Optical Frequency Comb Generation and its Applications

Sylwester Latkowski, Member IEEE and Prince Anandarajah, Member IEEE

The RINCE Institute, Dublin City University, Glasnevin, Dublin 9, Ireland
Tel: (3531) 700 7537, Fax: (3531) 700 5508
e-mail: prince.anandarajah@dcu.ie

EXTENDED ABSTRACT

Optical frequency comb sources (OFCs) have recently attracted a lot of interest due to wide ranging applications such as optical arbitrary waveform generation [1], photonic microwave signal generation [2], optical signal processing [3] and multi-carrier spectrally efficient transmission techniques with the sub-channel spacing equal to the symbol rate of each sub-channel [4]. OFC sources with good spectral flatness, stability and low linewidth are highly desirable for such applications. One of the conventional approaches used in realizing a comb source is based on mode-locked semiconductor and fibre lasers [5]. Although this technique can generate multi-carrier signals spanning over a wide bandwidth, it inherently suffers from cavity complexity and does not offer the free spectral range (FSR) tunability since the comb line spacing is fixed by the cavity length of the laser. Moreover, the optical linewidth of the individual comb lines can be relatively large (several MHz) preventing higher order (or low baud rate) advanced modulation formats to be imposed. Another technique that has been reported entails the use of a single, cascaded or dual drive Mach–Zehnder modulators (MZM) to generate the phase correlated optical frequency comb [6]. Although this technique provides a relatively flat optical comb, the large insertion loss of the modulator coupled with the modulation efficiency can prove prohibitive. The extra optical component also adds to the cost and complexity of the transmitter, rendering this technique unsuitable for short reach applications.

In this paper, an optical comb generation scheme, based on gain switching [7] of a discrete mode (DM) laser diode (LD) [8] is shown to be an attractive alternative. The results achieved show that the high SMSR and low jitter pulse train, which exhibit a corresponding multi-carrier spectrum, has the potential to be employed as a frequency comb generator. Such a comb generator enables simple and cost efficient generation of lightwaves with the precisely controlled channel spacing required for high information spectral density communication systems. In order to enhance the commercial applications and viability of the gain-switched DM laser as a comb source, we also carry out spectral comb expansion by employing a phase modulator and subsequently using a combination of linear/nonlinear pulse compression techniques [9].

![Figure 1](image1.png)

**Figure 1:** The optical spectra of (a) the gain-switched DM laser (b) gain-switched DM laser after phase modulation

The optical spectrum of the generated frequency comb from the gain-switched DM laser, as depicted in Fig. 1 (a), portrays a highly coherent eight-carrier signal spaced by 10.7 GHz. This was measured with the aid of a high resolution (20 MHz) optical spectrum analyzer. The optical linewidth of the individual tones were measured to be about 3.5 MHz by using a delayed self-heterodyne technique [10]. Expansion of the number of frequency comb lines (14 tones within a 3 dB window) and improvement in the spectral intensity flatness is achieved via phase modulation. Essentially, the number of tones is doubled after passing the initial gain-switched comb through a phase modulator as illustrated by Fig. 1(b). The number of generated sidebands could be further increased by exploiting the nonlinear effects in highly nonlinear fibre (HNLF). A consequence of pulse compression in the HNLF is a broader spectral envelope. Therefore, this technique is employed to multiply the number of frequency tones present in the gain-switched comb spectrum. The spectrum at the output of the pulse compression stage is shown in Fig. 3 and exhibits excellent flatness and enhanced spectral width. The frequency
spacing and 3 dB spectral width of the expanded comb were 10.7 GHz and >500 GHz, respectively. The number of spectral tones within a 3 dB spectral ripple is approximately 50.

![Figure 2: The optical spectrum of the expanded comb achieved with use of highly nonlinear fibre](image)

Finally, we demonstrate that an optimized, cost-efficient technique of gain switching a DM laser transmitter to generate a coherent optical multi-carrier signal can be considered as a potential candidate for the generation of millimetre wave signals, as cost efficient transmitter in passive optical network (PON) employing advanced modulation formats and in high-speed multi-carrier transmission systems targeting Terabit per second applications and beyond.

**ACKNOWLEDGEMENTS**

The authors would like to thank Achray Photonics for the high-speed butterfly packaging of the DM Laser and acknowledge the funding assistance from Enterprise Ireland CF TDP 08/324

**REFERENCES**