Wide wavelength tuning of sampled grating tunable twin-guide laser diodes

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Tuning characteristics of widely tunable twin-guide (TTG) laser diodes with sampled gratings (SGs) are reported. Two SGs, providing slightly different reflection spectra, enable wide tunability by means of Vernier effect tuning. The device structure is vertically integrated and, hence, a DFB-like laser is obtained, which makes a phase tuning section unnecessary and facilitates easy and fast device characterisation. Although the tuning section can tune the SG reflection spectra by only ~2 nm, an overall tuning range of 28 nm has been achieved by employing Vernier effect tuning. Within the aforementioned tuning range, five supermodes are usable and can be tuned continuously without any mode-hops. The lasers operate at ~1.55 μm wavelength and achieve a maximum output power of 12 mW.

Introduction: Widely tunable lasers with a tuning range of several tens of nanometres are generally regarded as key components for future optical communication networks. While several monolithic widely tunable lasers have been presented to date (an overview can be found in [1, 2]), characterisation and control remains a common issue to practically all presently available devices. Typically, three or even more tuning currents are required for quasi-continuous wavelength tuning. Recently, a novel device structure, the so-called widely tunable twin-guide laser with sampled gratings (SG-TTG) [3], which is based on the well-known tunable twin-guide laser with distributed feedback (DFB-TTG) [4] has been suggested. The main advantage of this novel device structure is its DFB-like behaviour that is typical for any tunable twin-guide laser. Owing to the vertical integration of active and tuning sections, a phase tuning section, which is usually required to adjust the cavity mode position in longitudinally-integrated devices, is needless. Needing only two tuning currents, the SG-TTG hence requires at least one tuning current less than comparable devices. This essentially facilitates efficient characterisation.

In this Letter we report on the tuning characteristics of sampled grating tunable twin-guide laser diodes that operate at ~1.55 μm emission wavelength and are tunable over a wavelength range of 28 nm. To the best of our knowledge, this is the first time ever that tuning characteristics of a DFB-like laser, which is capable of wide quasi-continuous wavelength tuning, are reported.

Device structure: The SG-TTG laser (Fig. 1) basically consists of the active region and the two vertically integrated tuning sections that also contain the SGs. The sampling periods $\Lambda_{s1,2}$ of the SG in tuning sections 1 and 2 are slightly different. The resulting comb-like reflection spectra show, therefore, a slightly different periodicity. This permits the use of the Vernier effect to achieve wide quasi-continuous wavelength tuning [5].

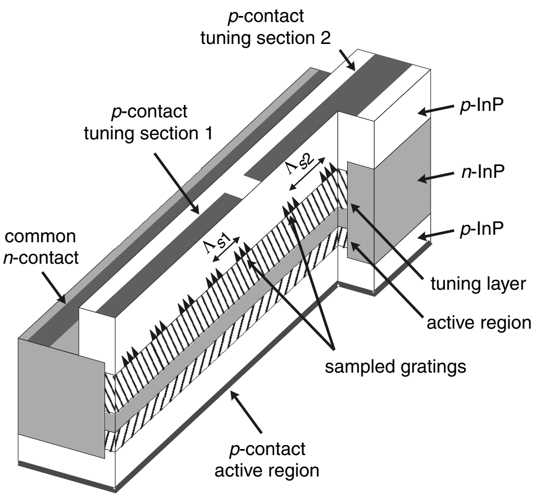

Fig. 1 *Schematic drawing of SG-TTG laser diode*

The device is fabricated in a buried heterostructure design. The active region consists of a strained-layer multi-quantum well, embedded in a separate confinement heterostructure. The tuning regions are formed by a 190 nm-thick GaInAsP ($\lambda_g = 1.37$ μm) layer. Gratings are patterned by electron beam lithography and formed by wet chemical etching in the *n*-InP separation layer that is situated between the active and tuning regions. The coupling coefficient of the grating is estimated to be 60 cm^{-1}. The sampling periods of the SG were chosen to be 69 and 75 μm, which is expected to result in a reflection peak spacing of 4.8 and 4.4 nm for tuning sections 1 and 2, respectively. Separate *p*-type contacts on top of the device allow for an independent biasing, and hence tuning, of the two tuning sections. The devices were cleaved to a length of 600 μm and AR-coated on both facets with a quarter-wave-thick Al_2O_3 film.

Device characteristics: The devices were operated in CW-mode at room temperature (20°C). At first, characterisation was carried out with the tuning sections being unbiased ($I_{t1} = I_{t2} = 0$ mA). The lasing threshold is reached at an active region current I_a of 24 mA and a maximum output power of 12 mW is achieved at ~100 mA. Single-mode emission with a sidemode suppression ratio (SMSR) in excess of 30 dB has been observed.

