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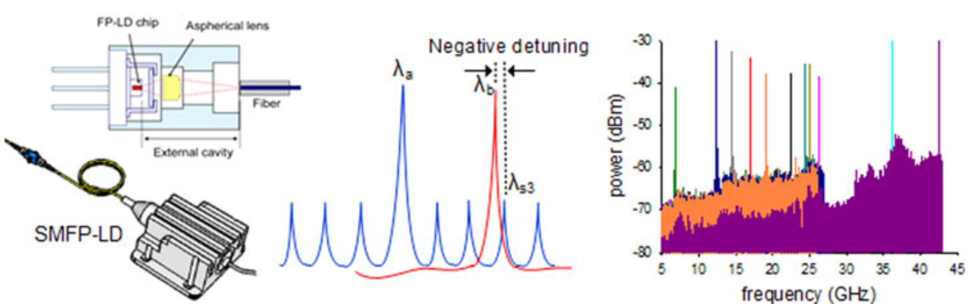

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Injection With Negative Wavelength Detuning for Multispectrum Frequency Generation and Hopping Using SMFP-LD

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Abstract: We propose and demonstrate a novel method to generate multispectrum frequency and hopping from one frequency spectrum to another using a single external cavity based Fabry–Pérot laser diode (FP-LD) subjected to a single optical injection with negative wavelength detuning. The external cavity based FP-LD has a single dominant mode, single-mode FP-LD (SMFP-LD), and hence the beating of the dominant mode and the injected beam, and the beating of the injected beam and the corresponding side mode of SMFP-LD are possible with a single optical injection. The generated frequency can be tuned to a wide range of GHz to several THz. Individual or simultaneous RF signals generation and hopping between microwave and millimeter wave spectrum are reported. The effect of the injected beam power on generating and hopping of RF frequency is analyzed in the case of negative wavelength detuning with the input beam injected on different modes of SMFP-LD. Also, the stability of beating wavelengths, power variations of beating wavelengths for an interval of 1 hour, and linewidth of RF signals are observed.

Index Terms: SMFP-LD, negative wavelength detuning, frequency hopping, injection locking, microwave photonics.

1. Introduction

Photonics generation of multi-spectrum frequency has drawn the extensive interest of researchers due to its unsurmountable advantages such as the ability to generate tunable signals with higher frequencies, simple configuration, transmission distance, and less susceptibility to electromagnetic interference. Due to these advantages, microwave photonics generation tremendously built its potentials for numerous applications such as wireless communication system [1], [2], radar system [3], biology [4], and others [5]–[7]. Microwave generation using optical fiber lasers, semiconductor lasers, and photonics crystal has been reported based on homodyne, heterodyne optical phase-locked loop [8], mode-locked lasers [9], optical frequency combs [10], side-band locking [11], and feedback injection locking [12]. The optical heterodyning method of beating two separate tunable lasers at a photodiode is simple in configuration but optical sources should be coherent preserving widely adjustable frequency offset between them. Feedback injection locking has good spectral purity but suffers from a limited tuning range attributed to loop bandwidth. Sideband injection locking requires reference source, hence, complex in configuration and expensive in cost. Also, reported methods are limited to the generation of single microwave frequency. Simultaneous microwave generation using quantum dot lasers with optical beating has been reported [13] which requires two external beams and a quantum laser diode. The requirement of two external lasers for simultaneous generation of RF signals can be removed by using SMFP-LD and a single external beam injection since SMFP-LD has a dominant mode under normal biasing condition. Also, the same injected single beam can be used for the generation of RF signals as well as a control signal for hopping/switching of generated RF signals of different bands. SMFP-LD has shown its significant presence through demonstrating optical switches [14], wavelength converters [15], logic gates [16], latches [17], and others [18]–[20] due to its significant characteristics of self-injecting mode, high side mode suppression ratio, and less current requirement, outperforming other semiconductor lasers. Microwave generation using SMFP-LD with feedback injection locking and two color laser has been demonstrated recently. However, for feedback injection locking it requires additional filters and amplifiers for each RF output and two color laser diode lacks tunability of the two color modes [11], [21]. Instead of feedback injection locking, microwave can be generated from beating any of the side modes or the dominant mode and the injected beam, which are mode-locked in SMFP-LD. This will remove the necessity of individual filters and amplifiers required for each RF signal generation using the feedback injection locking system. The RF signal generated by the beating of an injection locked lasers provides better performance in noise and linewidth than free running laser beams [22].

