# Development of a Micro ITLA for Optical Digital Coherent Communication

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**ABSTRACT** A Micro Integrable Tunable Laser Assembly (Micro ITLA) downsized by one-third (37.5×20.0 $mm^2$) of the standard ITLA is developed. The Micro ITLA has the feature of improving a higher output power and a narrower spectrum linewidth while maintaining the function of the specification of the standard ITLA[1)], and developing a compacted package module and a control circuit technology implemented with respect to the standard specification of the Micro ITLA[2)]. Furthermore, the spectrum linewidth of less than 300 kHz and the gridless wavelength output capacity (a minimum setting resolution: 0.1 GHz) were satisfied with a system requirement of more than 400 Gb/s.

## 1. INTRODUCTION

Since the large demand of mobile devices, such as the smart phones with their internet traffic, are increasing, the systems of 40 Gb/s and 100 Gb/s have been introduced in the backbone system of the transmission system. In order to expand more transmission capacity, a transmission trial of 400 Gb/s and 1Tb/s system utilizing an existing optical fiber in the field was reported[3),4)]. The 16 QAM modurations and 2 subcarriers is expected to be the most suitable configuration for the 400 Gb/s system.

A Nyquist Filter technology and a nonlinear compensation technology, both are based on DSP, was reported[5)] to deal with a long-haul and a large capacity transmission utilizing the multi-level modulation format.

In order for the 400 Gb/s transmission utilizing the multi-level modulation format to be achieved practically, a tunable laser is required with a spectrum linewidth of less than 300 kHz[6)], with a wavelength tunable functionality of 0.1 GHz spacing and with the accuracy in the frequency of ±1.5 GHz, and also a Micro ITLA featuring compactness and low consumption power from a system perspective.

## 2. CONFIGULATION OF MICRO ITLA

Figure 1 shows a frame format of the Micro ITLA comparing it with a standard ITLA. The size of the standard ITLA was 74.0×30.5 $mm^2$ and the developed Micro ITLA is 37.5×20.0 $mm^2$. The Micro ITLA is downsized by one-third of the standard ITLA from an area comparison point of view. The Micro ITLA mainly consists of a Laser module and a control circuit.

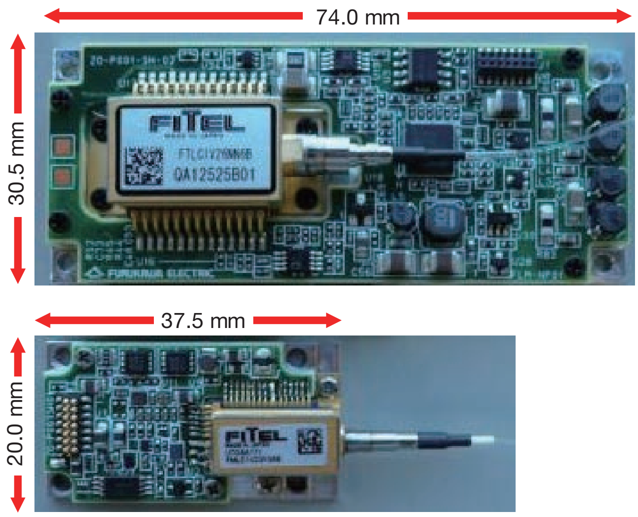


**Figure 1 Standard ITLA (Upper) and Micro ITLA (Lower).**

### 2.1 Laser Module

A laser chip embedded in a laser module is integrated with a distributed feedback (DFB) laser array with different emission wavelengths, a multimode interference (MMI) coupler for combining the output power from the DFB laser array and a semiconductor optical amplifier (SOA) to compensate for losses occurring in the MMI coupler. The numbers of the arrays of the DFB laser are twelve, the DFB laser is tuned in response to a set wavelength, and the full C-band or the full L-band wavelength are the output with a temperature control. In addition to the laser chip, a wavelength locker is mounted on the laser module to prevent a drift of the wavelength with the aging variation. The wavelength locker consists of two photo diodes

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(PD) and an etalon filter, and the feedback control between the optical output and the wavelength is implemented through one of the PDs monitoring the optical output and the other PD monitoring the optical output through the etalon filter. The module has two thermoelectric coolers (TEC) which can control the temperature of the laser chip or the etalon filter independently[7].

