RF or THz Signals Generated from DC Biased Multimode Lasers

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ABSTRACT
Although self pulsating (SP) lasers are DC biased, they feature a modulation of the output power. For the results presented in this paper, the SP frequency corresponds to the frequency spacing between longitudinal modes or its second harmonic. The performances of both a 40 GHz self pulsating distributed Bragg reflector laser and of a 660 GHz slotted laser are presented. For the first laser, the radio frequency (RF) signal was analysed on electrical spectrum analyser and its linewidth was smaller that the sum of the main optical modes, proving a passive modelocking of the mode phases. For the slotted laser, a bolometer interfaced to a FT IR spectrometer is used for the terahertz (THz) detection. A signal 10 times larger than the noise level was measured with this set up. Both lasers have demonstrated to be an easy solution to produce RF or THz signal generator.
Keywords: semiconductor laser, multimode longitudinal spectrum, radio frequency, and terahertz.

1. INTRODUCTION

In this paper, we present a study on self pulsating lasers generating a radio frequency (RF) signal or a terahertz (THz) signal. The devices feature a multimode behaviour which results in a fluctuation of the output emission despite the fact that these devices are DC biased. The self pulsation in these devices is generated from beating between the longitudinal modes of the emission spectrum. These lasers could be useful in many areas. With a mode spacing designed for 40 GHz, multimode lasers have demonstrated all optical clock recovery of a 40 Gb/s data signal [1]. More details on these devices and their performances as 40 GHz generator will be given in Section 2. Based on the physical understanding achieved on the self pulsation mechanism at 40 GHz, a novel device structure has been proposed, demonstrating generation of THz signal. THz signal generators have applications in medical imaging, satellite communication, spectroscopy, and sensing [2]. In Section 3, a characterisation of a THz self pulsating laser is given with a presentation of the performance achieved at 660 GHz measured with a bolometer interfaced to an FT IR spectrometer. Finally conclusions are drawn in Section 4.

2. SELF PULSATING LASERS FOR OPTICAL CLOCK RECOVERY

2.1 Laser description

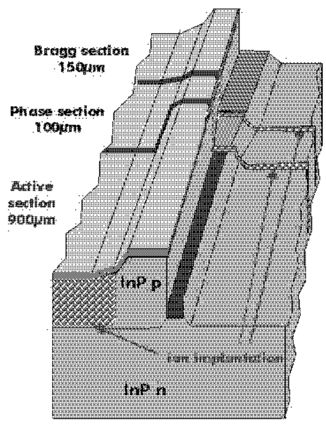


Figure 1. Schematic of the self pulsating DBR laser.

A distributed Bragg reflector (DBR) laser depicted in Fig. 1 has demonstrated its potential as 40 GHz signal generator [3]. This laser presents many advantages over some other structures [4] such as the reliability of the design leading to the expected self pulsation frequency and its low production cost. Self pulsating (SP) DBR lasers consist of three sections: the active section producing the gain for the structure, the phase section to finely tune the lasing modes and the Bragg section to control the emission spectrum. The particularity of SP DBR lasers, compared to those designed for other applications such as tunable lasers, is the need to operate in a multimode regime. Thus, the DBR laser under study has a short Bragg section of 150 μm, allowing it to have mainly 3 longitudinal modes. The active section is 900 μm long and consists of six quantum wells and five

The work reported in this paper was supported by Science Foundation Ireland under the Research Frontier Programme referenced 05/RFP/ENG0040.

1 4244 1249 8/07/$25.00 ©2007 IEEE

barriers of thickness of 8 nm and 10 nm respectively, surrounded by two separated confinement hetero structure guiding layers of total thickness of 200 nm. The 1.5 μm width of the waveguide was chosen to ensure a single transverse mode of the electric field. The phase section is 100 μm long, with a waveguide width expanding linearly up to the 1.8 μm width in the Bragg section. This section was designed to adapt the optical modes between the active and the passive optical waveguides. It is kept unbiased for all experiments reported in this article since it is only used for a fine tuning of the emitted wavelength. The different sections are electrically isolated (~ 1 MΩ) by ion implantation. Under large injection currents, such a DBR laser features a multimode longitudinal spectrum. The beating between these modes generates SP at frequency given by the mode spacing frequency:

$$\upsilon_{sp} = \frac{c}{2(n_g L_a + n_\varphi L_\varphi + n_B L_B)} \tag{1}$$

where c is the velocity of light, L_a, L_φ and L_B are the active, phase and effective lengths of the Bragg section respectively, n_g, n_φ and n_B the gain, phase and Bragg group indices, respectively.