In this paper, we use injection locking with negative wavelength detuning in SMFP-LD for demonstrating our innovation on (1) generating millimeter wave, simultaneous microwave and millimeter wave, and microwave using SMFP-LD with a single external beam injection, (2) analyzing the effect of negative wavelength detuning, injected beam power, wavelength detuning in different side modes for generating RF signals, and (3) multi-spectrum frequency hopping. The proposed scheme has a wide tunable range from few GHz to THz, ranging from microwave to millimeter wave spectrum. The spectrum domain results from 5 GHz to 402 GHz with a signal to noise power ratio of more than 25 dB is reported, which can be extended to THz [11]. The THz range is obtained when the external beam is injected to the higher side modes of SMFP-LD. The minimum power ratio obtained between RF signal and noise is more than 24 dB and linewidth is measured below 250 KHz for 42.5 GHz. The stability of beating wavelengths, the stability of power of beating wavelengths and the linewidth of RF signal are measured. The proposed scheme provides a good tunable ability of RF frequency, simple configuration, easy hopping from one RF signal to another (from microwave to THz), and does not need any reference source unlike in other schemes [23], [24]. Hence, the proposed scheme establishes its potential in many applications such as multi-functional radar system, satellite networks, 5G mobile network, and radio over fiber applications.

2. Operating Principle and Experimental Setup

The fundamental principle behind the injection locking in SMFP-LD is the injection of the external beam to the right side of side modes of SMFP-LD, i.e., positive wavelength detuning (wavelength difference between the injected beam and the corresponding side mode) as shown in Fig. 1(a). In Fig. 1(a), λ_a, λ_b, and λ_{s3} indicate the wavelengths of the dominant mode, the injected beam, and the 3rd side mode of the SMFP-LD, where an external beam is injected, respectively.

Two cases can be observed with positive injection locking: (1) the power of injected beam is not sufficient to suppress the dominant mode of SMFP-LD and both dominant mode and injected external beam exist known as weak injection locking as shown in Fig. 1(b) and (2) the power of injected beam is sufficient enough to suppress the dominant mode of SMFP-LD with sufficient amount of contrast ratio known as injection locking as shown in Fig. 1(c). With positive wavelength detuning, microwave generation is possible only by beating with a dominant mode and a weakly locked injected beam. When the external beam is injected to any of the side modes of SMFP-LD,

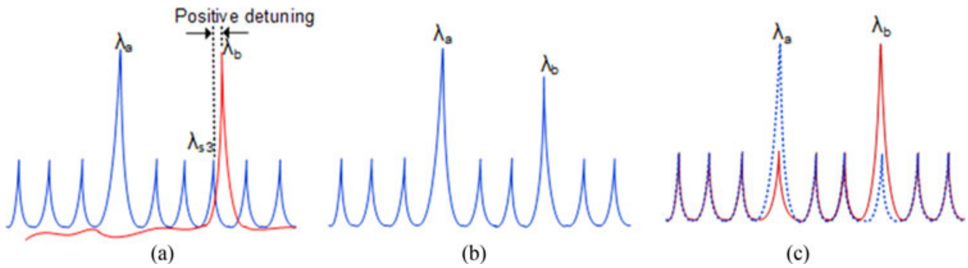

Fig. 1. Injection locking in SMFP-LD with positive wavelength detuning: (a) SMFP-LD under the normal biasing condition and injected external beam, (b) weak injection locking, and (c) strong injection locking.

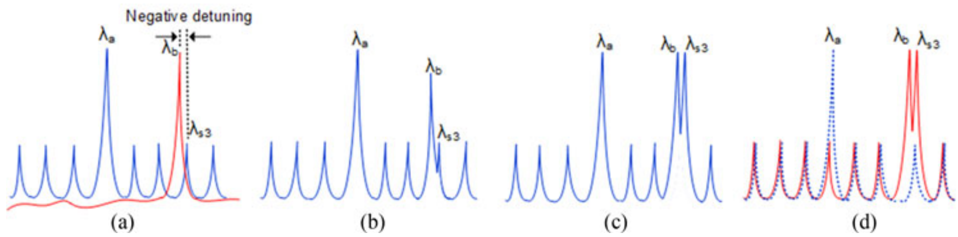

Fig. 2. Injection locking in SMFP-LD with negative wavelength detuning: (a) SMFP-LD under the normal biasing condition and injected external beam, (b) millimeter wave, (c) simultaneous microwave and millimeter wave, and (d) microwave.