### 2.2 Control Circuit

Figure 2 shows the control circuit block. The control circuit consists of a microcontroller and control circuits such as DFB, SOA, TEC1 and TEC2. The microcontroller determines the drive condition for each of the control circuits through calculating a reference target value and an adjustment parameter based on a command from the host module. The DFB control circuit keeps a constant ampere value to select a reference DFB laser based on a set wave length. The SOA control circuit keeps a constant value of the optical output power based on the PD monitor power. The TEC1 control circuit keeps a constant value of the output wavelength based on the PD monitor power transmitted through the etalon filter. The TEC2 control circuit keeps a reference position of the wavelength discrimination characteristics maintained at the constant temperature of the etalon.

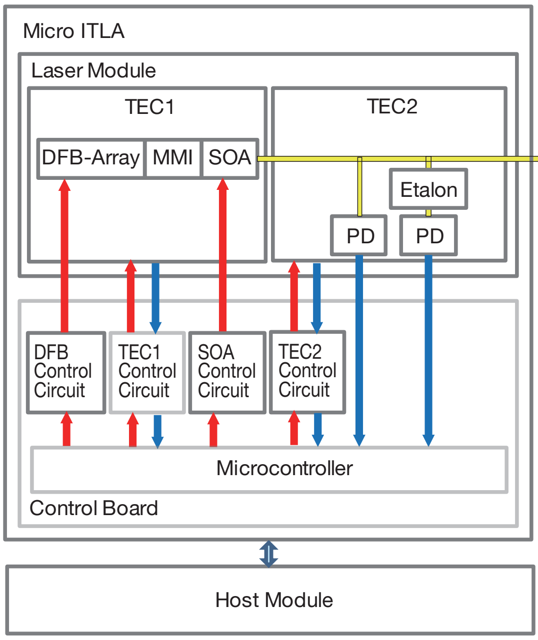


**Figure 2 Control circuit block.**

In order to adjust the size of the micro ITLA while maintaining the functionality of the standard ITLA, a reduction of the control process, an optimization of an electric filter, a relevant number of chip devices and an alternative function of the control circuit with a software were implemented. The final control circuit block was determined through simulation and evaluation experiments to investigate the influence on the changing of the design.

## 3. CHARACTERISTICS

Table 1 shows the standard specification of the Micro ITLA and the characteristics of the developed Micro ITLA with a tunable laser at 100 Gb/s and 400 Gb/s.

**Table 1 Specification of the Furukawa Micro ITLA.**

| Item | Standard Specification of Micro ITLA (Long Haul) | Specification of Furukawa Micro ITLA |
|---|---|---|
| Optical Output | 13.5 dBm | 16 dBm |
| Spectrum Linewidth | < 500kHz | < 300 kHz |
| Side Mode Suppression Ratio (SMSR) | > 40dB | > 40dB |
| Relative Intensity Noise (RIN) | < -135 dB / Hz | < -140 dB / Hz |
| Frequency Accuracy | < ± 2.5 GHz | < ± 1.5 GHz |
| Grid | 50 GHz | 0.1 GHz (minimum value) |
| Power Consumption | 5.0 W | 4.5 W |
| Size | 45 × 20 × 7.5 mm$^3$ | 37.5 × 20 × 7.5 mm$^3$ |

### 3.1 Spectrum Linewidth and Relative Intensity Noise (RIN)

A narrow spectrum linewidth and a small relative intensity noise is needed to carry the information on the optical phase and amplitude in the digital coherent optical communication. Figure 3 shows a spectrum linewidth measured with the delayed self-heterodyne interferometer for linewidth measurement. It was the result of the twenty four cases for the total twelve channels of the DFB array at the maximum or the minimum of the LD temperature respectively. The maximum width was around 250 kHz. Figure 4 shows the relative intensity noise. The result was less than -140 dB/Hz at 1 kHz to 20 GHz.

