A High Power Tunable Light Source for Coherent Communications Using a Distributed Reflector Laser Array Combined With an AWG Coupler

Yusuke Inaba[*1], *Maiko Ariga*[*1], *Kazuaki Kiyota*[*1], *Toshihito Suzuki*[*1], *Kazuki Yamaoka*[*1], *Shunsuke Okuyama*[*1], *Masayoshi Nishita*[*1], *Tatsuro Kurobe*[*1], *Hajime Mori*[*2]

ABSTRACT The high power and narrow beam linewidth of a tunable light source (TLS) is essential to achieve higher speed in digital coherent communication. In order to meet such requirement, we have developed the TLS which has integrated a Distributed Reflector (DR) Laser Array and an Arrayed Waveguide Grating (AWG) coupler. Improving the coupling efficiency by adjusting the transmission wavelength of the AWG coupler and the lasing wavelength of each of the lasers, using DR lasers which have backward Distributed Bragg Reflector (DBR) for the each laser, and reducing its threshold gain, the development of the laser chip with a high power and a narrow beam linewidth can be available. And moreover, by adapting a new configuration where a Semiconductor Optical Amplifier (SOA) is placed on a different thermo-electric cooler from the one the laser array chip is on in the module, a farther higher power/narrower beam linewidth can be obtained and a 19 dBm optical output / less than 70 kHz linewidth as required characteristics to the light sources on the next generation high-speed telecommunication has been achieved.

1. INTRODUCTION

In recent years, the expansion of the wireless communication network with a penetration in mobile devices such as smartphones or penetration in cloud computing, video transmissions and social networking services make communication's traffic increasing rapidly. In order to meet this, the introduction of the 100 Gbit high-capacity transmission system which uses digital coherent communication to achieve coherent detection by digital signal processing is being promoted.

In a digital coherent communication, the multilevel modulation utilizing optical phase information is used. In order to achieve a higher speed in communication, an increase of the signal capacity per symbol by a multilevel gain or by an improvement of the spectral efficiency utilizing a high density wavelength division multiplexing (WDM) method such as in the Nyquist WDM, are being promoted. With those factors, the lasers used for signal light sources and local oscillators are requiring a narrow spectral linewidth and a high power more than before. In particular, it is considered that an optical output more than 19 dBm and a linewidth less than 100 kHz are required for the communication in the 64 Gband, 64 Quadrature Amplitude Modulation (QAM)[1)-3)].

We have been developing a TLS of a Distributed Feedback (DFB) laser array type[4)]. It utilized the chip which has monolithically integrated multiple DFB lasers, a Multimode Interferometer (MMI) coupler and a Semiconductor Optical Amplifier (SOA). This TLS tunes the wavelength roughly by selecting one wavelength from the several wavelengths the DFB laser array is lasing with and then finely by changing the chip temperature by Thermo Electric Controller (TEC).

In order to improve its performance, we have proposed a TLS which utilizes the Arrayed Waveguide Grating (AWG) coupler shown in Figure 1[5)]. We will report its detail in this article.

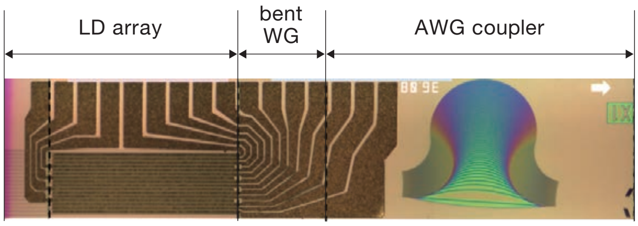

Figure 1 A Photograph of DR laser array chip combined with an AWG coupler.

