Highly coherent picosecond pulse generation with sub-ps jitter and high SMSR by gain switching Discrete Mode laser diodes at 10 GHz line rate

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Abstract: We demonstrate the generation of picosecond pulses with ~800fs jitter and SMSR in excess of 60dB by gain switching a Discrete Mode laser and compare the results with a commercial DFB laser.

OCIS codes: (060.2330) Fiber optics communications; (230.6080) Sources

1. Introduction

Terabit all-optical communications systems can be realised by reducing the inter channel wavelength spacing in Wavelength Division Multiplexed (WDM) systems or by increasing the per-channel data rate. The latter is extremely attractive as it can be realised through Optical Time Division Multiplexing (OTDM) and implemented in hybrid WDM/OTDM systems [1]. Key components for such OTDM systems are simple low-cost picosecond optical pulse sources that exhibit the required temporal and spectral purity. Picosecond pulse sources have been demonstrated using several different techniques such as pulse carving, mode-locking and gain-switching, all of which have unattractive attributes for the applications concerned. For example, pulse carving is achieved by gating continuous-wave (CW) light with a sinusoidally driven Electroabsorption Modulator (EAM). While this method offers short pulse generation over a wide wavelength range, it suffers from large insertion losses and requires the use of expensive components including post amplification. Similarly, mode-locking has the ability to generate very short pulses at fixed frequencies, however cavity complexity and limited repetition rate tunability are major disadvantages associated with this technique.

The simplest and most robust pulse generation techniques involves gain-switching of single mode DFB laser diodes [2]. The inherent simplicity of direct modulation, results in the gain-switched pulse source being cost-efficient, which proves to be of great practical significance with regard to market adoption. Unfortunately while low cost and simplicity are among the numerous advantages of this technique, it does suffer from some drawbacks, such as side mode suppression ratio (SMSR) degradation and relatively large temporal jitter. While these shortcomings have been overcome by self seeding [3] or external light injection [4], such corrective measures not only increase the cost and complexity of the pulse generation technique but also can lead to unstable operation.

In this paper, we investigate gain switching of single mode Discrete Mode laser diodes [5] and demonstrate simple generation of highly coherent picosecond pulses at 10GHz. We also compare the gain switching performance of DM lasers with that of conventional DFB laser diodes. The DM (DFB) laser yielded pulses with measured temporal jitter of ~800 (3ps) and a corresponding SMSR of 62dB (30dB). When the predominantly linear chirp of the DM laser is compensated for by launching the pulse train into a 200m length of commercial dispersion compensation fibre (DCF), near transform limited 10ps pulses at 10GHz are obtained that exhibit temporal jitter ~ 800fs and high SMSR of greater than 60dB.

2. Experimental set-up and results

The experimental set-up used is shown in Figure 1. The laser is gain switched by RF-amplifying a 10GHz sinusoid obtained from an RF synthesizer. The 3dB fibre coupler is used to enable simultaneous temporal and spectral measurement. The DFB-LD is a commercial high speed device packaged into a temperature controlled a hermetically sealed high speed butterfly package with a bandwidth of 18GHz at a bias current

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of 60 mA. It has a room temperature emission wavelength of 1545 nm and a threshold current of 15mA. Figure 2 (a) shows the DFB emission spectrum at a bias current of 55mA when measured using a high resolution optical spectrum analyzer (with a spectral resolution of approximately 25MHz). The measured SMSR is 68dB. The measured linewidth is instrument limited at approximately 25 MHz, but for the same emission power a self heterodyne linewidth of approximately 10MHz was measured. Figure 2(b) shows the spectrum under gain-switched modulation. The high speed, high contrast modulation leads to bimodal operation and the resulting SMSR is about 7dB (the second mode excited is essentially overlapped with the broadened lasing mode). In addition, the peak to background spectral contrast reduces to 32dB which is disadvantageous for OTDM implemented in hybrid WDM/OTDM systems.