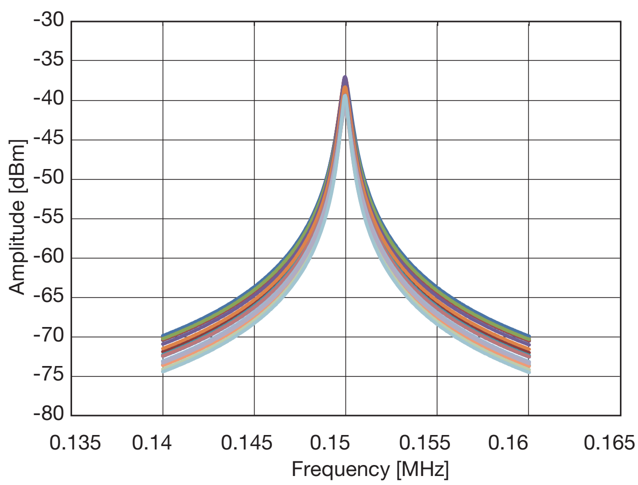


**Figure 3 Spectrum linewidth.**

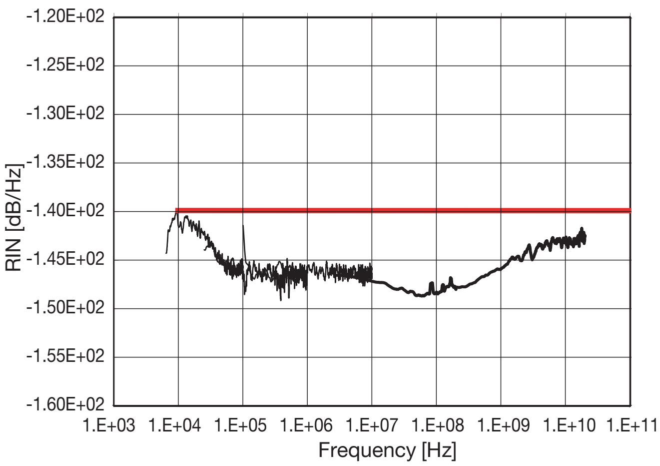


**Figure 4 Relative intensity noise.**

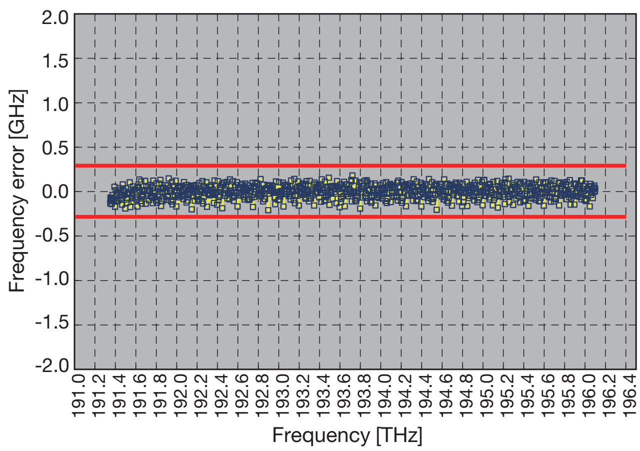


**Figure 5 Frequency error.**

### 3.2 Frequency Accuracy

Since a frequency transient mask is defined in the Micro ITLA standard specification, a precise state control management is needed especially in the stage of a light emitting process. An improvement of the frequency accuracy is achieved by precise adjustment of compensation parameters with the information for each of the control circuits synchronized by the microcontroller.