only the generation of a millimeter wave is possible because of the beating of the dominant mode and the injected beam. With positive wavelength detuning, mode shifting of corresponding side mode occurs and hence the microwave generation is not feasible in the side modes of the SMFP-LD, but the millimeter wave generation (due to the beating of the injected beam on side mode and dominant mode) is possible. Simultaneous microwave and millimeter wave generation with positive wavelength detuning between injected beam and corresponding side mode is not feasible due to mode shifting of corresponding side mode to the injected beam. In contrast, if the external beam is injected with negative wavelength detuning as shown in Fig. 2(a), following cases are observed. (1) The injected beam gains sufficient power without suppressing the dominant mode and without shifting the corresponding side mode to the injected beam as shown in Fig. 2(b). Hence, millimeter wave can be generated by beating the dominant mode and the injected beam, (2) on increasing the power of the injected beam, the power of corresponding mode increases without suppressing the dominant mode, as a result, simultaneous generation of microwave and millimeter wave is feasible due to beating of corresponding side mode and injected beam and by beating injected beam and dominant mode, respectively as shown in Fig. 2(c), and (3) on increasing power further, the dominant mode is suppressed, but still corresponding side mode does not shift to the wavelength of the injected beam. Injected beam and corresponding side mode would still exist as shown in Fig. 2(d), which provides microwave only.

The main difference between positive wavelength detuning and negative wavelength detuning is the mode shifting phenomena and the increase in mode power with an increase in the injected beam power. In positive wavelength detuning, the corresponding mode shifts to injected beam on increasing the power of input beam and hence the third and fourth stage of negative wavelength detuning cannot be observed. We noted here, in negative wavelength detuning, the microwave generated by beating injected beam and corresponding side mode is possible only up to the half of the free spectral range (FSR) which is 0.58 nm (1.16 nm/2). Wavelength detuning greater than half FSR will act as positive wavelength detuning to the previous mode. As a result, only one RF signal is possible by beating injected beam and the dominant mode.

The experimental setup of multi-spectrum frequency generation and hoping using SMFP-LD is shown in Fig. 3. The FP-LD used in the proposed scheme is specially designed and developed by modifying commercial FP-LD which has multi-modes under normal biasing condition. The

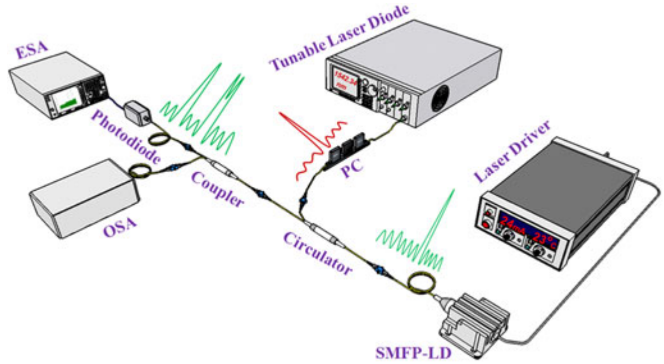

Fig. 3. Schematic of the experimental setup for generation and frequency hopping of the tunable millimeter wave, millimeter and microwave and microwave using external cavity based Fabry-Pérot laser diode. PC: polarization controller, OSA: optical spectrum analyzer, ESA: electric spectrum analyzer.

developed SMFP-LD has a dominant self-locked single longitudinal mode with high side mode suppression ratio (SMSR). The SMFP-LD is obtained by eliminating the inclinations of 6° to 8° of the coupling fiber present in conventional FP-LDs, thereby, forming an external cavity between the laser diode and the fiber. The SMFP-LD consists of an FP-LD chip with a multi-quantum well of 300 μm and an external cavity length of 4 mm. By varying the temperature, a mode-matching condition is achieved for both cavities. The refractive index of the active region changes with the change in the temperature. As a result, there is a change in the optical path length in the laser diode, providing the optimal mode-matching condition for single-mode oscillation. This single-mode oscillation can be tuned to another mode by varying the operating temperature, which gives the tunability of dominant mode wavelength to SMFP-LD. The self-locking mode of SMFP-LD is tunable over a wide range of wavelengths with a wavelength difference of about 10 nm [25]. SMFP-LD shows similar characteristics to those of multimode Fabry-Pérot laser diodes (MMFP-LDs) including the mechanical stability, wavelength stability, power stability of laser diode and also the output characteristics subjected to optical injection of external beams. The only difference between SMFP-LD and MMFP-LD is that the former does not require an external probe beam for signal processing.

