High-Precision Frequency Difference Locking System for Up/Downstream Lasers with 30 nm Interval in Next Generation Coherent PON

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Abstract: We demonstrated a high-precision frequency locking system based on asymmetric Mach-Zehnder interferometer (AMZI). The 1526 nm upstream laser realized a frequency difference stability of about 30 nm ±25 MHz with 1556 nm downstream laser.

1. Introduction

With the continuously growing demands for the access network bandwidth, coherent technology is considered as a promising candidate for realizing 100 G/λ in next generation PON [1]. However, the cost challenges such as advanced optical and electrical components must be resolved [2].

Using distributed feedback (DFB) laser instead of distributed Bragg reflector (DBR) laser or External-cavity laser (ECL) in optical network unit (ONU) can greatly reduce the light source costs. Whereas, the wavelength drift of DFB laser is more severe than the others [3]. Consequently, both local oscillation (LO) laser and upstream laser in ONU need to maintain a stable frequency difference with the downstream laser in optical line termination (OLT).

In this paper, high power and narrow linewidth 1526/1556 nm DFB laser chips are designed [4] and packaged into Transmitter Optical (TO) with thermoelectric cooler (TEC) and polarization maintaining fiber, which are used to be upstream and downstream lasers separately. A frequency locking system based on thin-film lithium niobite (TFLN) AMZI instead of advanced DSP system are proposed. By utilizing the periodic transmission characteristics of AMZI, frequency locking with an interval of 30 nm between the up/downstream lasers can be implemented, which cannot be solved by high-speed ADC or other pure electrical methods.

2. TFLN AMZI Design

Fig. 1(a) shows the schematic of the TFLN AMZI. A metallic micro-heater is made on the top of the TFLN waveguide. The ridge waveguide structure of the TFLN is shown in the Fig. 1(b). The thickness of TFLN is 600 nm, and the width of ridge waveguide is 1.5 μm with 300 nm etching depth. A 1 μm SiO_2 layer is deposited on the TFLN by using Plasma-Enhanced Chemical Vapor Deposition (PECVD).

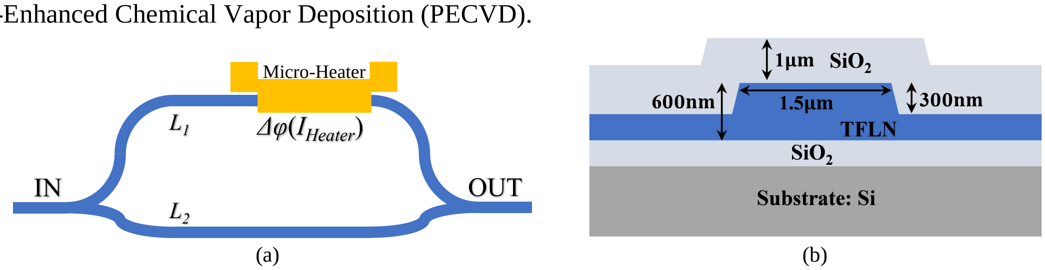


Fig. 1. (a)The schematic; (b)The ridge waveguide structure of the TFLN AMZI.

T_{AMZI} is the transmittance of the AMZI which is calculated using the following equation:

$$T_{AMZI} = \frac{1}{2}\left[1 + \cos\left(\frac{c}{\lambda} n_{eff}(L_1 - L_2) + \Delta\varphi(I_{Heater})\right)\right] \quad (1)$$

The T_{AMZI} is used to convert the frequency variation into the intensity variation. The length difference of two paths is 2655 μm, making the free spectral range (FSR) around 50 GHz. The I_{Heater} is used to generate $\Delta\varphi$ phase shift based on thermal-optic effect, making the transmission frequency characteristics shift.

3. Frequency Locking System Principle

Due to the periodic transmission frequency characteristics of AMZI, two lasers with larger wavelength intervals (30 nm) can be locked at different periods. Fig. 2 shows the spectra of 1556 nm downstream laser, 1526 nm upstream laser and AMZI. Two lasers are locked at the maximum transmission slope point of AMZI at different periods, which can achieve higher frequency detecting accuracy.