Since the present optical communication system sets apart at 50 GHz interval for C-Band and allocates the bandwidth of 50 GHz in each of the traffic data , the bandwidth of 50 GHz is occupied in spite of the data quantity or the transmission length. The system of more than 400 Gb/s can allocate the bandwidth with more flexibility, it allocates a wider bandwidth for the long-haul transmission using the BPSK modulation or the QPSK modulation, and if the large capacity data is transferred over a short distance, the frequency efficiency improvement using a modulation of 16 QAM or 64 QAM is achieved. The output wavelength is set at 0.1 GHz interval to adjust the flexible bandwidth allocation for the Micro ITLA. Figure 5 shows the evaluation result of a frequency error with the developed frequency error compensation algorithm. The horizontal scale in the figure shows a set frequency and the vertical scale shows a frequency error. The result of the frequency error was ±0.3 GHz at 0.1 GHz output wavelength interval. We achieved a frequency error within ±1.5 GHz over the entire frequency range or the entire output power range.

### 3.3 Power Supply Noise Resistance

The definition for the supply noise of the Micro ITLA standard specification is 1% as a maximum. If an electrical fluctuation component is overlapped with the laser light output, it appeared that a fluctuation of the modulation signal and the bit error rate are degraded. The developed control circuit has the suitable filter confirmation, the mounting position on the device and the wiring pattern compatible with the size reduction and the low noise.

Figure 6 shows the result of the power supply noise resistance. The power supply noise, such as ① 3.3 V±1% @ 500 kHz ② 3.3 V±5% @ 5 MHz ③ 1.8 V±1% @ 500 kHz ④ 1.8 V±5% @ 5 MHz, were applied and the frequency noise power spectral density (PSD) which are a standard indicator of the phase noise were evaluated and the noise was suppressed to an undetectable level where the frequency component of the applied power supply noise was not detected.

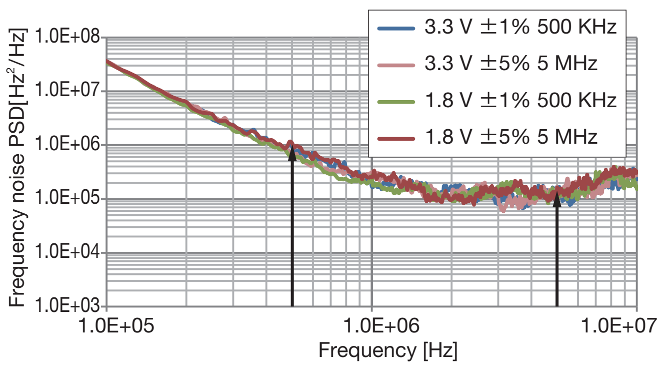


**Figure 6 Frequency noise PSD with voltage noise of power supply.**

### 3.4 Bit Error Rate(BER) Calculation

The spectrum linewidth of less than 300 kHz is needed for the 400 Gb/s transmission with the modulation system of QPSK or 16 QAM. However in the Micro ITLA with the wavelength tunable laser mounted on the control circuit, the phase noise is not indicated as the 1/f noise component or the white noise component, since the electrical noise is overlapped with the output of the tunable laser. It is possible to induce the transmission error on the system operation in spite of the spectrum linewidth being less than 300 kHz. Therefore, we calculated the BER of the QPSK signal with the offline digital coherent receiver[8] and we used it as a measure of the performance of the Micro ITLA.

Figure 7 shows the offline symbol error rate simulation of the Micro ITLA with the QPSK transmission. In the figure, the horizontal line shows the symbol to noise ratio (EsNo) and the vertical line shows the symbol error rate (SER). EsNo indicates the ratio of the noise to the symbol to use as a standard indication to evaluate SER simulated the deterioration of the optical signal-to-noise ratio (OSNR). The SER express the symbol error rate and is handled an evaluation indicator the same as the BER. There is no deterioration from the theoretical value and the light source performance is satisfactory for the transmission use.

