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ULTRA-STABLE VISIBLE LASER SOURCE BASED ON COMB-INJECTION LOCKED DFB FOR GAUGE BLOCK MEASUREMENT

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Abstract – We demonstrate an ultra-stable visible laser source that can be generated from injection locked infrared DFB based on optical comb. The optical comb was used as injection source and locked to an acetylene stabilization laser as a reference source of optical communication region. The DFB laser was selectively injection locked from only one among the comb mode with 25 GHz spacing.
The ultra-stable visible source can be generated after wavelength conversion (2th harmonic) of injection locked DFB laser in the PPLN (periodically poled LiNbO3) crystal. This source has a frequency stability of acetylene stabilized laser with 1.1×10^{-12} at 1 s of averaging time.

Keywords : injection lock, optical comb, DFB laser

1. INTRODUCTION

The optical frequency comb generator (OFCG) has revolutionized the field of optical frequency metrology over the past decade by providing an absolute frequency 'ruler' [1, 2]. The optical frequency comb can be used as optical source with high stabilized laser more than a few hundred thousand in the range of 500 nm to 2000 nm. Although the OFCG has a possibility as optical sources for the optical communication and for the high-resolution spectroscopy, it has been used in these applications only in limited cases due to the low power of each comb mode and the narrow mode-spacing. The recently-developed comb-injection-lock technique [3-5] has solved these problems by extracting a single comb mode and amplifying its mode power. This technique has been applied to the absolute frequency measurements utilizing the enhanced signal-to-noise ratio of the heterodyne beat between the comb and the laser to be measured. In this paper, we propose another application of the comb-injection-lock technique as interferometer for the length measurement; the frequency of the OFCG is fixed using a microwave reference and we select out a desired single comb mode by the injection-lock technique. The extracted comb mode can be utilized as an optical source in the interferometer for the length measurement, in the frequency synthesizer [6-9] and in the optical communication. ITU-T (International Telecommunication Union, Telecommunication Standardization Sector) recommends the standard frequencies for the channels of the dense wavelength-division multiplexing (DWDM) systems to have the prescribed frequency spacing and to be centered on the absolute frequency reference (193.1 THz) [10]. We select a desired single mode from an optical comb with a frequency spacing of 25 GHz.

2. EXPERIMENTAL SETUP

Figure 1 shows a schematic of the experimental setup for ultra stable visible laser source using injection locked infrared DFB lasers and PPLN crystal. The frequency of the optical comb generator was stabilized by an H-maser with a relative stability of 2×10^{-13}; a repetition rate of 25 GHz and a carrier envelope offset (CEO) frequency with zero.

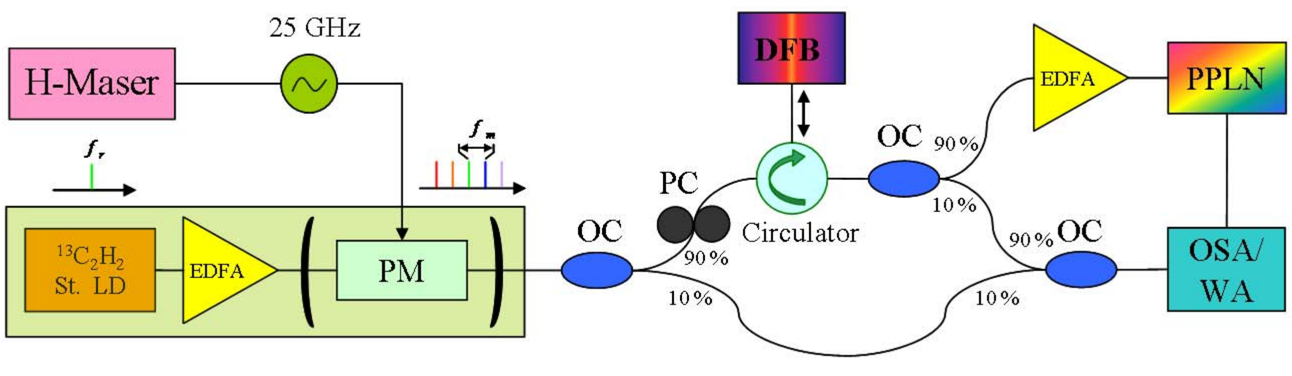

Fig. 1. Experiment scheme for stable laser generation based on injection locking (H-Maser: hydrogen maser, $^{13}C_2H_2$ St. LD: acetylene stabilized laser, EDFA: erbium doped fiber amplifier, PM: phase modulator, OC: optical coupler, PC: polarization controller, PPLN: periodically poled LiNbO3), OSA: optical spectrum analyzer, WA: wavelength meter