An LD driver (ILX Lightwave LDC-3724C) is used for biasing SMFP-LD, which has a facility of changing the biasing current and operating temperature. The operating temperature and the biasing current define the wavelength and power of the dominant mode of the SMFP-LD. A tunable laser module which has features of varying wavelength and power can be tuned from 1530 to 1560 nm, and 5.5 to 16 dBm, respectively, is used for injecting external light beams to the SMFP-LD. The external beam can be injected to any of the side modes in SMFP-LD including dominant mode with both positive and negative wavelength detuning. Attenuators, which are used at the output of the laser source to minimize the power from the tunable laser source, are not shown in Fig. 3. Polarization controllers (PCs) are used to control the polarization state of the external beams to the SMFP-LD which works in TE mode. The output from SMFP-LD is obtained through a circulator and is divided into two branches by 50:50 coupler among which one is fed to an optical spectrum analyzer (OSA, Yokogawa AQ6370C) set with 0.02 nm resolution, and another to an electrical spectrum analyzer (ESA, Agilent E4447A) set with 100 KHz resolution bandwidth via 50-GHz photodiode (PD, U2t XPDV2120R).

3. Experimental Result and Analysis

At first, we injected an external beam to the dominant mode to observe the generation of a microwave signal of different frequencies that correspond to wavelength detuning between injected beam and dominant mode as shown in Fig. 4. We set the constant power of −5.2 dBm to the injected beam. In Fig. 4(a), the red line refers external injected beam that has wavelength detuning of −0.19 nm. Fig. 4(b) shows the result in optical spectrum domain with wavelength detuning of −0.19 nm. On

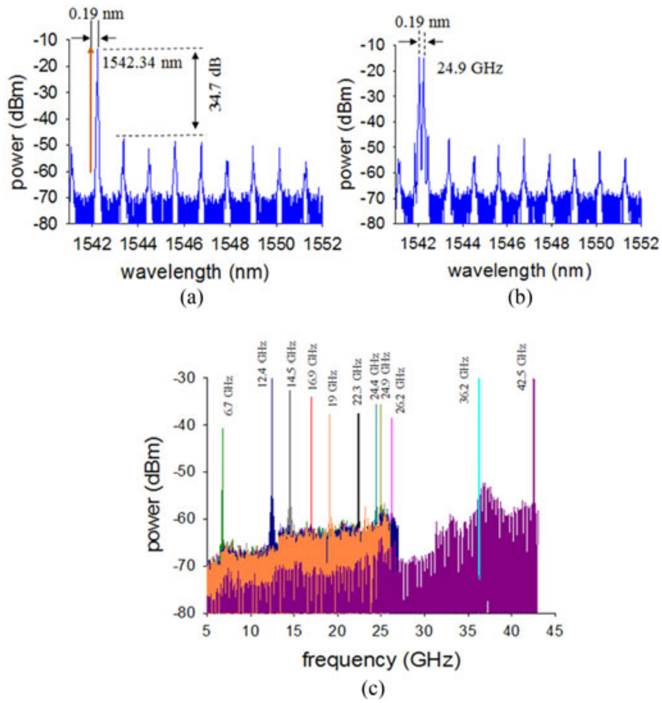

Fig. 4. Basics of generating microwave signal (a) optical spectrum of SMFP-LD, (b) generation of microwave signal with an injection of external beam with negative wavelength detuning, and (c) ESA diagram for generated different frequencies of microwave corresponding to different wavelength detuning.

increasing the power of input injected beam, the injected beam gains power equivalent to dominant mode, as a result, RF signal with a frequency of 24.9 GHz is obtained by beating these two peaks. By varying the wavelength detuning with the dominant mode, RF signal with a different frequency corresponding to that of wavelength detuning can be obtained, which is shown in Fig. 4(c). We observed the maximum RF frequency signal up to 42.5 GHz, the maximum frequency that can be observed by ESA E4447A. However, the optical domain results are observed to the THz range. Fig. 4(c) shows electrical spectrum analyzer (ESA) result of different microwave frequency signals. The same phenomena can be obtained in any of the side modes of SMFP-LD for generating microwave. The minimum power difference of signal to other frequency component is higher than 26 dB in the experiment.

When an external beam is injected into any of the side modes of SMFP-LD, the dominant mode and the injected beam are used as beating wavelengths to generate the millimeter wave whereas, external injected beam and corresponding side mode are required beams for generating microwave. In order to show a tunable feature of SMFP-LD, it is again biased by 23 mA biasing current at operating temperature of 21 °C. With these operating conditions, the dominant mode of SMFP-LD is shifted to 1540.74 nm with SMSR of 36 dB. In order to generate both microwave and millimeter wave simultaneously, the injected beam should be injected to side modes rather than the dominant mode. For the demonstration of our proposed idea of multi-spectrum frequency generation and hopping, we injected external beam on 3rd mode with wavelength detuning of −0.178 nm. The external beam can be injected to any of the modes with any wavelength detuning, the only parameter to control for different mode and different wavelength detuning is the power of the injected beam. With sufficient power of the external beam, the injected beam to 3rd mode gains enough power and hence beating of dominant mode, 1540.74 nm, and injected beam on 3rd mode, 1543.93 nm, occurs which gives the millimeter wave of 402.3 GHz, corresponding to a wavelength difference of 3.19 nm as shown in Fig. 5(a).