2.2 Self pulsating performances

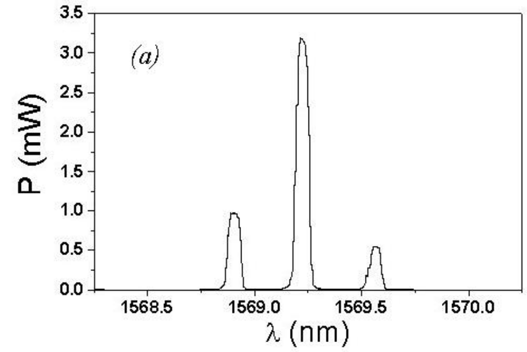


Figure 2(a). Optical spectrum measured for injected active and Bragg currents of 230 mA and 120 mA respectively.

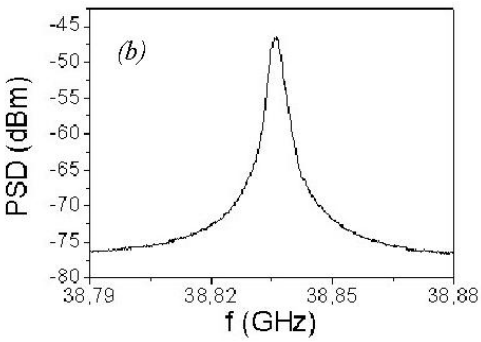


Figure 2(b). Electrical spectrum of photocurrent observed corresponding to the optical spectrum.

The optical spectrum of the SP DBR laser is analysed by injecting the signal into a 0.07 nm resolution bandwidth spectrum analyser. To avoid any perturbation induced by optical feedback a 70 dB isolator is placed between the laser under test and the OSA. Fig. 2*a* shows a multimode spectrum for the gain section biased at 230 mA, the phase section at 0 mA and the Bragg section at 120 mA. The longitudinal mode spectrum presents three dominant modes separated by 0.33 nm approximately. Using a tunable band pass filter, each mode can be selected and their respective linewidth is measured to be ~700 kHz. In Fig. 2*b* the corresponding RF spectrum is shown under the same experimental conditions than that of Fig. 2*a*. The RF signal is centred at a frequency of 39 GHz with a full width at half maximum of ~1.5 MHz. This frequency corresponds to the 0.33 nm mode spacing between the longitudinal modes measured from Fig. 2 at a wavelength of 1560 nm. Therefore the sum of linewidth of the modes involved in the beating is less than the RF signal linewidth. This is interpreted by a passive mode locking of the mode through carrier density pulsation (CDP). A complete development of this mechanism is detailed in [3].

3. THZ GENERATION FROM A SELF PULSATING LASER

At the frequency of 40 GHz, the FWM effect involved is the CDP due to the interaction between the gain and the total optical power. If the detuning between modes increases, CDP is still the predominant effect up to 100 GHz [5]. Above 100 GHz and below 1.5 THz the carrier lifetime is too long and the efficiency of the CDP is overcome by the carrier heating process. The optical beating cannot modulate the carrier pulsation anymore but the effect of the beating is more noticeable on the carrier distribution and consequently of the quasi Fermi levels and carrier's temperature. Therefore it seems possible to generate a self pulsating laser with a self pulsating frequency beyond 100 GHz, in this case the key FWM contributing factor is the CH.

3.1 THz laser's design

A first approach is to use a SP DBR laser. From Eq. (1), the overall cavity length of the structure has to be small on the order of few tens of μms. The Bragg section will need to be short in order to achieve a broad reflection spectrum. This implies that the reflection coefficient will be low, so the gain section must be long in order to overcome the excessive mirror losses induced by a short Bragg section. Hence the SP DBR laser is not the ideal candidate for THz generation. An alternative is based on Fabry Perot laser with grooves etched along the active layer [6]. By etching grooves at key positions along the top contact of the active layer, it is possible to design a one dimension photonic band gap. The FP resonance determines the spectral separation between consecutive modes, but the etched band gap suppresses or enhances some specific FP modes. It is possible therefore to choose some given modes and to control the detuning between modes. The THz SP laser is depicted in Fig. 3. It is a multi quantum wells InAlGaAs Fabry Perot (FP) laser. The 2 μm ridge waveguide of the laser provides a spatial single mode output. The device is 350 μm long and the dimension of the grooves is 1 μm.