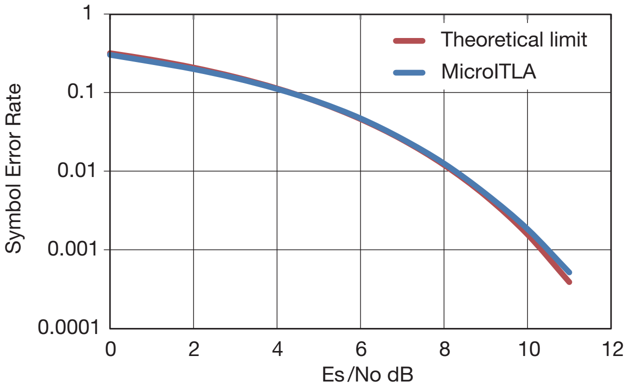


**Figure 7 Offline Symbol error rate simulation of Micro ITLA with QPSK transmission.**

### 3.5 Reliability

Table 2 shows the reliability test specification items of Telcordia GR-468-CORE[9] used as the standard in the telecommunication network. The examples of the evaluation result are shown in Figure 8 and 9. The figure 8 shows the result of the power change in the high temperature operation test and the figure 9 shows the wavelength change in the high temperature operation test. After 2000 hours at 75°C, the fiber output power of ±10% and the wavelength of ±10 pm were obtained and these values were within the specification.

The power change and the wavelength change for the electrostatic discharge (ESD) test are shown in Figure 10 and 11 respectively. After applying 600 V, the fiber output of ±10% and the wavelength of ±10 pm were obtained and these result were within the specification. The results of the other test items were compliant with the specification.

**Table 2 Reliability test of Telcordia GR-468-CORE[9]**

| Test item | Test condition | Criteria |
|---|---|---|
| Mechanical shock | 500 G, 1 msec, 5 times/axis | Δ Pf < ± 10%<br>Δ λ < ± 10 pm |
| Vibration | 20 G, 20-2000 Hz, 4 min/cycles, 4 cycles/axis | Δ Pf < ± 10%<br>Δ λ < ± 10 pm |
| Thermal shock | Δ T=100 degC, 15 cycles | Δ Pf < ± 10%<br>Δ λ < ± 10 pm |
| Fiber Integrity -Twist | 0.5 kgf, 10 cycles | Δ Pf < ± 10% |
| Fiber Integrity -Side Pull | 0.25 kgf, 90°, 5 sec | Δ Pf < ± 10% |
| Fiber Integrity -Cable Retention | 0.5 kgf, 1 min | Δ Pf < ± 10% |
| High Temperature Operation | Pf=40 mW, Tc=75 degC, 2000 H | Δ Pf < ± 10%<br>Δ λ < ± 10 pm |
| High Temperature Strage | Ta=85 degC, 2000 H | Δ Pf < ± 10%<br>Δ λ < ± 10 pm |
| Temperature Cycling | Ta=-40/+85 degC, 500 cycles | Δ Pf < ± 10%<br>Δ λ < ± 10 pm |
| Damp Heat | Ta=85 degC, 85%RH, 1000 H | Δ Pf < ± 10%<br>Δ λ < ± 10 pm |
| ESD | C=100 pF, 1.5 kohm, HBM, 0 ~ ± 6 kV | Δ Pf < ± 10%<br>Δ λ < ± 10pm |
| Internal Moisture | — | Water vapor content <5,000 ppm |

