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Novel Measurement Scheme for Injection Locking Experiments with Semiconductor Lasers

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Injection locking experiments with semiconductor lasers started in the early eighties. A lot of work was performed since then mainly dealing with locking range and stability, noise, modulation, chirp and linewidth reduction, sidemode injection locking, optical frequency conversion and microwave signal generation. However, there is a lack of quantitative comparison between experimental data and theory. The main reason for this relies on the fact that the experimental set-ups used in most former studies are based on the free-space propagation of light. This causes difficulties in controlling the exact amount of light injected into the slave laser cavity, because the spatial overlap between the optical mode in free-space and the slave laser waveguide is unknown. The experimental set-up presented in this paper allows to overcome this problem. The light generated by the master laser travels through an optical fibre before being injected into the cavity of the slave laser. Using the reciprocity principle, it is possible to control accurately the absolute light power injected from the master laser into the cavity of the slave laser once the power coupling coefficient between the slave waveguide mode and the fibre mode is determined. In addition, the polarisation can be fully controlled despite the birefringence of the optical fibre.

The master and slave used in the experiment were both DFB diode lasers emitting near 1.3 [μm]. Various measurements were carried out showing typical injection locking behaviour with semiconductor lasers (e.g. stable locking, undamped relaxation oscillations, chaos, nearly degenerate four-wave mixing and period doubling). The measurements were compared carefully with the results from a standard rate-equation based model by means of the corresponding power spectra. Measurements and model were linked analytically to make a quantitative comparison possible. Knowing the power coupling between the optical mode in the fibre and the slave laser waveguide, it turned out that measurements and model could be related entirely via the distributed cavity loss of the slave laser. The spectra were normalized with respect to the power spectrum of the free-running slave laser. Measured and calculated power spectra agree very well in all situations, from classical injection locking to chaotic behaviour. Differences mainly stem from some mismatch between the experimental and theoretical operating points, inaccurate parameter values and from noise being neglected in the model. The presented set-up may be easily adapted for experiments with passive optical feedback.

Future work using this experimental set-up will be performed with diode lasers emitting at 1.55 [μm], where Rayleigh backscattering in the fibre and thus undesired light feedback into the slave laser is reduced substantially.

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Effects of the phase difference between the coupling constants upon the threshold characteristics of nonuniformly complex-coupled distributed feedback devices.

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Purely index-coupled distributed feedback (DFB) lasers are well-known components with practical application as optical sources in telecommunication networks using wavelength division multiplexing. Unfortunately, spatial hole burning makes them somewhat problematic above-threshold so that more complicated multisection structures (with multiple phase shifts, phase adjustment region or distributed coupling coefficient for example) have to be designed. On the other hand, gain coupling mechanisms in Bragg gratings attract attention from many research groups and promising devices are expected. Such complex-coupled DFB (CC-DFB) structures have already been studied through the relative amount of gain and index couplings, assuming a fixed phase difference between the two contributions (generally 0 or π) [1]. On the other hand, by lifting the restriction of this fixed phase difference, conventional CC-DFBs have been found to exhibit various interesting and useful properties [2] but, to date, nonuniformly complex-coupled (NCC-DFB) devices have not been addressed.

A comprehensive analysis of multisection DFB lasers with a stepwise constant complex coupling coefficient is derived analytically and numerically. A symmetrical three-section device is studied since it provides major simplifications without loss of physical generality. Solving coupled-wave equations at threshold reveals that the longitudinal profile of coupling, the relative amount of index and gain contributions in each section as well as the phase difference between the coupling constants play quite decisive a role in the modal and spatial (internal fields) properties of complex-coupled structures. Net gain versus detuning graphs, stationary field patterns and field envelopes corresponding to various coupling configurations are presented.

The analysis of CC-DFBs requires considering the modal overlap between the stationary field and the periodic gain variation which is responsible for the high mode discrimination. This concept of *standing wave effect* [3] is extended to multisection devices and quantitatively discussed in order to explain the discrepancies between uniformly and nonuniformly complex-coupled structures. The complex coupling profile is also discussed by its influence on spatial hole burning and threshold gain margin, usual criterions of optimizing sources in optical fibre telecommunication systems.

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