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Simultaneous O-Band/C-Band wavelength-swept active mode locking laser for multi-band OCT imaging

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Abstract— **This paper shows experimentally dual wavelength swept at multi band (O,C-Band) property with active mode locking (AML) method. Unlike conventional wavelength swept laser, AML wavelength swept laser does not require any wavelength selecting filter in the cavity. The cavity has two free spectral ranges (FSRs) depend on dual path configuration. This wavelength swept laser can be useful for wide-band fiber-optic application.**

I. INTRODUCTION

In the last decade, optical coherence tomography (OCT) has become an important technology used for micrometer-scale cross sectional imaging based on the interfered optical signals between the sample and the reference [1], [2]. There are several methods to constitute spectroscopic information. However, conventional methods depend on wavelength dependency at one wavelength band only [3]. OCT using two spectral ranges has been reported in time-domain [4], spectral-domain [5], and full-field [6]. However, there are several limitations such as slow acquisition rate or free-space configuration.

Swept source-OCT (SS-OCT) has become one of the dominant OCT techniques, due to its fast speed imaging ability that uses a high sweeping rate of the wavelength-swept source [1], [2]. Various types of wavelength-swept lasers have often been proposed in order to achieve not only a high repetition rate of the wavelength sweeping but also high signal-to-noise ratio (SNR). Recently, in addition, dual-wavelength swept laser using single two-window polygon scanner was demonstrated for OCT imaging and implemented to demonstrate the advantage of a second wavelength band for high-quality OCT spectroscopic analysis with low computational costs [7].

In this study, we experimentally investigated the dual-wavelength swept laser based on active mode locking method. AML laser does not require any wavelength-selecting filter such as fiber Fabry-Perot filter or polygon scanner. Therefore, filter-less dual-wavelength swept laser is demonstrated.

II. PRINCIPLE AND EXPERIMENT

Fig.1 shows the experimental set-up of the constructed dual-wavelength swept AML fiber laser. The cavity consists of semiconductor optical amplifier (SOA) for gain, two of 2x2 50:50 couplers for dual path cavity, a polarization controller (PC) and dispersion compensation fiber (DCF) for the high dispersive cavity. Because of dual path cavity configuration, the cavity has two free spectral ranges, F_{10} and F_{20}, as expressed in eq. (1)

$$F_{10} = \frac{c}{n(L+l_1)}, \; F_{20} = \frac{c}{n(L+l_2)} \qquad (1)$$

When the cavity of fiber laser has a chromatic dispersion, free spectral range (FSR) is a function of wavelength. Neglecting high order dispersion, the relation between wavelength λ and F can be simply expressed as [8],

$$\lambda_{mn} = -\frac{n_0}{cDF_{n0}}(F_n - F_{n0}) + \lambda_0 = -\frac{n_0^2(L+l_n)}{c^2 D}(F_n - F_{n0}) + \lambda_0 \qquad (2)$$

where L is a cavity length, n is a refractive index of fiber, D is dispersion parameter, c is a velocity of the light, subscript n is a number of path, and F is a FSR of cavity (=c/nL).
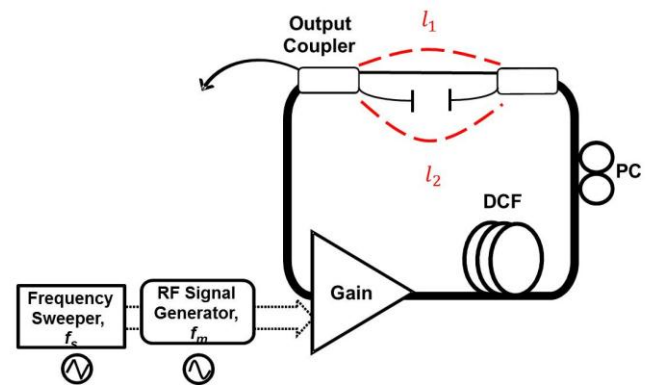

Fig. 1. Set-up of dual-wavelength swept active mode locking laser

By applying modulation signal to the cavity, we can generate a short pulse train and lock the lasing mode at a wavelength among the gain region. This technique is called active mode locking. [9] When the frequency of modulation signal (f_m) is an integer times (N) of FSR, stable active mode locking is occurred at a wavelength.

$$f_{mn0} = N \cdot F_{n0} \qquad (3)$$

Then equation (2) can be simply changed to,

$$\lambda_{mn} = -\frac{n_0{}^2 L_n}{c^2 ND}(f_m - f_{mn0}) + \lambda_0 = -\frac{n_0}{cDf_{mn0}}(f_m - f_{mn0}) + \lambda_0$$

(4)

, where f_{mn0} is $N \cdot F_{n0}$, λ_{mn} is output wavelength. Equation (4) means that if we change frequency of modulation signal repeatedly, the wavelength of active locking laser can be shifted repeatedly. We simply change frequency of modulation signal by FM modulation and then lasing wavelength is also swept.

