Physical Sciences, Physics Division, P.O. Box 114, 45142 Jazan, Kingdom of Saudi Arabia. (sabdulrhmann@jazanu.edu.sa)

INTRODUCTION & AIM

Technology of optical communications changed the world as small village
Communication helps us to get closer one to the other and exchange information

➢ **In near future "local-area-communication network" is planned to be driven to each home.**

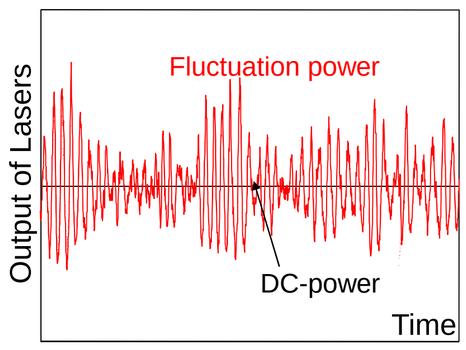




Long wavelength SLs such as InGaAsP/InP are the most applicable light sources
In this work we concern with OFB in the transmitter side, specifically in semiconductor lasers

Critical limitation to Optical Fiber Communications

The laser itself has intrinsic fluctuation, which is seen on the output power. The power fluctuates about its dc-value
In the laboratory of optical communication in Kanazawa University in Japan, we succeeded to develop and establish a versatile time delay model to analyze operations of SLs under an arbitrary amount of OFB.



AIMS OF THE WORK

Investigating impact of Non-radiative rate and OFB strength on the SLs dynamics, RIN and **phase** noise (FN).
Determine the optimum conditions to operate InGaAsP/InP SLs subject to a wide range of optical feedback with low **RIN and phase** noise

THEORETICAL FRAME

Modified Rate Equations Including Noise Sources

$$\frac{dS}{dt}=\left\{A-BS-G_{th0}+\frac{c}{n_D L_D}\ln|T|\right\}S+\frac{a\xi}{V}N+F_S(t)$$ photon number equation

$$\frac{d\theta}{dt}=\frac{\alpha a\xi}{2V}(N-\bar{N})-\frac{c}{2n_D L_D}(\varphi-\bar{\varphi})+F_\theta(t)$$ optical phase equation

$$\frac{dN}{dt}=-\frac{a\xi}{V}(N-N_g)S-N\left(\frac{1}{\tau_r}+\frac{1}{\tau_{nr}}\right)+\frac{I}{e}+F_N(t)$$ carrier number Equation

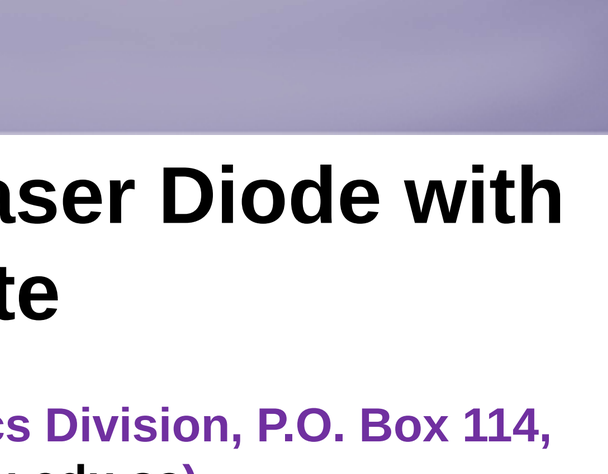
$$T=1-\frac{1-R_f}{R_f}\sum_{m=1}^{\infty}(R_f R_g)^{m/2}e^{-jm\psi}\sqrt{\frac{S(t-m\tau)}{S(t)}}e^{j[\theta(t-m\tau)-\theta(t)]}=|T|\,e^{-j\varphi}$$