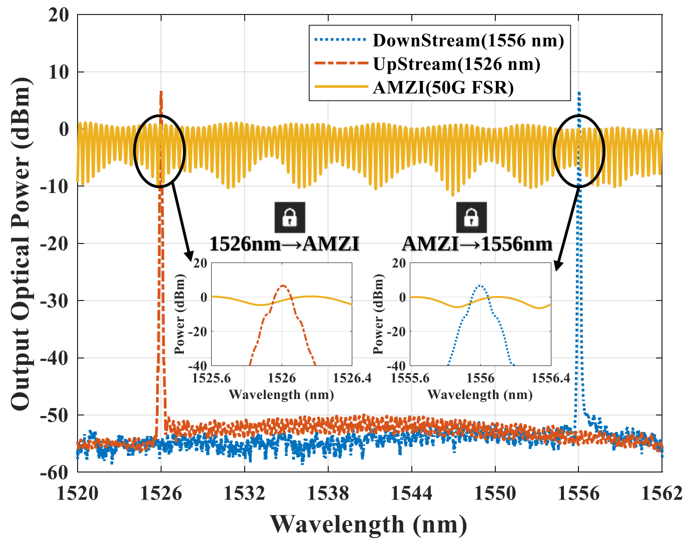
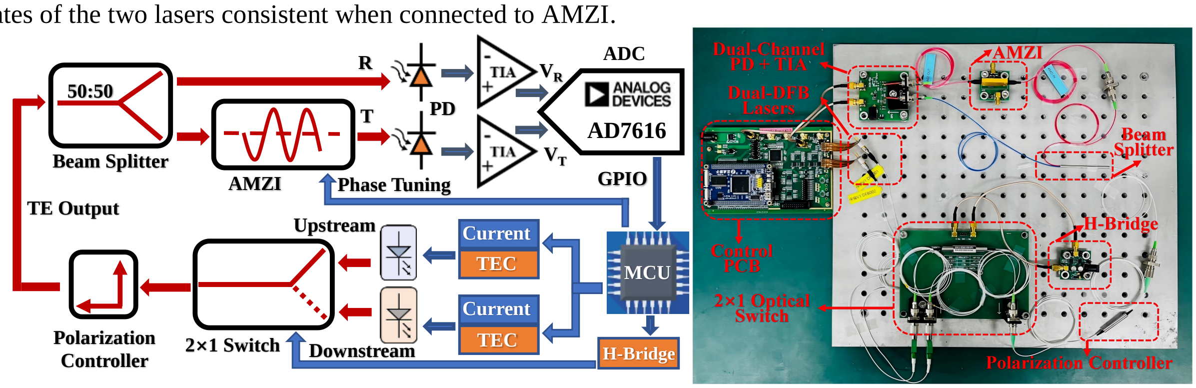


Fig. 2. The spectra of downstream laser, upstream laser and AMZI.

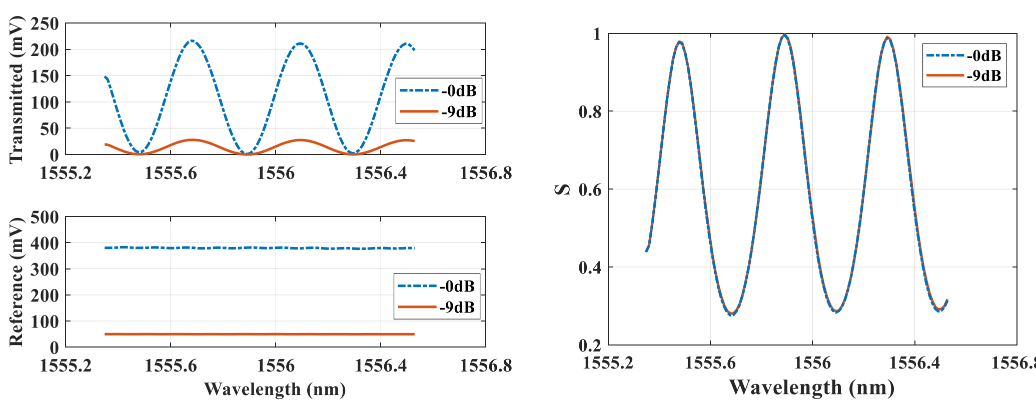
The schematic and photograph of the frequency locking system is shown in Fig. 3. A 2 ×1 optical switch is used to make the up/downstream lasers time-sharing access to the AMZI. A polarization controller makes the polarization states of the two lasers consistent when connected to AMZI.