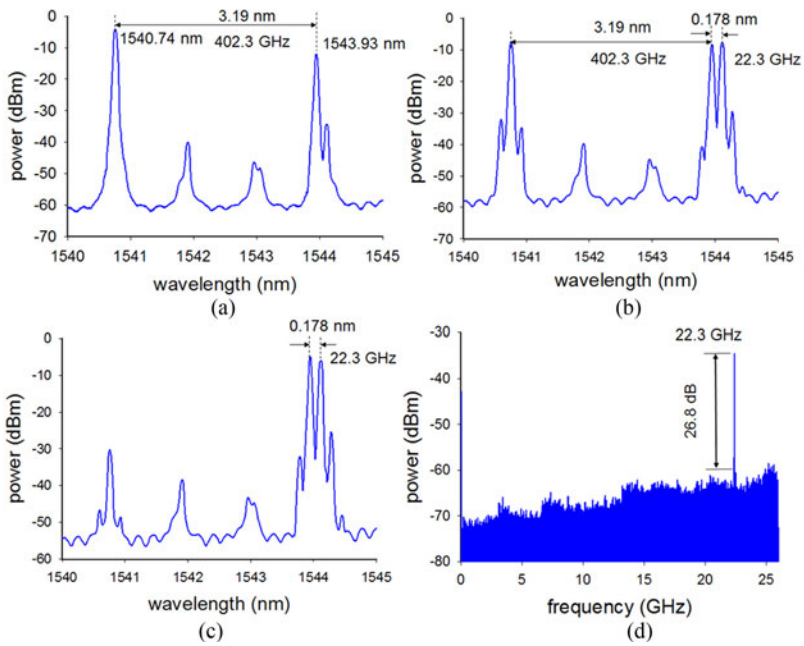

Fig. 5. Spectra of generated RF signals. Optical spectrum: (a) millimeter wave, (b) simultaneous microwave and millimeter wave, and (c) microwave. (d) Electrical domain microwave.

Since the external beam is injected with negative wavelength detuning, increasing the power of the external beam contributes not only to increase the power of the injected beam, but also helps to obtain sufficient amount of power by corresponding side mode without suppressing the dominant mode as shown in Fig. 5(b). As a result, simultaneous microwave and millimeter waves are generated. It is possible because of the negative wavelength detuning which prevents the wavelength shifting of the side mode of the SMFP-LD to the injected beam unlike in positive wavelength detuning. With negative wavelength detuning, it is observed that the decrease in power of dominant mode is not significant as compared to power gained by side mode. Hence, beating of side mode and injected beam as well as the beating of injected beam and dominant mode of SMFP-LD is possible, which makes the feasible generation of both microwave of 22.3 GHz (corresponds to the wavelength detuning of -0.178 nm) and millimeter wave of 402.3 GHz simultaneously. Besides the millimeter wave of 402.3 GHz, an additional RF signal of 422.6 GHz (402.3 GHz $+$ 22.3 GHz) can also be obtained through the optical beating of the dominant mode of the SMFP-LD and the 3rd side mode as shown in Fig. 5(b). The dominant mode will be suppressed with further increase in power of external beam and generates the microwave of 22.3 GHz only, as illustrated in Fig. 5(c).

In Fig. 5(b), harmonics are seen on the both sides of the dominant mode and the 3rd mode whereas in Fig. 5(c), harmonics are only seen on the 3rd mode which is due to the four-wave mixing. Since the harmonics have less power compared to the dominant mode, injected beam and corresponding side modes, the effect of harmonics is negligible in the generation of the RF signal. The power of harmonics generated is maintained at least 26 dB below the power of injected beam, dominant mode, and corresponding side mode while generating simultaneous microwave and millimeter wave. The wavelength difference between generated harmonics is twice the wavelength detuning, 0.35 nm. The electric domain result of the generated microwave of 22.3 GHz is shown in Fig. 5(d) which has a signal to noise power ratio of 26.8 dB. The millimeter waves of 402.3 GHz and 422.6 GHz are not observed in electrical spectrum analyzer (ESA) due to a limited operating range of the photodiode (PD) which has a bandwidth of 45 GHz and ESA E4447A that has a maximum range of 42.5 GHz. The frequency of the generated signal can be varied by varying the wavelength detuning and injecting beam from one side mode to another side mode, which provides the tunable feature of the proposed multi-spectrum generator.

