Development of ITLA Using a Full-Band Tunable Laser

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ABSTRACT A laser control module complying with the integrable tunable laser assembly (ITLA) standards has been developed. A DFB laser array that covers either the C- or L-band in wavelength is incorporated in this module, enabling precise wavelength control by using a wavelength locker integrated with the laser. Also, by controlling each the SOA, DFB laser and two independent TECs, the optical output intensity and wavelength can be tuned. Moreover, dithering functions have been implemented including FM for SBS suppression and AM for signal discrimination. In this paper, the configuration of this module is described and main characteristics including wavelength stability are presented.

1. INTRODUCTION

With the explosive growth in the Internet traffic in recent years, capacity expansion of dense wavelength-division multiplexing (DWDM) systems is advancing, creating a need for implementation of flexible networks that can reconfigure themselves depending on traffic situations, and for cost reduction. For this reason, conventional distribution feedback (DFB) lasers with fixed wavelengths are rapidly being replaced with broadband wavelength tunable lasers that permit lasing wavelength tuning with ease. Figure 1 shows the outline of a DWDM communication system. DWDM systems require, since multiple optical signals with different wavelengths are simultaneously transmitted, light sources that are stabilized in both wavelength and optical output. And since fixed wavelength light sources were used conventionally, it was necessary to keep so many light sources as spares for system maintenance that the cost became a problem. But, by using light sources of wavelength tunable laser that permit arbitrary wavelength tuning, reduction of the system operation and maintenance costs can be achieved. Moreover, light sources of wavelength tunable laser allow for reconfiguration of wavelength allocation depending on situation.

To satisfy such system requirements, wavelength tunable lasers based on various principles have been proposed as shown in Table 1 [1)~5)]. However, they are complicated in their wavelength tuning method, raising problems of operation characteristics under external environment changes and deterioration with age. On the other hand, taking much interest in the long-term stability of thermally wavelength tunable DFB lasers, we have been developing laser modules that incorporate, on a single substrate, arrayed DFB lasers with different lasing wavelengths, S-shaped waveguides and optical couplers [6)~9)].

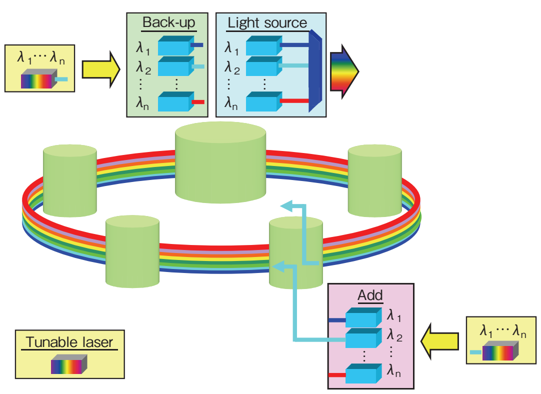

Figure 1 Outline of DWDM communication system.

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Table 1 Typical wavelength tuning technologies.

Literature No.	General description
1)	SG-DBR-LD
2)	SSG-DBR-LD
3)	MEMS-based compact external cavity LD
4)	External cavity LD using temperature-controlled etalon filter
5)	Surface-emitting LD using length-controlled MEMS cavity

The OIF (Optical Internetworking Forum) has established OIF-ITLA (Integrable Tunable Laser Assembly)-MSA (Multi-Source Agreement) as standard specifications, in order to improve the compatibility of wavelength tunable lasers with various configurations and formalities as mentioned above. Table 2 shows main specifications of ITLA-MSA.

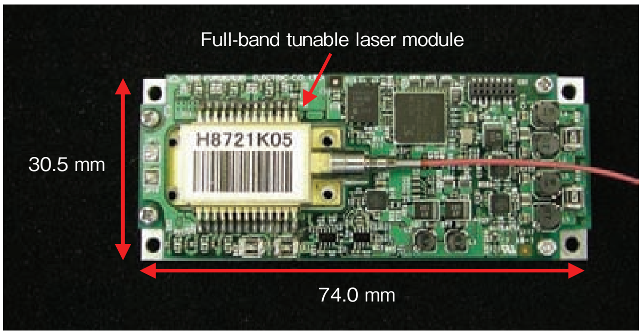
Table 2 ITLA-MSA specifications (Long Haul / 50-GHz channel spacing).