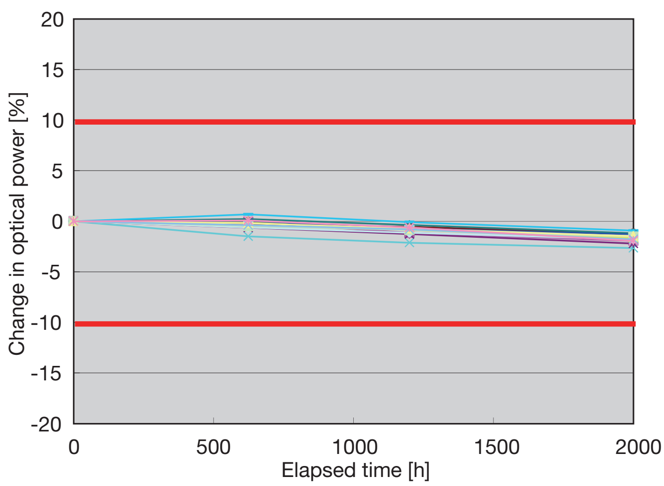


**Figure 8 Power change in high temperature operation test.**

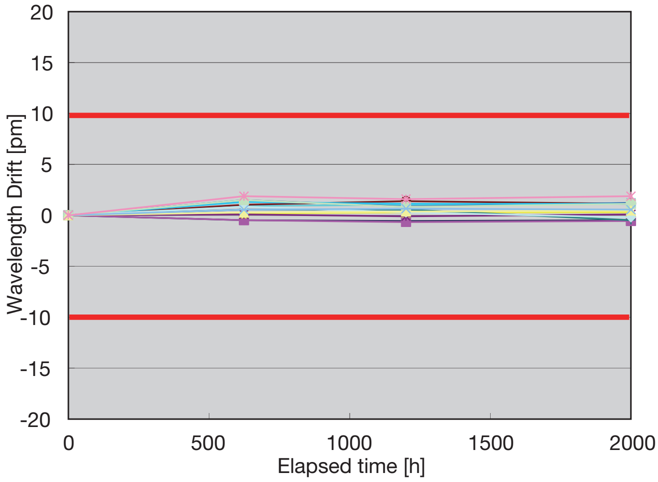


**Figure 9 Wavelength change in high temperature operation test.**

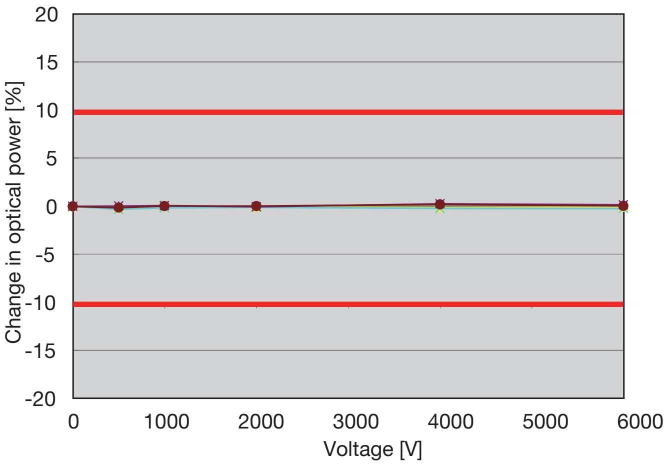


**Figure 10 Power change in ESD test.**

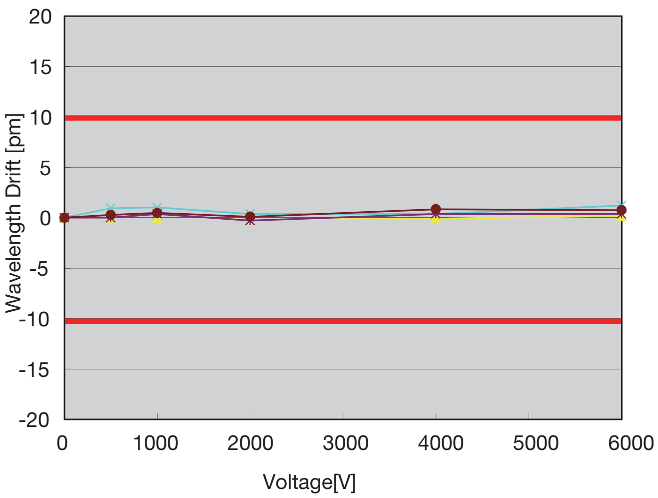


**Figure 11 Wavelength change in ESD test.**

## 4. CONCLUSION

The compact and low power consumption Micro ITLA suitable for 400 Gb/s system was developed. The spectrum linewidth of less than 300 kHz and the gridless wavelength output capacity function (a minimum resolution: 0.1 GHz) interval were achieved, and also the reliability tests were compliant to the Telecordia GR-468-CORE of the telecommunication business standard. We would pursue the development of an improved develop the Micro ITLA with higher output power, lower power consumption and narrower spectrum linewidth.

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