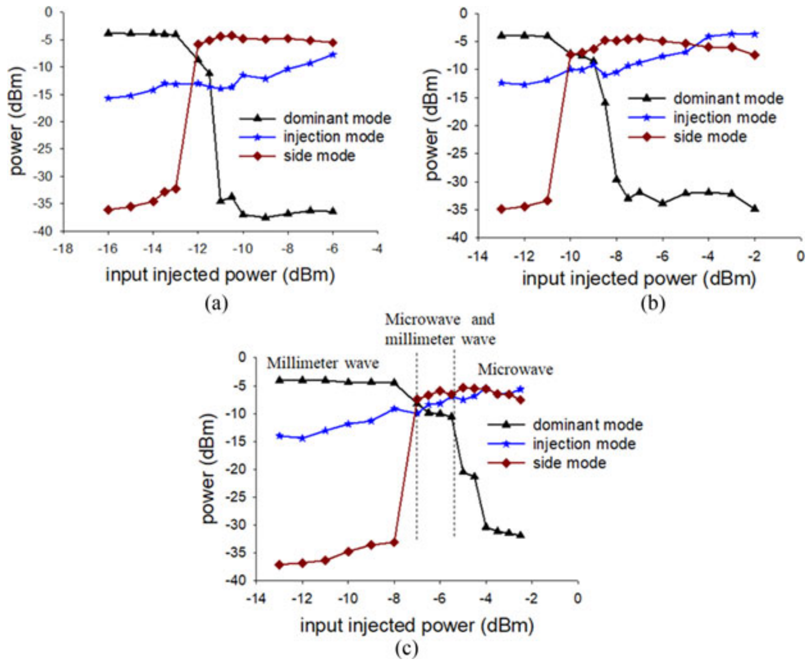

Fig. 6. Effect of negative wavelength detuning on the generation of microwave and millimeter wave with negative wavelength detuning of (a) 0.08 nm, (b) 0.12 nm, and (c) 0.17 nm.

The generation of the microwave with the corresponding mode has the tunability range of about 0.58 nm. Higher than 0.58 nm in the negative wavelength detuning, the wavelength detuning act as positive wavelength detuning to the next lower side mode of the SMFP-LD. In this case, simultaneous microwave and millimeter wave generation is not possible because corresponding side mode cannot gain sufficient power required for an optical beating. However, the generation of only one RF signal, either microwave or millimeter wave, that corresponds to the wavelength detuning of higher than 0.58 nm is possible with the optical beating of the dominant mode and the weakly locked injected beam.

Fig. 6 illustrates the input power required for generating multi-spectrum frequencies and the impact of input injected beam on dominant mode, corresponding side mode, and injected mode when the external beam is injected on the 3rd side mode of SMFP-LD with a wavelength detuning of -0.08 nm, -0.12 nm, and -0.17 nm. It is clear from Fig. 6(a) that three different regions can be attained with negative injection locking in contrast to positive injection locking where only two stages known as weak injection locking without suppression of the dominant mode and injection locking with fully suppressed dominant mode are observed. Hence, only a single RF signal is feasible without negative wavelength detuning. In Fig. 6(a), the injected beam gains sufficient amount of power when the input injected beam power is higher than -16 dBm. As a result, millimeter wave can be obtained by beating the dominant mode and the injected mode whose wavelength difference is 3.19 nm.

Beyond -13.5 dBm, corresponding side mode gains the power on increasing the power of the injected beam. As a result, three beams exist with sufficient power for optical beating, as a result, millimeter wave corresponding to 3.19 nm and microwave corresponding to the wavelength detuning of 0.08 nm is generated. This simultaneous generation of microwave and millimeter wave is possible due to the injection locking with negative wavelength detuning. A further increase in the power of the injected beam, the dominant mode of SMFP-LD is suppressed with ON/OFF contrast ratio of more than 26 dB, as a result, only microwave is generated as shown in Fig. 6(a). Similarly, for the wavelength detuning of -0.12 nm, the power requirement for generating different RF frequencies and hoping of generating RF frequencies is illustrated in Fig. 6(b). Millimeter wave is generated

