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Feedback-Insensitive Integrated Laser

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It is well known that semiconductor lasers are highly susceptible to external optical feedback (EOF)[1] which is detrimental to laser performance in many applications. EOF is normally prevented using optical isolators, but these cannot be integrated. Therefore we propose to fabricate an integrated feedback-insensitive laser. Simulations show that such a device can be realized as a ring laser in which the clockwise (cw) and counterclockwise (ccw) modes are not optically coupled. We have studied in detail two configurations of integrated ring lasers that show such characteristics. The theoretical analysis for both configurations is based on rate equations backed up by results from simulation packages.

The first ring laser configuration studied is a so called S-ring laser and is sketched in figure 1a. Here, A and B are 2x1 couplers and O is a 2x2 coupler. The field in the ccw mode splits in A and B and joins the cw mode in B and A, respectively. This creates a different behaviour in the cw and ccw directions which favors the cw over the ccw mode such that the ccw mode will be suppressed. Ref. [2] has implemented such a laser and suppression of the cw mode by 35 dB was observed, but EOF sensitivity was not addressed. Back reflections reaching the out coupler port of the ccw mode will end up in the cw mode and hence are expected to be suppressed as well.

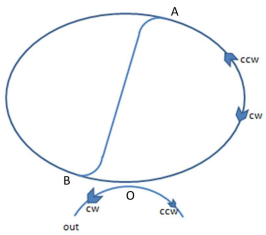

Fig 1a: schematic layout of S-ring laser

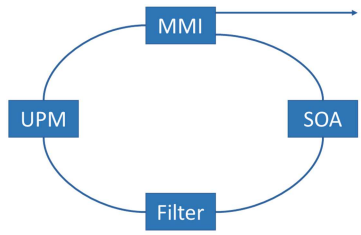

Fig 1b: schematic layout of ring laser with UPM

A rate equation analysis for this laser shows that without EOF the cw mode will contain more power than the ccw mode, but the damping of the latter is typically weak, i.e. not exponential but proportional to $1/t^2$, where t is time. Since the ccw mode is at threshold, it is most susceptible for external feedback from the cw mode. Our theory predicts as high as ~10dB cw-ccw power ratio at ~1% EOF. Simulations also show the laser spectrum to be highly sensitive to the feedback. From this we predict that the robustness of such a laser is insufficient for practical applications.

The second laser studied consists of a ring laser and a built-in unidirectional phase modulator (UPM) as shown in figure 2a. Apart from the semiconductor optical amplifier (SOA) and the multi mode interferometer (MMI) for out coupling, the ring contains a UPM and an appropriate spectral filter. The UPM is explained and demonstrated in [3]; ideally it has unit transmission in one direction (the cw direction in this case) and redistributes power in the other direction over various frequencies as shown in figure

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2b. Thus, assuming ideal components total isolation is achieved at the designed operation frequency when this component is combined with a spectral filter.

Analysis shows suppression of ccw mode with respect to cw mode of ~30dB for ~1% EOF (power). Figures 3 show the simulated dependence of the RIN and linewidth on the

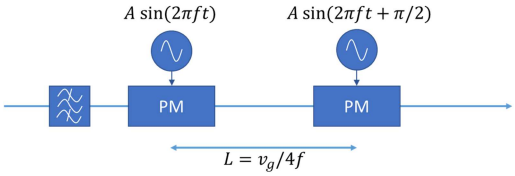

Fig 2a: schematic layout of UPM

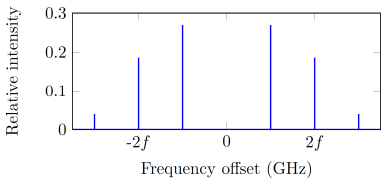

Fig 2b: transmission of UPM in reverse direction

fraction R of output power that is returned to the laser for three transmission values of the single-pass transmission T_{UPM} of the UPM and filter combination at the operation wavelength. These figures show negligible influence on the RIN and linewidth of the cw output when T_{UPM} is sufficiently small. We therefore conclude that this proposed laser will be highly insensitive to EOF. We have fabricated a photonic integrated circuit with a ring laser with UPM which is currently being characterized. Its design and initial experimental results will be presented.

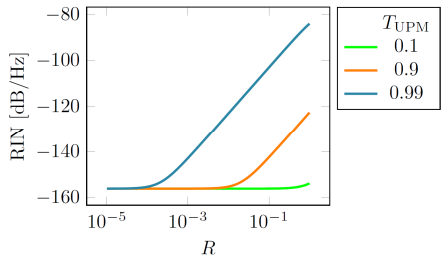

Fig 3a: RIN vs EOF and UPM transmission

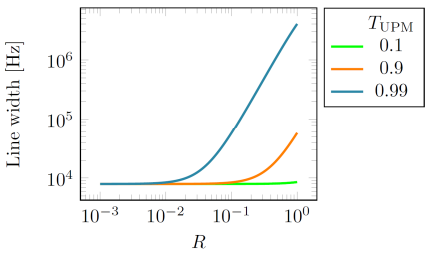

Fig 3b: line width vs EOF and UPM transmission

References

[1] R. Tkach and A. Chraplyvy, Journal of Lightwave Technology, 4(11):1655–1661, 1986.
[2] Hongjun Cao, Hui Deng, Hai Ling, Chiyu Liu, Vladimir A. Smagley, Robert B. Caldwell, Gennady A. Smolyakov, Allen L. Gray, Luke F. Lester, Petr G. Eliseev, and Marek Osinski, Applied Physics Letters 86, 203117 (2005); doi: 10.1063/1.1931044
[3] Christopher R. Doerr, Nicolas Dupuis, and Liming Zhang, Optics Letters, 36(21):4293, November 2011.

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