Employing both tuning currents, the emission wavelength can be tuned between 1534 and 1562 nm over a 28 nm wavelength range. Within this wavelength range, five supermodes are recognised (Fig. 2). These can be accessed by using different combinations of the two tuning currents. Furthermore, each of these supermodes can be tuned continuously over a wavelength range of 0.45–1.5 nm, depending on the supermode location. The continuous tuning range of each supermode is determined by two factors. First, by the performance of the tuning sections; for a well-working TTG laser, a continuous tuning range of 6–7 nm is achievable. Secondly, the order of the supermode is significant. Since a certain amount of tuning is already necessary to overlap higher-order reflection peaks of the SGs, this amount of tuning is no longer available for the continuous tuning of the supermode. From DFB-TTG lasers that were fabricated along with the SG-TTG lasers, it is known that the continuous tuning range that is achievable from the present devices is ~2 nm. Therefore the continuous tuning range of the various supermodes of the SG-TTG laser is limited to less than 2 nm. The main supermode, which is located around 1562 nm, is tunable by 1.5 nm. All higher-order supermodes show a smaller continuous tuning range, since tuning by 0.4–0.5 nm is already necessary to switch to the next higher-order supermode. Spectra of the upper and lower limits of each supermode are shown in Fig. 2. The supermode hops occur regularly, as expected. However, one has to mention that the SG centre wavelength (1562 nm) and the gain peak (1535 nm) are not aligned. Therefore, with increasing tuning current, supermode hops occur only towards shorter wavelength (with respect to the grating centre wavelength). Furthermore it can be seen from the spectra in Fig. 2 that a supermode, to be located around 1557 nm, is missing for unknown reasons.

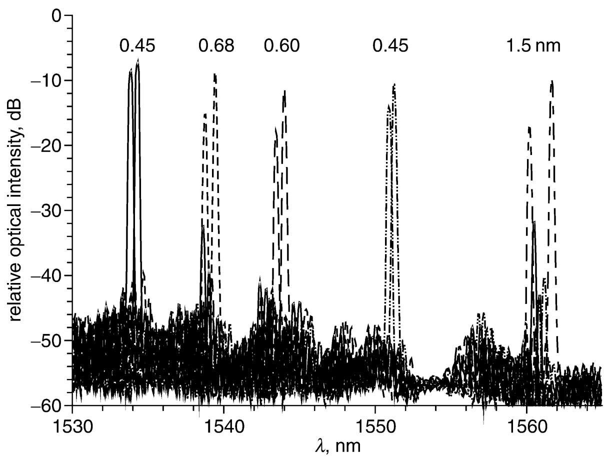

Fig. 2 *Optical emission spectra, showing upper and lower limits of five supermodes*

The continuous tuning range of each supermode indicated in upper part of image

The SMSR shows only slight variations during tuning and stays between 25 and 37 dB over the whole tuning range. The behaviour of emission wavelength and SMSR during continuous tuning of the supermode is depicted in Fig. 3 (for two selected supermodes). As can be seen, the emission wavelength is shifting continuously towards shorter wavelength with increasing tuning currents as can be expected for electronic tuning owing to the free-carrier plasma effect.

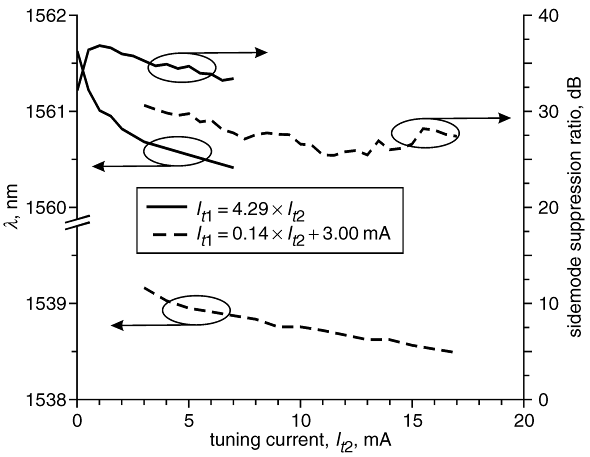

Fig. 3 *Behaviour of wavelength and SMSR during tuning for two selected supermodes*

Conclusions: We have demonstrated successfully a monolithic widely tunable laser diode that is capable of quasi-continuous wavelength tuning with only two tuning currents. The widely tunable twin-guide lasers with sampled grating achieved a tuning range of 28 nm, which is presently only partially accessible. The SMSR remains between 25–37 dB over the whole tuning range. A maximum output power of 12 mW has been obtained. Further improvement of the continuous tuning range of the device can be expected to yield full wavelength coverage.

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