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Widely Tunable Integrated DBR Laser Array with Fast Wavelength Switching

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1. Introduction

Tunable lasers are a key to achieving colorless operation of transceivers or transponders for dense wavelength division multiplexing (DWDM) transmission systems and networks, and thus, many kinds of device structures have been developed for wide wavelength tuning [1]. Among them, a tunable laser with distributed Bragg reflector (DBR) mirrors has the potential for rapid tuning as fast as several nanoseconds (limited by carrier lifetime), which may be useful for advanced dynamic network reconfigurations and optical burst switching, as well as simplified inventory and provisioning. However, the wavelength switching time of a conventional tunable DBR laser is still on the order of sub-milliseconds, which is determined by the control circuits for cavity phase adjustment.

To avoid the phase adjustment problem, reducing the cavity size is effective, and rather wide wavelength tuning over a 40-nm tuning range has been demonstrated in a tunable VCSEL (vertical cavity surface emitting laser). However, the tuning speed is limited by the fundamental mechanical vibration frequency of a MEMS (Micro electromechanical systems) mirror [2]. With both wide tuning and fast wavelength-switching, a short-cavity DBR laser array has been proposed to expand the mode-hop-free tuning range [3].

We proposed and fabricated a short cavity laser with an active DBR, which we call an SC-ADBR laser, for stable laser operation [4, 5]. This laser has a single quantum well in the DBR. The threshold current is almost unchanged during 6-nm tuning and stable laser oscillation has been achieved even at higher temperatures. The arrayed devices are packaged by Furukawa Electric [6], a collaborator in the "Development of Photonic Network Technology Project" supported by NEDO, and are being used to demonstrate optical burst switching (OBS) [7].

2. Device structure and fabrication

A photograph of a sample SCA-DBR laser array and its schematic cross sectional are shown in Fig. 1. The chip size of the device is 2500 x 550 μm. This device consists of six-channel SCA-DBR lasers, S-bend waveguides, a multi-mode interferometer (MMI) coupler, and a semiconductor optical amplifier (SOA). Each SCA-DBR consists of a 35-μm "gain" section between two active DBRs (front: 200 μm, rear: 300 μm), which consist of undoped InGaAsP bulk layers and an InGaAsP single quantum well (SQW).

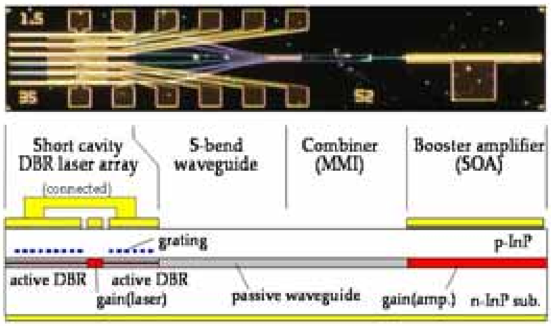

Fig.1 Photograph and cross-sectional diagram of SCA-DBR laser array

Carriers injected in the DBR section fall into the SQW to cause optical gain, overflow carriers change the refractive index of adjacent InGaAsP guide layers, and the lasing wavelength is varied through a plasma effect. The SQW gives an optical gain of about 2 dB and this loss compensation is attained without sacrificing tuning efficiency [4].

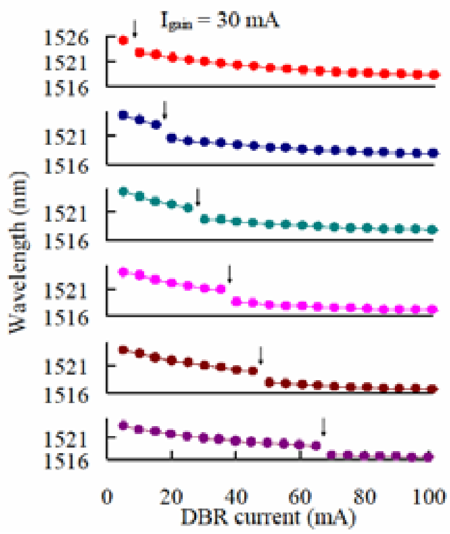

Fig. 2 Wavelength tuning of SC-ADBR laser with controlled phase between front and rear gratings

Even in short cavity DBR lasers, mode-hop occurs inherently when the roundtrip phase of the cavity is equal to an integral multiple of 2π. Thus, the adjustment of the round trip phase, which is the sum of the phases of the gain section and an additional phase difference between DBR gratings, is very important in order to cover all International Telecommunication Union (ITU) wavelength grids. Figure 2 shows the experimental tuning characteristics for the additional controlled phase difference of 0 to 5/6 x 2π with steps of 1/6 x 2π, which is achieved by carefully controlling the electron beam lithography used to from the gratings. This phase adjustment is applied to all stripes in the laser array based on the refractive index dispersion measurement. [5]

3. Tuning characteristics

Figure 3 plots the lasing wavelength as a function of DBR current for a four-channel array. The laser gain and SOA currents were fixed at 30 mA and 100 mA, respectively. The SQW of the DBR section of this laser array was doped to n-type, so as to avoid mode-hops at low DBR current where the rapid change in SQW gain might cause an additional phase shift by the changing threshold current. It should be noted that there were no mode hops during 6-nm tuning in any of the four laser stripes. A six-channel SC-ADBR laser was also fabricated to demonstrate 30 -nm wavelength band tuning.

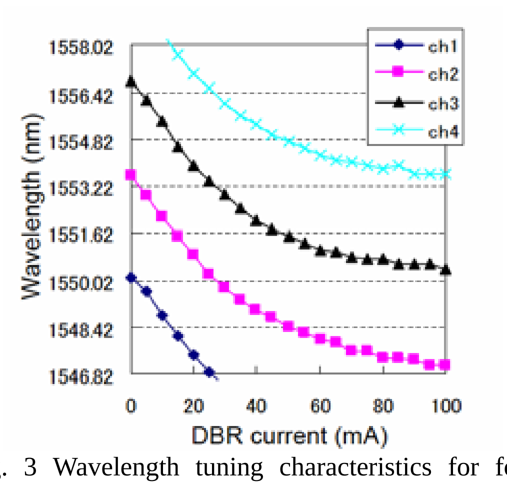

Fig. 3 Wavelength tuning characteristics for four -channel SC-ADBR laser array

Rectangular current pulses were applied to the DBR section, and the optical signals output through a tuneable optical filter were electrically memorized and summarized to observe wavelength switching behaviour. As shown in Fig. 4, the measured switching speed of the SC-ADBR lasers was as fast as 5 ns for δλ=2nm tuning.

Fast wavelength switching less than 10 μsec between ITU grids has been demonstrated for a packaged laser array driven by control circuit board [6].

4. Conclusion

We proposed a short cavity DBR laser array with an n-type single quantum well in the DBR section to achieve mode-hop-free tuning in the wide wavelength band exceeding 30nm. Continuous wavelength tuning of 6 nm, and rapid tuning (5 ns) have been demonstrated for advanced dynamic networks.

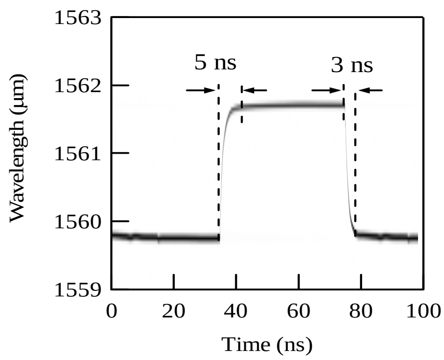

Fig. 4 Wavelength switching characteristics

5. Acknowledgement

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