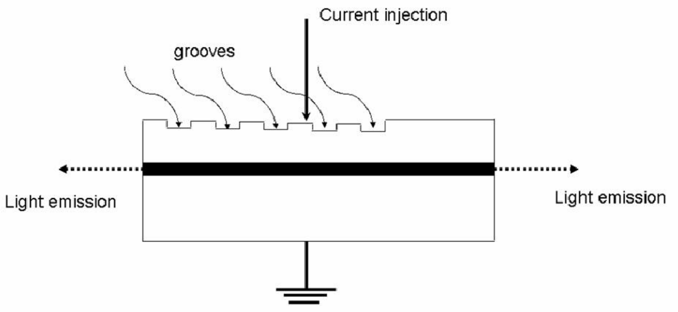
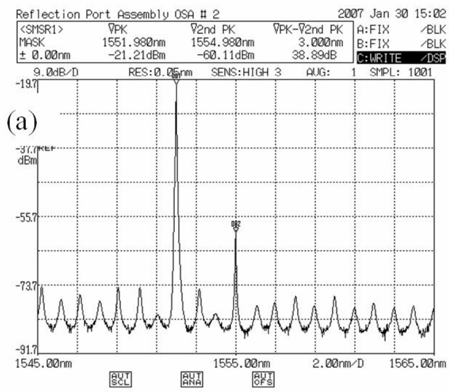


Fig. 3. THz SP laser's schematic.

3.2 THz performances

Fig. 4*a* shows an optical spectrum at a bias current of 60 mA. The resolution of the optical spectrum analyzer is 0.05 nm. The ripples are separated by 1 nm corresponding to a free spectral range of 120 GHz at 1550 nm and are due to the Fabry Perot modes of the 350 μm cavity. These modes are controlled thought the grooves placed along the cavity of the laser. The grooves pattern enhances a main mode at 1551.98 nm and a second mode at 1554.98 nm however rejected at 39 dB approximately. From an optical communication point of view this device is considered as a single mode device.



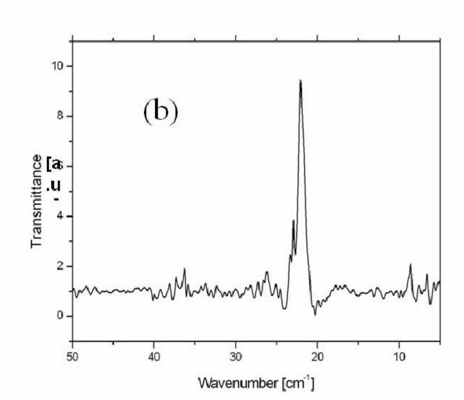


Fig. 4(a). Optical spectrum at 60 mA and 25 °C. *Fig. 4(b). THz spectrum at 60 mA and 25 °C.*

In the same experimental conditions the laser emission has been analyzed using a FT IR spectrometer interfaced to a bolometer temperature controlled at 4.2 °K, with a detectivity bandwidth from 360 GHz to 11 THz. Hence there is no possible detection of 330 GHz wave, however any signal above 360 GHz can be analyzed. Fig. 4*b* shows the THz spectrum for a bias current of 60 mA and a temperature of 25 °C. The spectrum features a 660 GHz, corresponding to the second harmonic of the beating between the two main modes of the device. The THz signal achieved is about 10 times larger than the level of noise detected by this set up. The linewidth of the THz signal is 27 GHz. Such a measurement has been duplicated as a function of bias current [7].

4. CONCLUSIONS

In this paper, we have demonstrated the generation of a RF or THz signals exploiting the mode beating in DC biased multi modal lasers. The DBR lasers emitting at 40 GHz could be used in all—otical communication for clock distribution and or clock recovery functions [1]. For the THz emission, the device under test is a Fabry Perot laser with a grooves implemented along the active layer. This type of laser can be easily produced as the grooves do not require any re growth. The signal measured is at 660 GHz with a contrast ratio of 10 approximately. This signal is the second order harmonic of the free spectral range set by the groove pattern at 330 GHz. For this detuning the THz signal must have been generated by intra band effects, more efficient than the inter band in this spectral range. The THz performance achieved needs further study in order to find out the interplay between the strength and the linewidth of the THz signal versus the number of lasing modes.

ACKNOWLEDGEMENTS

This project is supported by Science Foundation Ireland under the Research Frontier programme referenced 05/RFP/ENG0040.

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