(a) (b)

Fig. 3. (a)The schematic; (b)The photograph of the indirect locking system.

In order to eliminate the impact of power on frequency deviation detection, a 50:50 beam splitter is added to the next stage of the optical switch, one of output port is connected to AMZI and the other is used as a power self-reference. V_T and V_R represent the voltage of transmitted light and the voltage of reference light, respectively. Fig. 4(a) shows the V_T and V_R under different light power attenuations which are -0 dB and -9 dB.



(a) (b)

Fig. 4. (a) The voltage of transmitted light and reference light; (b) The normalized transmittance characteristics under different power.

Parameter S is defined as normalized transmittance and calculated using the following equation:

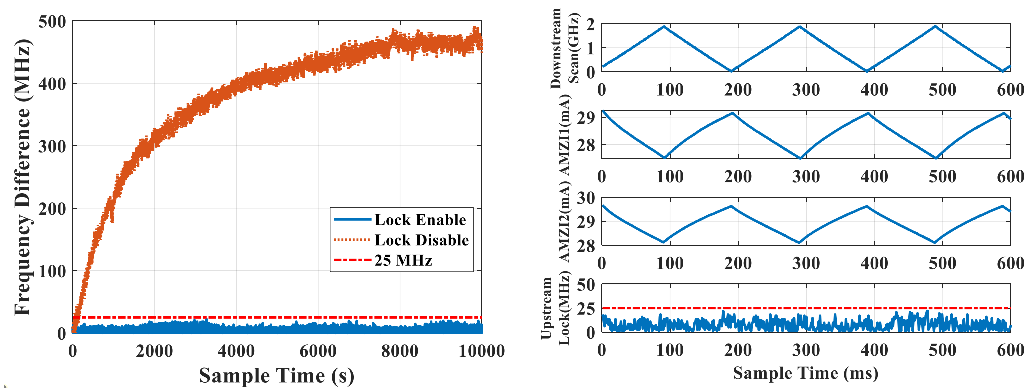
$$S = \frac{V_T - V_R}{V_T + V_R} \tag{2}$$

Fig. 4(b) shows the parameter S of overlap under different optical powers. The addition of reference light makes the up/downstream lasers with different powers to have consistent normalized transmittance characteristic. By calculating the parameters S of the up/downstream lasers passing through the AMZI, the frequency deviation can be obtained.

4. Test Results

In order to test the locking performance of 30 nm interval, two 1526 nm upstream lasers are locked to one 1556 nm downstream laser through two AMZIs. Two 1526 nm lasers are beaten to monitor the frequency difference.

Fig. 5(a) shows the long-term static frequency locking results. Compared to the frequency difference drift to 500 MHz with locking disable, a ± 25 MHz frequency difference between the two 1526 nm upstream lasers can be maintained when enable the locking. It demonstrates that both upstream lasers can be precisely locked to the downstream laser.



(a) (b)

Fig. 5. (a)Long-term static frequency locking results; (b)Dynamic frequency locking test results.

The frequency of the downstream laser is scanned in a triangular wave form. The scanning amplitude is about 2 GHz and the scanning speed is about 20 MHz/s. The I_{Heater} of two AMZIs are recorded which are adjusted at the same trend to shift their transmission characteristics. The frequency of two upstream lasers is controlled to follow the AMZIs. Fig.5(b) shows that the frequency difference between two upstream lasers can still be maintained at ±25 MHz, which demonstrates great locking performance between two lasers with a 30 nm interval.

5. Conclusion

A frequency difference locking system based on the AMZI is demonstrated for the first time and realize a stability of about 30 nm ±25 MHz between up/downstream lasers, which is the highest DFB lasers frequency difference locking accuracy of wide wavelength interval (> = 30 nm). This low-cost, high-precision and wide-interval frequency difference locking methods demonstrates excellent application potential in the next generation coherent PON.

6. Funding

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7. Reference

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