To search page

2013

Development of 100 Gb/s Full-band Wavelength Tunable Laser for Digital Coherent Communication (Sumitomo Electric Industries)

~ Discrete Semiconductor/Others ~

In the Wavelength Division Multiplexing (WDM) transmission system rapidly spreading since the mid-1990s, a full-band wavelength tunable laser that covered a wide wavelength range (about 40nm) in the 1.55μm band in one device was awaited, and development became active globally. Furthermore, since the mid-2000s, narrow line width characteristics and large light output became more important for multilevel phase-shift-keying modulation, for full-scale introduction of 100Gb/s digital coherent communication.

There are many kinds of full band wavelength tunable lasers, and representative examples are shown in Fig.1. They are classified into two types, one being a monolithic integration type and the other is external resonator structure type. The former is classified into a DFB (Distributed Feedback) array type, a DBR (Distributed Bragg Reflector) type, and a DR (Distributed Reflector) type, and the latter is classified into a variable wavelength mirror type and a tunable wavelength filter type, each of which has been further diversified and various characteristic technologies has been developed[1]. Each has advantages and disadvantages, and the external resonator structure is superior from the viewpoint of the narrow line width, while the monolithic integrated structure is excellent in miniaturization and integration with other elements.

With the above background, in 2007, Sumitomo Electric Industries reported a unique full-band wavelength tunable laser called CSG-DR (Chirped-Sampled-Grating Distributed Reflector)[2]. As shown in Fig.2, the DR structure has an active SG-DFB (Sampled Grating DFB) region and a passive CSG-DBR region connected to each other, and SOA (Semiconductor Optical Amplifier) is also integrated in the output part. In the SG structure used in the SG-DFB region, diffraction gratings having a reflection function with respect to light propagating in the active layer were spatially formed at equal intervals, and a periodic gain spectrum as shown in Fig.3 was generated.

On the other hand, in the CSG structure used in the CSG-DBR region, the spacing of the arranged diffraction gratings is slightly changed (chirped), and due to the interference effect of each reflected light, a periodic reflection spectrum with gentle envelope shape appears in the reflection spectrum, and it can be controlled by the power input to the heater integrated in the CSG-DBR region. The individual peak wavelength in the reflection spectrum changes in proportion to the average power of the three heaters and the gentle peak wavelength of the envelope shape varies with the gradient of the power applied to the three heaters.

The wavelength variable operation is realized by using the vernier effect, in which the peak wavelength interval of the gain spectrum and the peak wavelength interval of the reflection spectrum are slightly shifted by the adjustment of the diffraction grating interval. That is, only peaks where the peak wavelength of the gain spectrum matches the peak wavelength of the reflection spectrum are selected as the oscillation mode, and the wavelength can be varied by the average input power to the three heaters. However, with only the principle of oscillation mode selection based on the vernier effect, a plurality of modes appears in which both peaks coincide with each other at wavelength intervals determined by the difference period between the gain spectrum and the reflection spectrum, and it becomes a factor hindering stable single mode operation. Therefore, by adjusting the average power of the heater and selecting the desired peak, at the same time, the envelop-shaped gentle reflection peak position is adjusted by adjusting the temperature gradient between the heaters to the vicinity of the desired wavelength, and oscillation with only the desired wavelength is realized. Furthermore, by adjusting the temperature of the whole element, both the gain peak of SG-DFB and each reflection peak of CSG-DBR move at the same time, so that the wavelength of the selected oscillation mode can be continuously varied.

Fig. 4 shows a chip top view of the CSG-DR-LD. A laser structure is fabricated by using a mixed crystal material composed of InP and InGaAsP on an InP substrate generally used as a semiconductor laser for long distance communication. For the active layer through which laser light propagates, materials of different compositions are used in the active SOA and SG-DFB regions and in the passive CSG-DBR region, and they are connected by using a crystal growth technique called butt joint growth, which is a characteristic feature of this technology.

From the viewpoint of high light output and narrow line width, this laser has the following features.