Item	Specification
Frequency error	ITU Grid ±2.5GHz
Optical output	10 ~ 13 dBm
Power consumption	6.6 W or less
Dither	Optional (AM/FM)
Linewidth	10 MHz or less
RIN	-135 dB/Hz (10 MHz ~ 10 GHz)
SMSR	40 dB or more
Size	74.0 x 30.5 x 10.5 mm^3
Communication IF	RS232C
Power supply voltage	-5.2 V / +3.3 V

Here we have developed an ITLA with a control circuit board complying with the MSA, that integrates a full-band wavelength tunable laser covering the whole wavelength range of either the C- or L-band. The ITLA has achieved, by each controlling the semiconductor optical amplifier (SOA), DFB laser and two thermoelectric coolers (TECs), precise control of optical output intensity and wavelength. Moreover, two kinds of dithering functions have been implemented as options, including frequency modulation (FM) for stimulated Brillouin scattering (SBS) suppression and amplitude modulation for signal discrimination. In this paper, the configuration of this ITLA is described and main characteristics including optical characteristics and power consumption are presented.

2. CONFIGURATION OF ITLA

Figure 2 shows the ITLA developed here. A control circuit that is designed taking account of power consumption and noise has been implemented on a substrate measuring 74 mm x 30.5 mm with a height of 10.5 mm, whereby the circuit is used to control the full-band tunable laser module. Below will be described the configuration of ITLA.



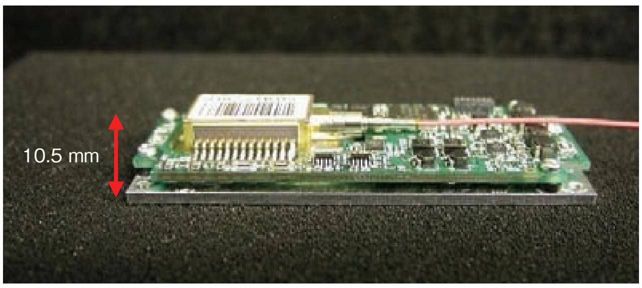


Figure 2 Appearance of ITLA.

2.1 Full-Band Tunable Laser Module

Figure 3 shows a schematic configuration of the full-band tunable laser module. The laser chip incorporated consists of a DFB laser array with different lasing wavelengths, an optical coupler that combines optical outputs, and an SOA that compensates for the loss due to the optical coupler. The DFB laser array has 12 lasing elements, and the lasing wavelength of each element has a spacing of about 3.5 nm. By thermally tuning the wavelength of a selected DFB laser corresponding to the desired ITU grid, over a temperature range between 10 ~ 50°C, it is possible to cover all the full-band wavelength grids. In addition to the laser chip mentioned above, a wavelength locker is incorporated in the laser module to suppress laser's wavelength drift due to temporal change. The wavelength locker comprises two photo diodes (PDs) and an etalon filter, whereby one of the PD monitors optical output, and the other monitors the light that passes through the etalon to be used for wavelength control. The curve shown in Figure 4 is known as the wavelength discrimination curve, and shows the relationship between lasing wavelength and wavelength monitor current. Using the slope of the wavelength discrimination curve, the wavelength shift is detected as a change in photodiode current. Also, the laser module has two TECs, allowing the temperature of the laser chip and etalon to be controlled independently. In the conventional structure in

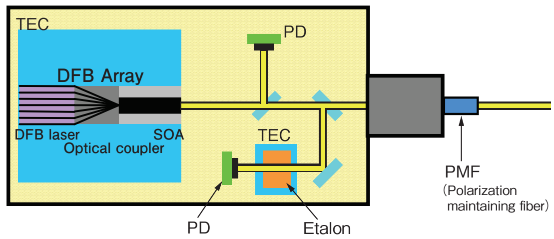


Figure 3 Configuration of full-band tunable laser.

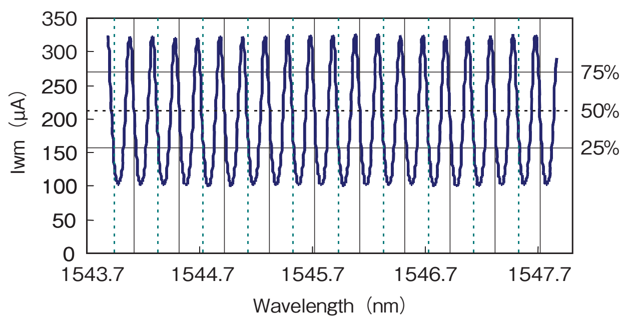


Figure 4 Wavelength discrimination characteristics with 25-GHz spacing.

which a single TEC is used for controlling laser temperature, changes in etalon temperature tend to cause wavelength drift, making control and manufacturing of the module difficult. In the module structure presented here, the use of two independently controllable TECs based on Peltier element enables enhancement of wavelength controllability and relaxing of manufacturing tolerances.