[*1] Telecommunications and Energy Laboratories, R&D Division
[*2] Strategic Planning Department, R&D Division

2. CONFIGURATION OF THE TUNABLE LIGHT SOURCE (TLS)

2.1 A Semiconductor Laser Chip With Integrating a DR Laser Array and an AWG Coupler

The TLS uses an AWG coupler as the coupler which combines several lasers. Since an AWG coupler has a wavelength selectivity, by adjusting its transmission wavelength to the lasing wavelength of each laser, a high coupling efficiency, unrealizable with a MMI coupler, is available. Therefore, the TLS with an AWG coupler has the advantage of a high power output over the TLS with an MMI coupler. DR lasers are adopted as the lasers in the array instead of the DFB lasers which are conventionally used. The DR laser is the combination of a DFB laser and a DBR mirror. The DR laser can be said to have an advantage in terms of a low threshold gain which is essential for narrow linewidth[6].

2.2 The Configuration of the Module

The configuration of the TLS module is shown in Figure 2. Another feature of the TLS we proposed herein is that a SOA chip is separate from the laser array chip. The laser array chip outputs the light through the AWG coupler, and the light enters into the SOA through bulk optics and an isolator. This configuration has two advantages. One is that the SOA is on a different TEC from the one on which the laser array chip is. A laser-array-type TLS needs to operate the laser chip at a wide temperature range for the wavelength tuning. Since the SOA has a low optical output at high temperature and a large power consumption of the TEC at low temperature, it is difficult to achieve a high power output with a low power consumption while the SOA is operating at the wide temperature range as same as the laser array chip. This limitation is considerably mitigated in this proposed configuration therefore it has the advantage of a high power output. The other advantage is that there is an isolator between the laser array chip and the SOA. This can prevent Amplified Spontaneous Emission (ASE) generated in the SOA from returning into the laser array chip. In a conventional configuration where a DFB and a SOA are monolithically integrated, the ASE increases with an amplification factor therefore the linewidth tends to be wider at a high power output. However, this effect can be avoided in the new configuration.

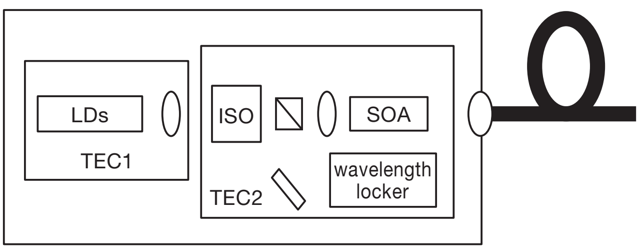

Figure 2 Schematic of the TLS module.

In this new configuration, the mean of wavelength control is not changed, therefore the advantage of a wavelength control that is simple and highly reliable can be available.

3. THE DESIGN AND FEATURE OF THE CHIP

The laser array chip consists of a DR laser array, bent waveguides and the AWG coupler. The DR laser array and the bent waveguides have a buried hetero (BH) structure which is suitable for active devices with a high reliability and a high injection efficiency.

Since the arrayed waveguides in the AWG coupler have an advantage in downsizing due to its small bending radius and its low dependency on the crystal orientation, the arrayed waveguides have a deep ridge structure. The waveguides with different structures are monolithically integrated in one chip by a sophisticated fabrication process. It is essential to configure the lasers and the AWG coupler in the same material system for a laser-array-type TLS. This is because the coupling efficiency decreases if the lasing wavelength and the AWG transmission wavelength do not change simultaneously during the temperature tuning. The insertion loss of the AWG coupler is estimated as 4-6 dB (Figure 3).

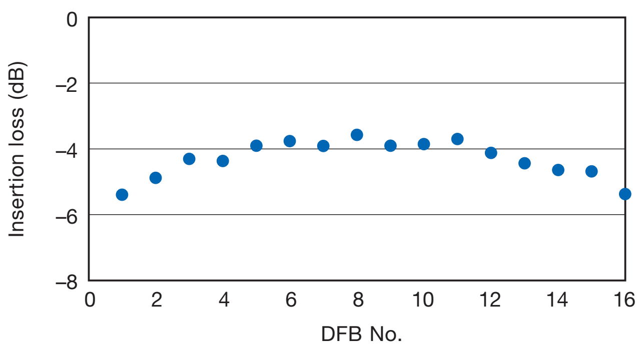

Figure 3 Insertion loss of the AWG coupler.