Ψ : Phase difference between delayed and reflected field at R_f

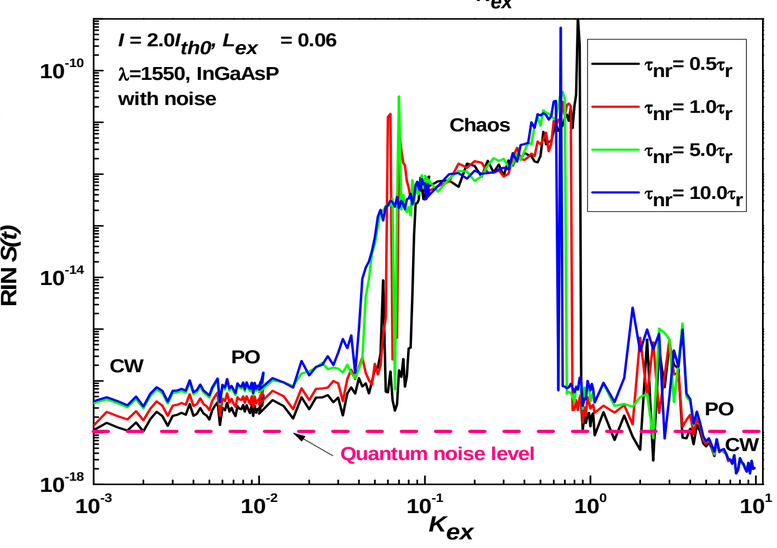
RESULTS & DISCUSSION

Bifurcation diagrams of a SL under OFB when I/I_{th0}=2.0

Under very weak OFB
stationary solution bifurcates first into a stable limiting cycle characterizing PO
The HB point is moved to lower values of the OFB strength K_{ex} by increasing τ_{nr}

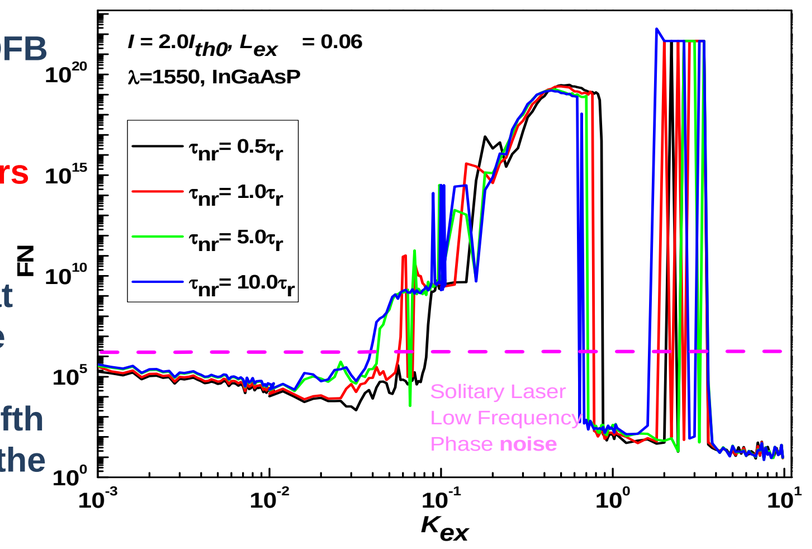


Under strong OFB
the laser stability is improved and moves toward stable operations with stable output
Changing **non-radiative recombination rate** changes the rout-to-chaos of the laser from SH type to PD type depending on its value.



RIN under weak OFB higher than quantum noise level
In Chaotic region RIN is enhanced six orders higher than quantum noise level.
Under very strong OFB and at lower values of non-radiative recombination rate is suppressed approximately to the quantum noise level

Phase noise (FN) under weak OFB near to FN of Solitary laser
In Chaotic regions FN is enhanced more than 12th orders of magnitude of Solitary FN approximately.
Under very strong OFB and at lower values of non-radiative recombination rate FN is suppressed approximately to fifth order of magnitude lower than the Solitary laser FN



CONCLUSION

Non-radiative rate significantly affects the laser dynamics, RIN, phase noise. Phase noise and RIN is reduced at weak and strong OFB. In the chaotic region the phase and RIN enhanced to more than 12 and 6 order of magnitude more than solitary and quantum noise level, respectively. Reduction in the non-radiative recombination rate shifts the chaotic state to stable states. The RIN and phase noise approaches the quantum noise level.
Authors suggest that: operating semiconductor lasers with low non-radiative recombination rate with weak or strong OFB improve their instability.

ACKNOWLEDGMENT

The authors gratefully acknowledge the funding of the Deanship of Graduate Studies and Scientific Research, Jazan University, Saudi Arabia, through project number: (RG24-S058).

REFERENCES

[1] S. Abdulrhmann, et al., IEEE J. Sel. Top. Quantum Electron., 9 , pp. 1265–1274, 2003.
[2] Salah Abdulrhmann, and Jabir Hakami, Appl. Sci., 13(24), pp. 13099, 2023.