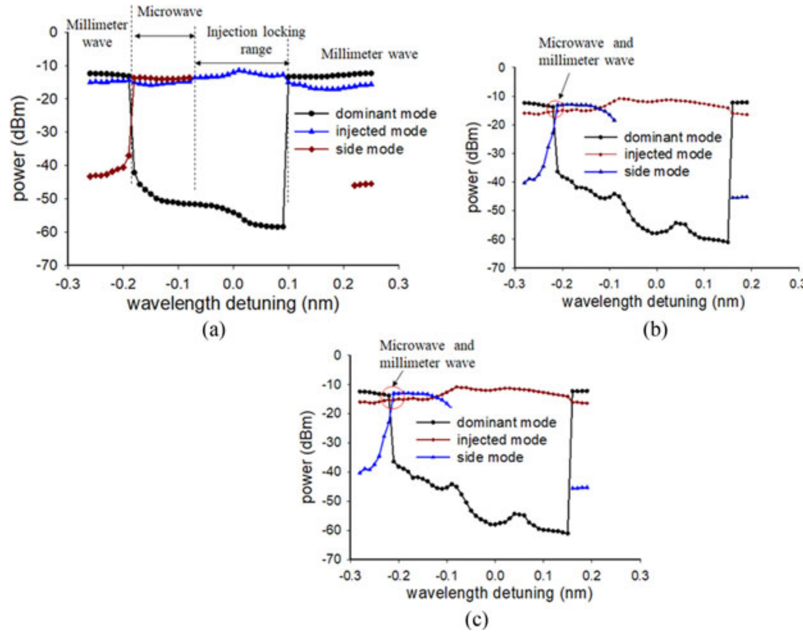

Fig. 7. Generation of multi-spectrum frequency; millimeter wave, simultaneous microwave and millimeter wave and microwave with a constant optical input injected power of −5.2 dB for (a) 1st mode, (b) 3rd mode, and (c) 5th mode.

when the power of injected beam is below −10 dBm. By increasing the injected power from −10 dBm to −8.5 dBm, simultaneous microwave and millimeter wave are obtained. When the input power is increased beyond −8.5 dBm, the dominant mode is suppressed with sufficient amount of power, which is recorded as 23 dB, and hence only microwave is generated. Fig. 6(c) shows the threshold power increases to −7 dBm for generating higher frequency microwave corresponding to the wavelength detuning of −0.17 nm. With these results, we can conclude that irrespective of the wavelength detuning, three regions (a) millimeter wave, (b) simultaneous microwave and millimeter wave and (c) microwave can be obtained by only changing the power of the injected beam while all other variables are kept constant. Also from Fig. 6, it is clear that the dynamic input power range for generating the microwave corresponding to the higher wavelength detuning is larger compared to that of lesser wavelength detuning. The input dynamic-power-range of 1.5 dB and 2 dB is obtained for the case of −0.12 and −0.17 nm wavelength detuning, respectively.

The feasibility of generating millimeter wave, simultaneous microwave and millimeter wave, and microwave by injecting the input beam to any of the side modes is shown in Fig. 7. For the verification of the generation of millimeter wave, simultaneous generation of both microwave and millimeter wave, and microwave in any of the modes of SMFP-LD, TLS is further injected to 1st mode and 5th mode of the SMFP-LD with a constant injected beam power of −5.2 dBm. Injecting beam in farther modes gives high-frequency millimeter wave signal, ranging to few THz. In order to show the possibility of different wavelength detuning that can be used for generating multi-spectrum frequencies, we varied wavelength detuning by changing the wavelength of injected external beam. The effect of changing wavelength detuning on the power of dominant mode, injected mode, and side mode with a constant power of an external injected beam is shown in Fig. 7. Fig. 7(a)–(c) show the observed power of the output beams when an external beam is injected to 1st, 3rd, and 5th mode of the SMFP-LD. In Fig. 7(a), both dominant mode and injected external beam is logic high for the wavelength detuning range from −0.19 nm to −0.28 nm and 0.1 nm to 0.25 nm with the maximum power difference (between the dominant mode and the injected beam) of 3 dB and 5 dB, respectively, whereas the side mode has a power gain of about 2 dB only, with the injection of external beam. Hence, in these regions, only millimeter spectrum signal with different frequencies

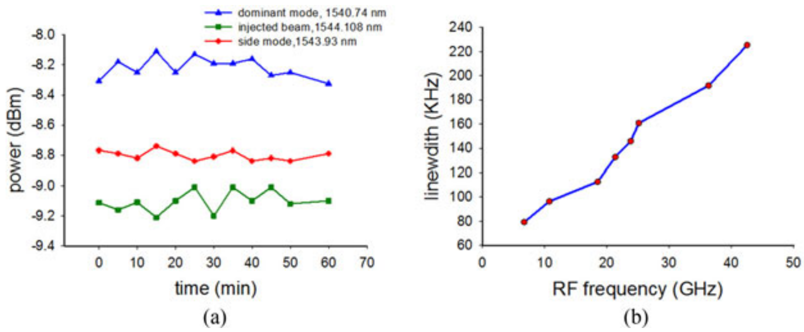

Fig. 8. Output signal performance measurements (a) power stability of beating wavelength and (b) linewidth of generated microwave signals.