Each of the 16 DR lasers in the laser array consists of an active DFB section in which current is injected and a passive DBR section. The DFB section contains the phase shift of its grating. Both gratings of the DFB section and the DBR section are fabricated in the same lithographic process in order to avoid an unintentional phase shift. The DFB section has the grating as a waveguide core adjacent to an active layer. On the other hand, a periodically etched waveguide core itself is the grating in the DBR section. The etched parts are filled with a clad material, and a coupling factor of the grating in DBR section can be enormously large with a high refractive index to contrast between the core material and the clad material. Therefore, the high reflection ratio is obtained in a short length DBR and a narrow linewidth is obtained with this high reflection ratio.

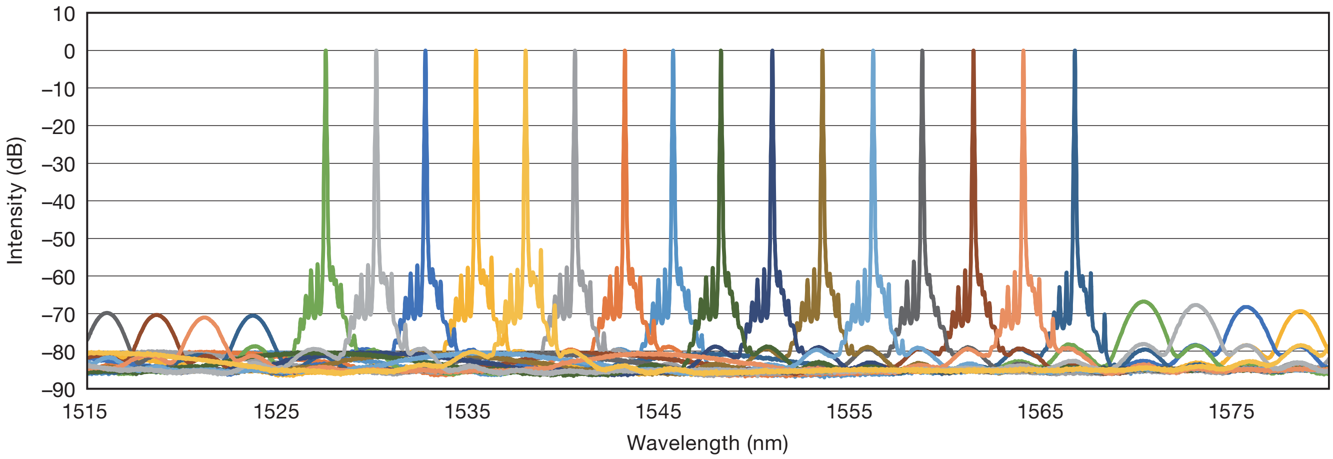

Figure 4 **Lasing spectra of an AWG-DR laser array chip.**

The lasing spectra of the AWG-DR laser chip are shown in Figure 4. Single mode operations are obtained in all the 16 DR laser. The output of the chip shows the characteristic spectra that the ASE in the wavelengths other than the lasing wavelengths of the lasers are cut off due to the wavelength selectivity of the ASE.

4. THE DESIGN AND FEATURES OF THE MODULE

As shown in Figure 2, each of the laser array and the SOA are bonded on different TEC. This enables to drive the SOA at the low temperature to obtain higher output. On the other hand, the number of optical parts mounted in the package is increased compared to our previous modules because the lasers and the SOA are separated. However, we have succeeded to mount these parts in a very small module by using a precise adhesive bonding technology[7].

The optical output vs SOA current characteristics of this TLS module is shown in Figure 5. An optical output more than 19 dBm is obtained in all 16 wavelengths.