2.2 Control Circuit Block

Figure 5 shows the control circuit block diagram of the ITLA. In the temperature control circuit for the two independent TECs, the first control circuit controls the temperature of the etalon to suppress wavelength drift, while the second controls the temperature of the DFB laser to make the temperature correspond to a predetermined wavelength. By means of the two temperature control circuits, the wavelength can be controlled with high stability and high precision. In the DFB laser current control circuit and the DFB wavelength channel switching circuit, the laser of an arbitrary wavelength channel is driven based on the preset data stored in the memory on the circuit board. Since the SOA current control circuit controls the SOA current based on the monitored value of optical output intensity, the intensity can be changed independently of wavelength control. Also, functions conforming to MSA have been implemented on this ITLA, which carry out diverse command processing and communication of various alarms such as wavelength, temperature, optical intensity, etc. to higher-level devices. Moreover, the built-in CPU allows version upgrade of its firmware, without impacting the wavelength and optical output.

In terms of SBS suppression FM, any suitable signals are generated in the module, which are then superimposed on the DFB current. As for signal discrimination AM, the TxTrace circuit in the ITLA converts the TxTrace signal that is input from higher-level devices via connector to suitable signals, and subsequently superimposes them on the SOA current. One of the features of this ITLA is that, since this structure allows independent control of the DFB and SOA currents, the dithering functions can be controlled without being interfered from the other, enabling simultaneous control.

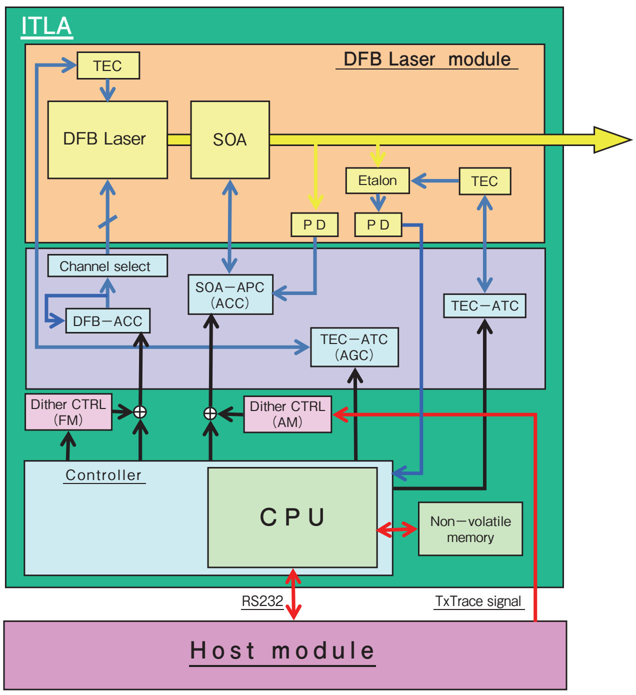


Figure 5 Block diagram of ITLA.

3. CHARACTERISTICS EVALUATION

Main characteristics of the ITLA developed here will be presented in this Section. A laser module with a wavelength locker adapted to 50-GHz C band was mainly used for the evaluation. Below will be described the wavelength tunable range and wavelength stability, followed by performance evaluation including power consumption, noise characteristics such as linewidth and relative intensity noise (RIN). Lastly, evaluation results of dithering functions will be summarized.

3.1 Wavelength Tunable Range and Wavelength Stability

ITLAs are required to provide performance equivalent to that of conventional fixed wavelength DFB lasers, so that a variety of specifications are set out in the MSA with regard to optical characteristics [10]. The ITLA developed here has achieved, to make it adequate for 50-GHz spacing DWDM systems, extremely precise wavelength control by controlling the temperatures of the laser and etalon. Figure 6 shows optical spectrum traces, where two lasers were used to lock the wavelength to arbitrary wavelength channels. From the Figure it can be seen that this ITLA is adequate for both C-band (1530 nm ~ 1565 nm) and L-band (1565 nm ~ 1610 nm). Also, the side-mode suppression ratio (SMSR) is 40 dB or better-- amply good result. Moreover, it is possible to make this ITLA adequate for 25-GHz spacing DWDM systems, by changing the laser to the one having wavelength discrimination characteristics shown in Figure 4.