(1) By using thermo-optic effect by integrated heater for vernier control, spontaneous emission of light noise is suppressed which is generated by the method using plasma effect by current injection, and narrow line width (low phase noise) is realized.

(2) High output characteristics can be realized by adopting the DR structure (DFB + DBR), and phase adjustment between DFB and DBR is unnecessary.

Improvements were made based on this structure, and in 2013, high output performance exceeding +16 dBm of the optical fiber output and narrow line width characteristics below 200 kHz were compatibly realized, and it was adopted as a monolithic integrated light source for 100 Gb/s digital coherent communication (3). Also, for the narrow linewidth operation, a flow to actively investigate the thermal control method was accelerated.

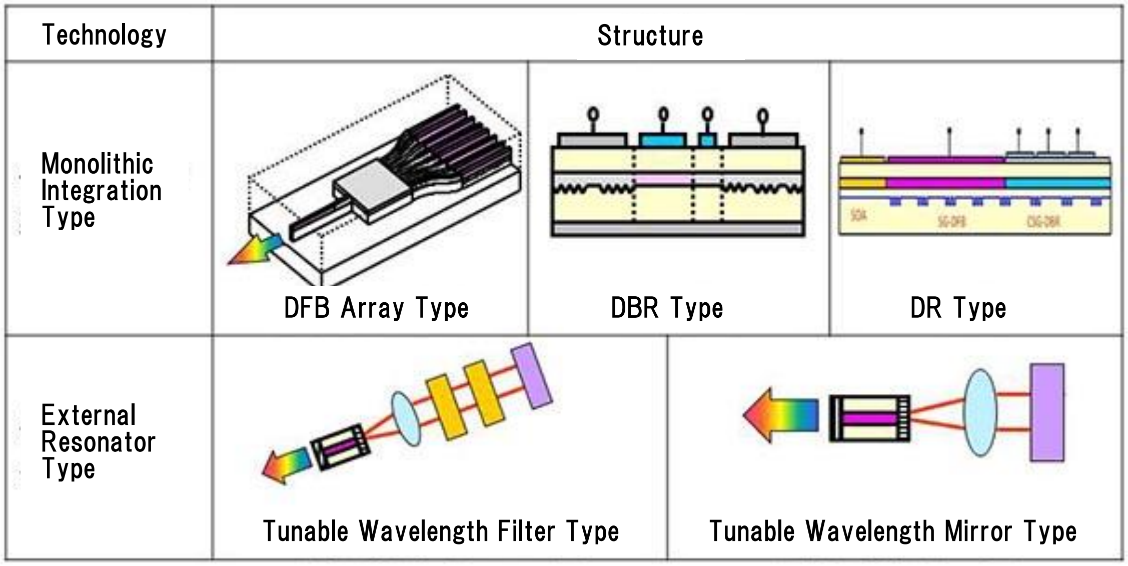

Fig. 1: Structure of a typical full-band tunable wavelength laser

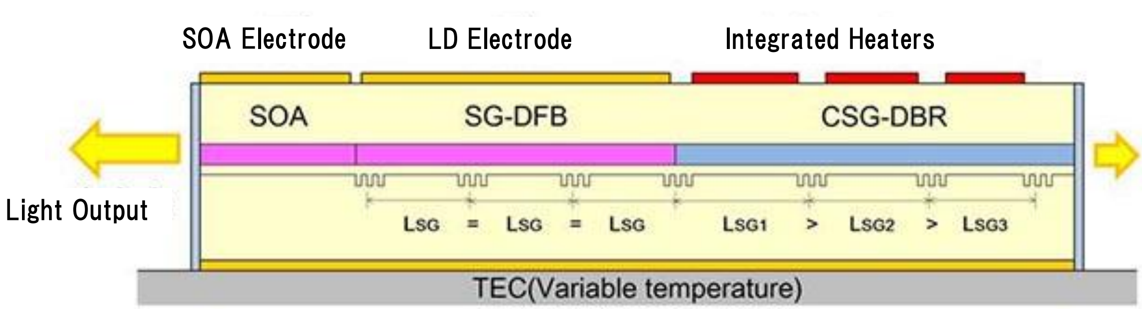

Fig. 2: Schematic view of the cross section of the CSG-DR laser

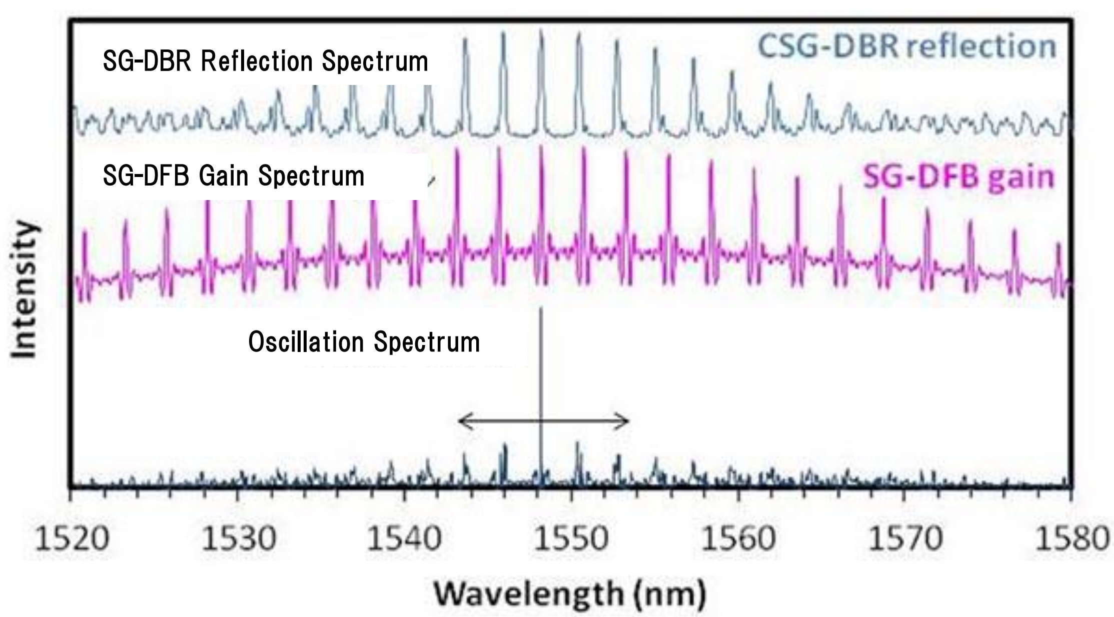

Fig. 3 Oscillation spectrum (Calculation example)

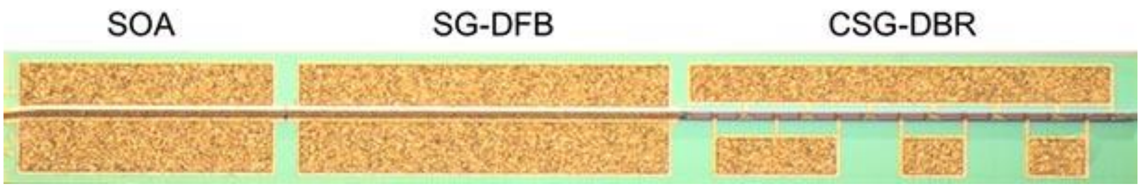

Fig. 4 Chip picture of CSG-DR-LD
(By courtesy of Sumitomo Electric)

References:

[1] Jens Buus, “Tunable Lasers in Optical Networks”, J. Lightwave Technol., vol. 24, No. 1, 2006.
[2] T. Ishikawa, T. Machida, H. Tanaka, Y. Oka, H. Shoji, T. Fujii and S. Ogita, “A novel high output power full-band wavelength tunable laser with monolithically integrated single stripe structure”, European Conference on Optical Communication (ECOC2007), no. PD2.4, 2007.

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