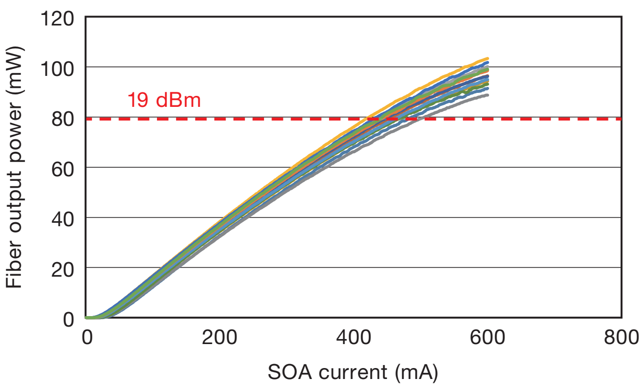

Figure 5 **Optical output – SOA current characteristics of the TLS module.**

The SOA current dependence of linewidth is shown in Figure 6. The solid line shows the linewidth of the new configuration proposed in this article and the dashed line shows the linewidth of a conventional module which has monolithically integrated lasers and a SOA. In the case of the conventional module, the linewidth becomes wider with the increase of the SOA current. However, in the case of the new configuration, it can suppress the influence of the ASE light from the SOA by an isolator existing between the lasers and the SOA, therefore the linewidth is narrower compared with the conventional module especially at high temperatures. The measuring results of the linewidth at each wavelength for the new configuration module are also shown in Figure 7. The linewidth less than 70 kHz can be obtained at both 35°C and 65°C of lasers' driving temperature with the effect of the DR laser implementation.