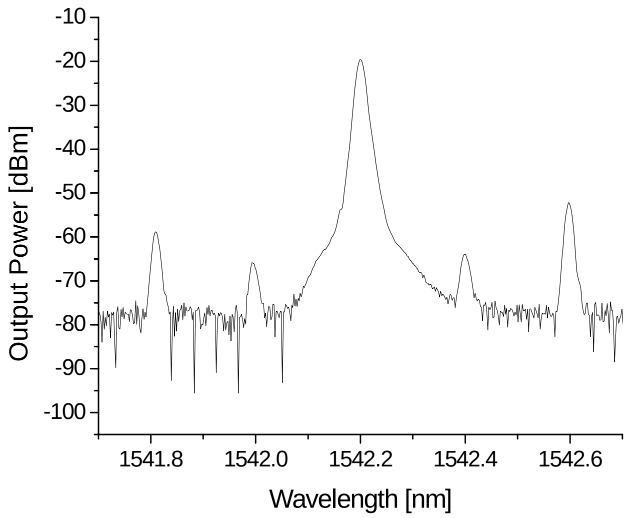

Fig. 2. Optical output spectrum before passing through PPLN crystal from injection locked DFB laser

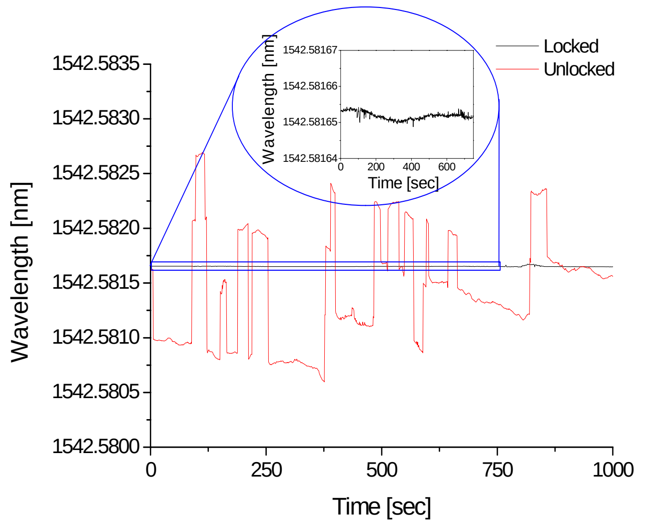

Fig. 3. Wavelength fluctuation before and after injection locking of DFB laser from optical comb spectrum analyzer with 25 GHz spacing.

An acetylene stabilized laser was used as a reference source (seed laser) for optical comb generation. The reference laser is the acetylene stabilized laser (Neoark) with a fiber coupled output power of 600 µW and a frequency stability of 1×10^{-11} for a 1s averaging time. The free spectral range of the optical comb generator is a sub-harmonic of the modulation frequency produced by the PM (phase modulator) with 25 GHz, and the phase-shifted lights are again built up as a modulation of the isolated acetylene stabilized laser injected seeding. The comb signal is split into two directions for injection and monitor beam.

In order to inject the comb modes into the DFB laser, a DFB laser module without an isolator was installed behind the PC (polarization controller). The center wavelength of DFB laser is 1542.72 nm at an output power of 20 mW and can be tuned by adjustment of current and temperature for selecting of different frequency comb components.

The PPLN consists of a waveguide with one input and output fiber in the device. The phase matching wavelength and temperature are a 1542.2 nm and 73.4 °C, respectively.