As we tune the mode locking frequency around 570 MHz, Fig. 2 shows static dual-wavelength lasing spectra of laser output. The output wavelengths are 1261 nm and 1506 nm when the frequency of modulation is 571.17 MHz. When the frequency is changed to 571.89 MHz, the wavelengths are come out at 1329 nm and 1539 nm, respectively.
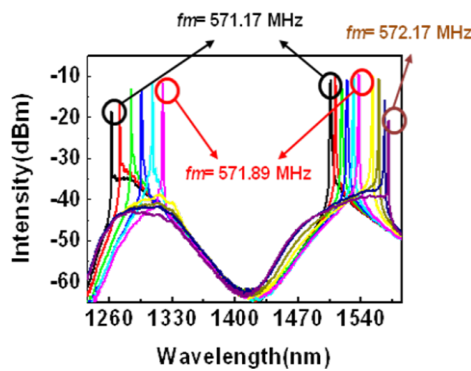
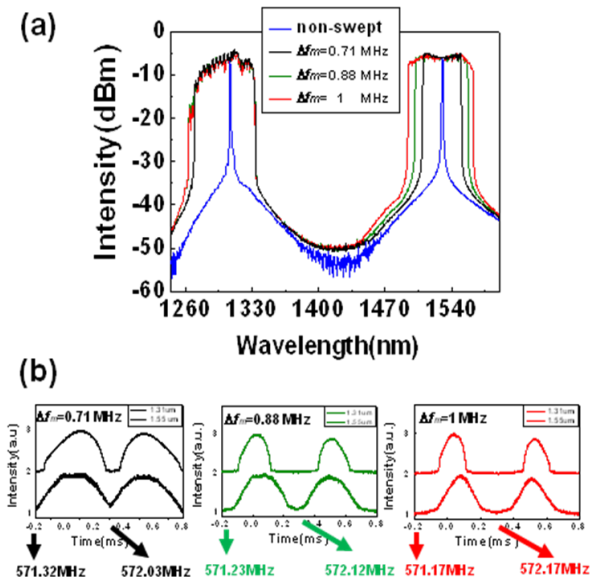

Fig 2. Output static spectra of dual-wavelength laser

Fig 3. Peak-hold spectra of the dual-wavelength laser

For the experiment, we use an external FM-function of RF signal generator to modulate frequency of modulation signal. Triangular signal from function generator is used for FM modulation. The frequency of this FM modulation is the sweeping rate of laser. The sweeping rate is easily controlled by frequency of FM modulation. Fig.3 (a) shows peak-hold mode spectra of sweeping output at 1 kHz rate when Δfm is 0.71MHz, 0.88MHz and 1MHz , respectively. Fig.3 (b) shows time tracking spectra of each Δfm.

III. CONCLUSIONS

Simultaneous O-Band/C-Band wavelength-swept active mode locking fiber laser is demonstrated for fiber-optic sensors. Because of the dual wavelength performance, the dual-band output spectrum is obtained for this laser. AML laser does not require any wavelength-selecting filter such as fiber Fabry-Perot filter or polygon scanner. Therefore, filter-less dual-wavelength swept laser is demonstrated.

IV. ACNOWLEDEMENT

REFERENCES

[1] D. Huang, E. A. Swanson, C. P. Lin, J. S. Schuman, W. G. Stinson, W. Chang, M. R. Hee, T. Flotte, K.Gregory, C. A. Puliafito, J. G. Fujimoto, "Optical Coherence Tomography", Science 254, p1178-1181 (1991).

[2] W. Y. Oh, B. J. Vakoc, M. Shishkov, G. J. Tearney, and B. E. Bouma, ">400 kHz repetition rate wavelength-swept laser and application to high-speed optical frequency domain imaging," Opt. Lett., 35, p2919–2921 (2010).

[3] C. Xu, P. Carney, and S. Boppart, "Wavelengh-dependent scattering in spectroscopic optical coherence tomography" Opt. Express 13, p5450-5462 (2005).

[4] F. Spöler, S. Kray, P. Grychtol, B. Hermes, J. Bornemann, M. Först, and H. Kurz, "Simultaneous dual-band ultra-high resolution optical coherence tomography", Opt. Express 15, p10832-10841 (2007).

[5] S. Kray, F. Spöler, M. Först, and H. Kurz, "High-resolution simultaneous dual-band spectral domain optical coherence tomography" Opt. Lett. 34, p1970-1972 (2009).

[6] D. Sacchet, J. Moreau, P. Georges, and A. Dubois, "Simultaneous dual-band ultra-high resolution full-field optical coherence tomography" Opt.Express 16, 19434-19446 (2008).

[7] Youxin Mao,* Shoude Chang, Erroll Murdock, and Costel Flueraru "Simultaneous dual-wavelength-band common-path swept-source

[8] optical coherence tomography with single polygon mirror scanner", Opt. Lett.36, p1990-1992 (2011)

[9] S. Yamashita, M. Asano, "Wide and fast wavelength-tunable mode-locked fiber laser based on dispersion tuning", Opt. Express 20, p9299-9306 (2006).

[10] G. P. Agrawal, "Applications of Nonlinear Fiber Optics", Academic Press, San Diego, Calif, USA (2001).