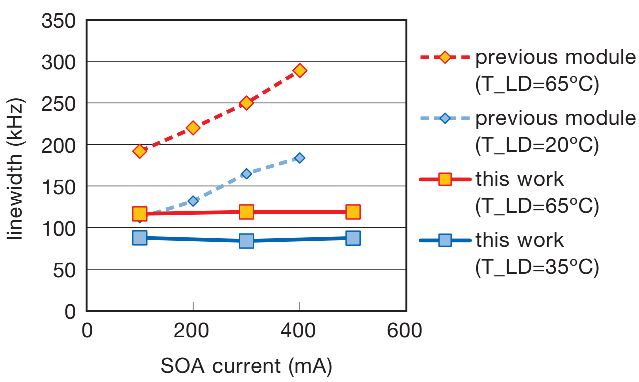

Figure 6 **SOA current dependence of the linewidth.**

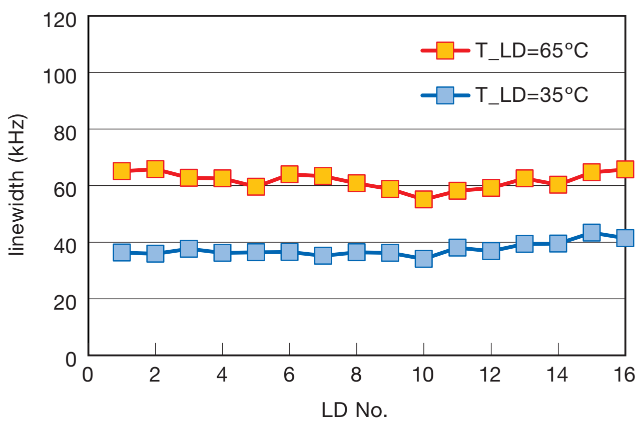

Figure 7 **Linewidth of the TLS module.**

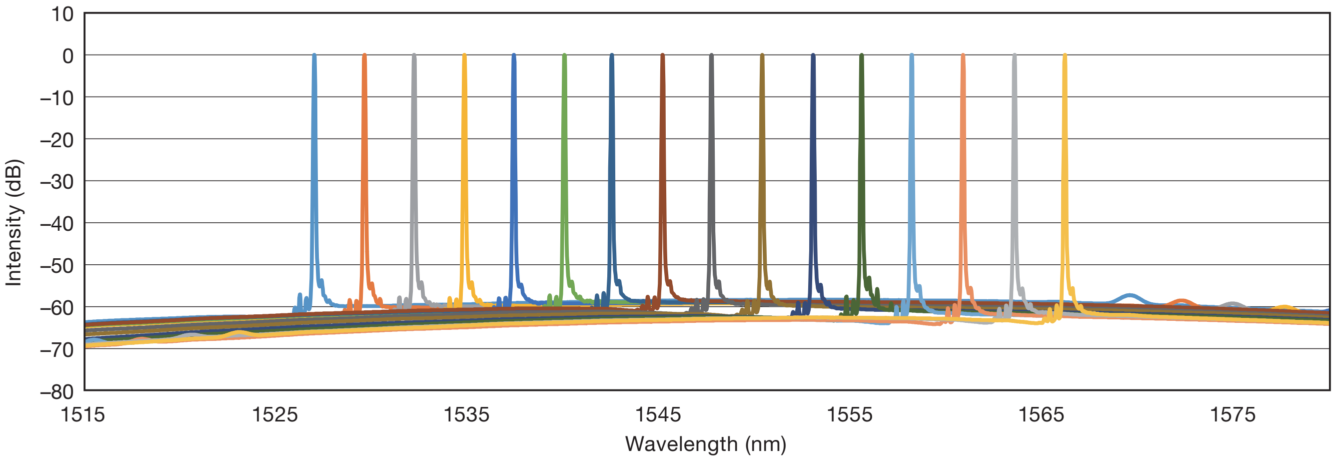

Figure 8 Lasing spectra of the TLS module.

The lasing spectra of the TLS module are shown in Figure 8. Signal to Spontaneous Emission Ratio (SSER) can be obtained a value of more than 50 dB.

5. CONCLUSION

For a High power and a narrow beam linewidth of a TLS which is essential to achieve a higher speed in digital coherent communication, we have developed the TLS which has integrated a DR Laser Array and an AWG coupler. We implemented the new configuration where the laser array chip and the SOA chip are separated and an isolator is inserted between them, and consequently were able to obtain the characteristics of a 19 dBm optical output and a less than 70 kHz linewidth.

REFERENCES

1) M.C. Larson, A. Bhardwaj, W. Xiong, Y. Feng, X.D. Huang, K.P. Petrov, M. Moewe, H.Y. Ji, A. Semakov, C.W. Lv, S. Kutty, A. Patwardhan, N. Liu, Z.M. Li, Y.J. Bao, Z.H. Shen, S. Bajwa, F.H. Zhou, and P.C. Koh, "Narrow linewidth sampled-grating distributed Bragg reflector laser with enhanced side-mode suppression", 38th Optical Fiber Communications Conference, M2D.1. (2015).
2) U. Eriksson, J.-O. Wesstrom, Y. Liu, S. Hammerfeldt, M. Hassler, B. Stoltz, N. Carlsson,S. Siraj, E. Goobar, Y. Matsui, "High Performance Narrow Linewidth Thermally Tuned Semiconductor Laser", 41st European Conference on Optical Communication, We1.5.1 (2015).
3) K. Sato, "Demonstration of Silicon Photonic Hybrid Ring-Filter External Cavity Wavelength Tunable Lasers", 41st European Conference on Optical Communication, We2.5.4 (2015).
4) T. Kimoto, G. Kobayashi, T. Kurobe, T. Mukaihara, S. Ralph, "Narrow linewidth tunable DFB laser array for PDM-16QAM transmission", The 18th OptoElectronics and Communications Conference, MK2-6 (2013).
5) T. Suzuki, K. Kiyota, S. Okuyama, Y. Inaba, M. Ariga, T. Kurobe, "Tunable DFB Laser Array Combined by Monolithically Integrated AWG Coupler", The 25th International Semiconductor Laser Conference TuC3, (2016).
6) G. Kobayashi, K. Kiyota, T. Kimoto, T. Mukaihara, "Narrow linewidth tunable light source integrated with distributed reflector laser array", 37th Optical Fiber Communications Conference, Tu2H.2. (2014).
7) M. Ariga, T. Sugaya, T. Kimura, K. Akizuki, Y. Nakajima, Y. Arashitani, "Development of the FBT Laser Module with Adhesive Bonded Structure", Furukawa Review, No. 40 (2011).