are possible with the constant input injected beam power of −5.2 dBm. On the contrary, wavelength detuning of −0.18 nm with corresponding side mode, a microwave of 22 GHz is generated along with millimeter wave corresponding to 142 GHz. On increasing wavelength detuning from −0.18 nm to −0.07 nm, both side mode and injected mode are high which generates microwave spectrum signals with different frequencies corresponding to wavelength detuning. Millimeter wave is not generated because the dominant mode is suppressed. Beyond −0.07 nm to 0.1 nm, the dominant mode is suppressed together with the wavelength shifting of side mode of the SMFP-LD to the injected beam due to injection locking phenomena and hence, no any microwave and millimeter wave is generated between the detuning range of −0.07 nm to 0.1 nm. However, the uncovered detuning range of −0.07 nm to 0.1 nm can be changed by varying input injected beam power and hence the wavelength detuning range of −0.07 nm to 0.1 nm can be used for the generation of RF signal. The similar phenomena are observed in 3rd mode and 5th mode, which shows there exists a wavelength detuning range where both microwave and millimeter wave can be generated with constant input injected power. The small difference in ON/OFF contrast ratio and other observation is due to the variation in the power of the side mode under normal biasing condition. By changing the mode where the input beam is injected, the frequency of the millimeter wave can be changed. Fig. 7 also shows that injecting input beam on higher side modes will provide better simultaneous microwave and millimeter wave generation since the power difference of all three beams are small at the specific frequency of microwave and millimeter. Also, the same power level of three beams can be obtained by injecting an external beam of a lower power to the nearer side mode.

The power stability of beating wavelengths and linewidth of generated microwave signals is illustrated in Fig. 8. We observe the variation of beating wavelengths over a period of 1 hour with an interval of 5 min. The difference between beating wavelengths is constant within the resolution of OSA of 0.02 nm. This is an important property because the wavelength variation is the most influencing parameter for the RF signal generation using an optical beating. Fig. 8(a) shows the power variation of the beating wavelengths (dominant mode, injected beam, and corresponding side mode) while generating simultaneous microwave and millimeter wave RF signals. The maximum power variation of 0.2 dB is observed during the observation period of 1-hour time. The linewidth for microwave of 6 GHz to 42.5 GHz with a constant power of the input injected beam is illustrated in Fig. 8(b). The linewidth increases from about 100 KHz to 230 KHz for 42.5 GHz. The increase in linewidth with an increase in frequency of the generated microwave is due to the constant injection power used for the generation of all frequencies. Generating higher frequency requires higher wavelength detuning and the farther modes from the dominant mode of SMFP-LD. Hence the strength of injection decreases with higher wavelength detuning and injecting to a farther mode with constant power that contributes on linewidth of higher frequency generation, which can be reduced by changing the power of input injected beam. With the increase in the injection ratio by increasing the input beam power, linewidth can be reduced further for respective RF signals [26].

4. Conclusion

We proposed and experimentally demonstrated multi-spectrum simultaneous photonics signal generation and hoping that ranges from 6.7 GHz to 402 GHz. The range of generating an RF signal can be further increased to the THz range by injecting beam on farther side modes of the SMFP-LD subject to a single external beam injection using negative wavelength detuning. Increasing the power of the injected beam with a negative wavelength detuning, we observe mainly three states: (a) increase on the power of the injected beam without suppressing the dominant mode, hence, the dominant mode and the injected beam are beating wavelengths for the generation of RF signal, (b) increase the power of corresponding side mode, as a result, two simultaneous RF signals can be obtained with different frequencies and (c) suppress the dominant mode but the injected beam and the corresponding side mode exist, which are the beating wavelengths for the RF signal generation. These three states can be obtained by controlling the power of injected beam and thus hopping from millimeter to simultaneous microwave and millimeter wave, to microwave is attained. The effect of the power of the injected beam is analyzed to different modes of SMFP-LD, which shows the same result of the transition to the generation of RF signals. The generated microwave has signal to noise power ratio of more than 26 dB. The stability and power variation of beating wavelengths are observed for about 1-hour time interval which shows the variation in wavelengths are below the instrument resolution of 0.02 nm and the power variation is about 0.2 dB. The maximum linewidth of less than 250 KHz is measured for 42.5 GHz RF signal. With these observations and results, the proposed scheme can be used for optical wireless network, spectroscopy and Radar system. Also, by applying a certain pattern for varying the power of the injected beam, secure data transmission can be attained as the carrier RF frequency changes with changes in the injected power.

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