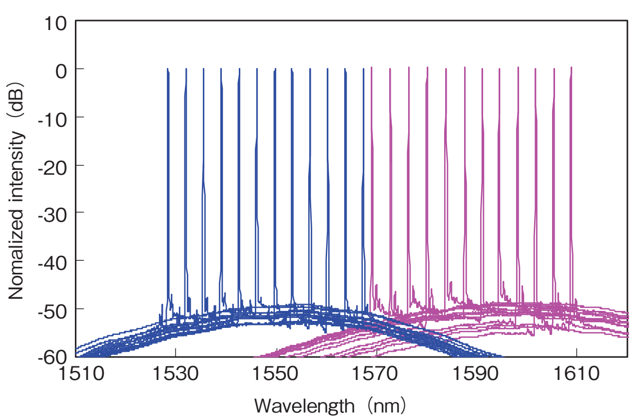


Figure 6 Lasing spectra at C band and L band.

Figure 7 shows the error in targeted frequency corresponding to optical output changes ranging from 7 dBm to 13 dBm for every wavelength channel. It has been confirmed that, to whatever wavelength channel the target is set, the frequency error is ±0.5 GHz or lower at any optical intensity, showing that the wavelength is maintained at a high level of stability. In addition, it has been shown that the wavelength stability is sufficiently within ±2.5 GHz, i.e., ITLA-MSA specification.

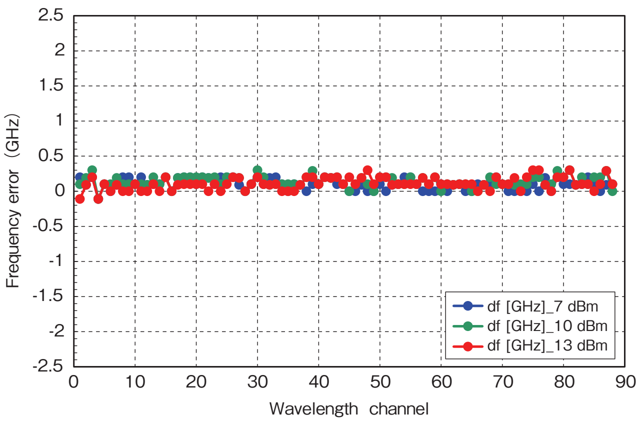


Figure 7 Frequency stability.

3.2 Performance Characteristics

In order to realize long-haul transmission, it is necessary to satisfy MSA standards with respect to noise characteristics such as spectrum linewidth and RIN [10]. Figures 8 and 9 show the measured linewidth at each wavelength and the measured RIN at each wavelength, in different ambient temperatures, respectively. In all measurement results, virtually no changes in noise due to differing ambient temperatures were observed, thus the low-noise characteristics suitable for long-haul transmission have been confirmed.

The MSA stipulates, with the aim of being incorporated in 300-pin transponders, not only transmission characteristics but also the size and power consumption [10]. This full-band tunable laser module has achieved, by using two independent TECs, low maximum power consumption of 4.2 W or less. Figure 10 shows the power consumption at each wavelength at ambient temperatures of 75°C and -5°C, both of which are assumed to cause high power consumption. It has been confirmed that the power consumption is 4.2 W or less at each wavelength channel.

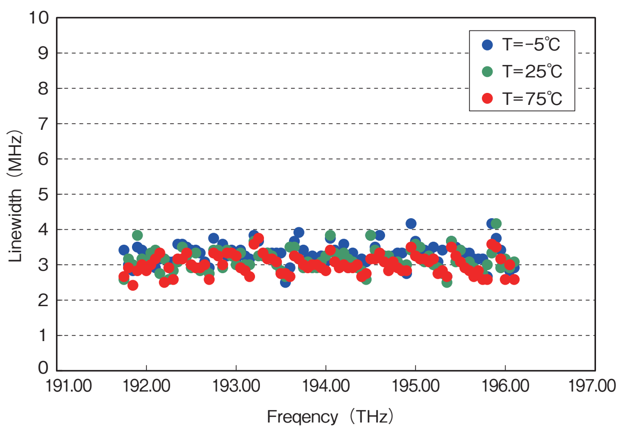


Figure 8 Linewidth characteristics.