3. RESULTS

When the acetylene stabilized laser with the reference frequency (f_r) was injected into the fiber ring cavity, part of the seeding laser was modulated frequency (f_m) by the PM (phase modulator). The frequency of the light in the intracavity was multiplely interfered ($n \times f_m$) ; n: integer) after a round trip. As a result, the laser could achieve periodical comb generation ($f_{comb} = f_r + n \times f_m$). This is the basic principle of comb generation for a seeded frequency shifted laser. When the beam of the seed laser is injected into the optical cavity of optical comb generator, optical comb lines are displayed on an optical frequency of 25 GHz was applied to the PM device in the comb generator, and a reference laser of 1542 nm was injected into the optical cavity. Since the acetylene A modulation stabilized laser is injected into the optical cavity, the component generated 25 GHz by the PM are again built up in the cavity after round trip and the repeated process creates the broad comb spectra. Because the frequency reference of the optical frequency comb is the frequency of the seed laser, the frequency of the comb changes according to the frequency of the seed laser. This means that we can control the carrier envelope offset of the pulses. The optical output spectrum of injection locked DFB laser to the 25 GHz comb shows the Figure 2. The optical combs are injected into the DFB laser without an isolator. After the injection locking of the comb, the S/N ratio of the DFB laser was improved by relative to that before injection locking. In other words, the S/N ratio of the injection comb was also improved by the amplification process of the DFB laser. The linewidth also was reduced (not shown in the figure) due to the optical spectrum analyzer's limited resolution of about 1.25 GHz. To achieve the injection locked to the arbitrary comb line (frequency), DFB laser could be tuned the frequency by adjusting the temperature and current. Since the injected comb power into the DFB laser cavity was a few hundred μW after passing through the circulator, locking range can be adjusted over 200 MHz. As mentioned above, even though each comb mode has a very low power of a few ten μW, an individual comb mode can be used as an independent laser source through injection locking of the DFB laser, which serves as an amplifier and a mode selection filter. To investigate the characteristics of the injection locked DFB laser, wavelength meter was used as a recorder. Figure 3 shows the wavelength value versus time before and after injection locking of DFB measured by wavelength meter (HighFinesse) with relative accuracy of 5×10^{-8}.

As can be seen in Fig. 3, the frequency of the DFB laser drifts more than 250 MHz (~ 2 pm) without the injection-lock. We can confirm the injection-lock by observing this frequency drift to disappear. In Figure 3, the insert shows the magnified view wavelength value, which is attributed to the measurement limit of wavelength meter. We can confirm that frequency stability of injection locked DFB laser equals to acetylene stabilized laser.

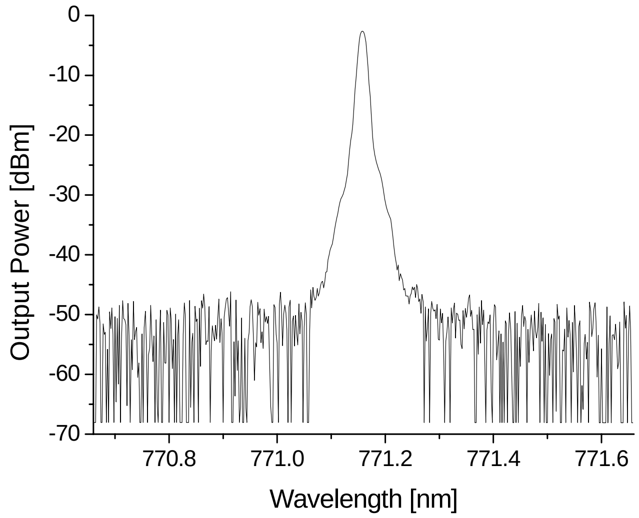

Fig. 4. Second harmonic spectrum after passing through PPLN crystal from injection locked DFB laser. The resolution of optical spectrum analyzer is a 0.01 nm.

After passing through the PPLN (periodically poled LiNbO3) by injection locked DFB laser, second harmonic signal (SHS) could be obtained by optical spectrum analyzer as shown in Figure 4. To achieve the phase matching of input beam, temperature of PPLN crystal was optimized at 75.8 °C. The SHS can also be tuned by selection of adjacent comb mode (fine tuning) or temperature adjusting of PPLN (fine tuning).

4. CONCLUSIONS

We have demonstrated ultra-stable visible laser source based on injection locked DFB laser from an optical comb generator. We controlled the carrier envelope offset of pulses by using the injection-seeding technique and controlled the repetition rate by using the phase modulator. Due to these strong advantages, the DFB laser using the comb-injection-lock is expected to be adopted as a light source for the length metrology, for the ITU-T grids in optical communication, and for the THz sources.

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