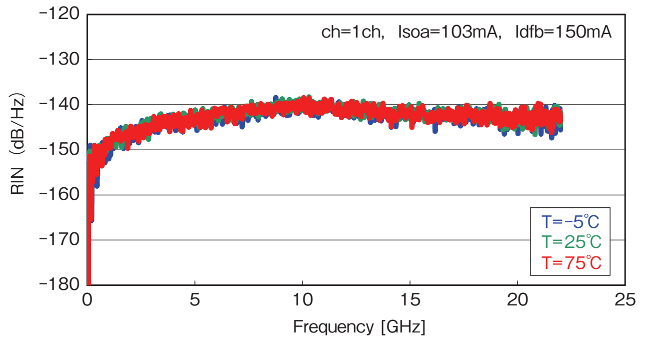


Figure 9 Relative intensity noise characteristics.

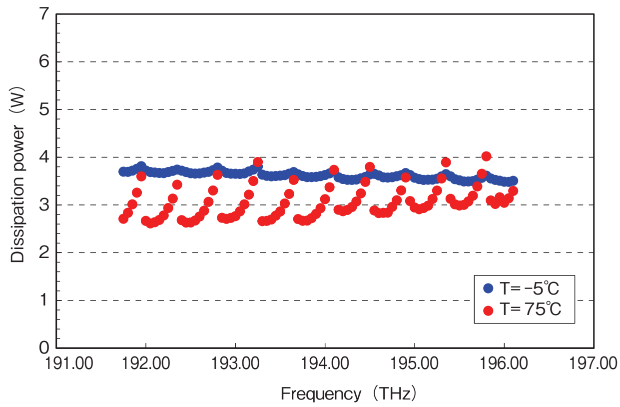


Figure 10 Power consumption.

3.3 Dithering Function Characteristics

Since light reflection due to SBS has a significant influence on communication systems such that it limits the transmissible optical intensity, suppression of such reflection is essential. Frequency modulation is one of the countermeasures to suppress SBS, so that, in this ITLA, control of optical wavelength is carried out by modulating the DFB laser driving current using specified frequency and amplitude patterns. Figure 11 shows the measured reflection loss vs. optical output intensity, in which the optical output intensity is measured using an optical power meter, after passing through a single-mode fiber 30 km in length. It can be seen that, with FM dithering off, the reflection loss increases as the optical output intensity increases, while with dithering on, reflection loss due to SBS remains low showing virtually no change irrespective of the level of the optical output intensity. Thus, it has been shown that the frequency modulation is functioning effectively.

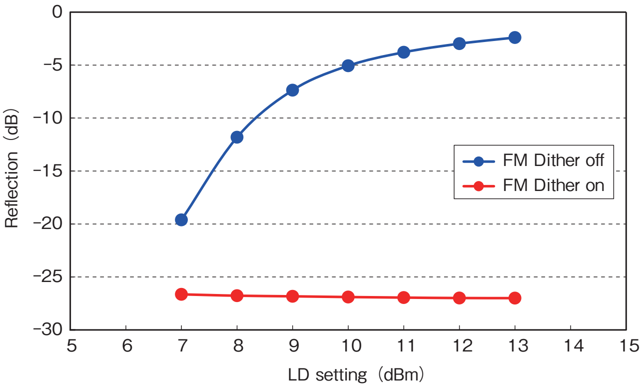


Figure 11 Reflection loss characteristics with a 30-km SMF.

Amplitude modulation for signal discrimination is the function in which an arbitrary discrimination signal TxTrace sent from the higher-level device is used to control the optical output intensity in order for the receiver to discriminate the transmitter. In this ITLA, control of optical output intensity is achieved by converting the TxTrace signal from the higher-level device into suitable signals, and subsequently superimposes them on the SOA current.

4. CONCLUSIONS

An ITLA incorporating a full-band tunable laser compliant with MSA has been developed. This ITLA covers the entire range of either the C- or L-band, achieving wavelength locking for DWDM systems of 50-GHz spacing. It is also applicable to 25-GHz spacing systems by changing the laser used. Since this ITLA offers multi-function performance including dithering function incorporated as an option, it is expected to make a significant contribution to performance enhancement, downsizing and cost reduction of DWDM systems.

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