The DM laser is a ridge waveguide Fabry-Perot laser diode constrained to lase in a single mode of the Fabry-Pérot cavity by introducing etched features onto the surface of the ridge to create topological refractive index perturbations that select a single mode of the cavity [5]. It is packaged in an optically isolated uncooled coaxial package with a room temperature bandwidth of about 10GHz. It has a room temperature emission wavelength of 1539nm and a threshold current of 16mA. Figure 3 (a) shows the DM emission spectrum obtained when the laser is operated CW at a bias of 55mA. The measured SMSR is 70 dB. The suppressed sub-threshold Fabry-Pérot modes are visible and correspond well to the measured chip length of $L_{cav} = 350\mu m$. Again the measured line-width is instrument limited whereas for the DM laser under these operating conditions a self heterodyne line-width of approximately 800kHz was measured [5] Figure 3(b) shows the spectrum under gain-switched modulation where indications of sideband generation on the lasing mode are apparent. In contrast to the DFB, the SMSR is preserved under the high speed, high contrast modulation with a SMSR of 68 dB which is highly advantageous in hybrid WDM/OTDM systems. Figure 3(c) shows an expanded view of the modulated spectrum showing efficient sideband generation in the lasing mode (approximately 13, 10GHz sidebands are generated within 10dB of the spectral envelope peak) and two small equidistant features on either side of the spectrum corresponding to the subthreshold FP cavity modes. We note that the (OSA measured) linewidths of generated sidebands are the same as that of the CW spectrum and in both cases is instrument limited. Figure 4 shows measured gain-switched pulses for the DFB and DM laser. The pulsewidth for the gain switched DM laser is 22.3ps while the pulsewidth for the gain switched DFB laser is 10.3ps which we attribute to the higher bandwidth of the DFB device. More importantly the rms jitter of the gain switched DM pulses is measured to be ~ 800fs while that of the DFB is measured to be ~3ps. The fact that DM lasers give better performance in terms of jitter and SMSR than DFB lasers can be explained by the structure of the laser itself. In DFB lasers, two grating modes are in competition with the cavity (FP) modes, whereas DM lasers are truly single mode lasers [5]. When the predominantly linear chirp of the DM laser is compensated by launching the pulse train into a 200m of commercial dispersion compensation fibre (DCF), near transform limited 10ps pulses at a repetition rate of 10GHz are generated.

4. Conclusions

We have demonstrated an optimum, cost efficient technique to generate picosecond optical pulses with excellent coherent properties by gain switching a discrete mode laser. The generated pulses exhibit extremely small temporal jitter of ~ 800fs and also display excellent SMSR of ~68dB, without the additional complexity of injection seeding. Moreover the high pulse to pulse coherence is demonstrated by observation of efficient generation of coherent sidebands off the lasing mode at the modulation frequency. This, together with the jitter and near transform-limited pulse performance gives strong encouragement that such a cost efficient pulse source could be employed as a transmitter for spectrally efficient modulation formats such as DPQSK where data signals are imposed on the individual sidebands [6].

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5. References

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6. FIGURES

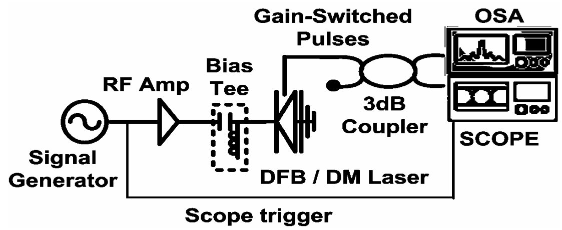

Fig. 1. Experimental set-up

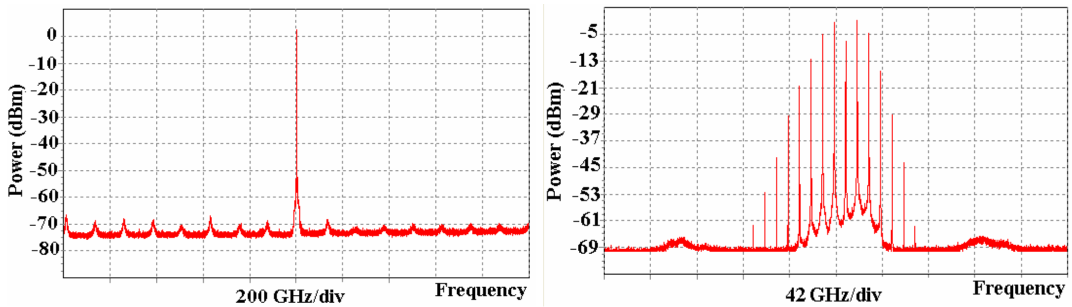

Fig. 2. Spectra from (a) CW and (b) Modulated DM laser

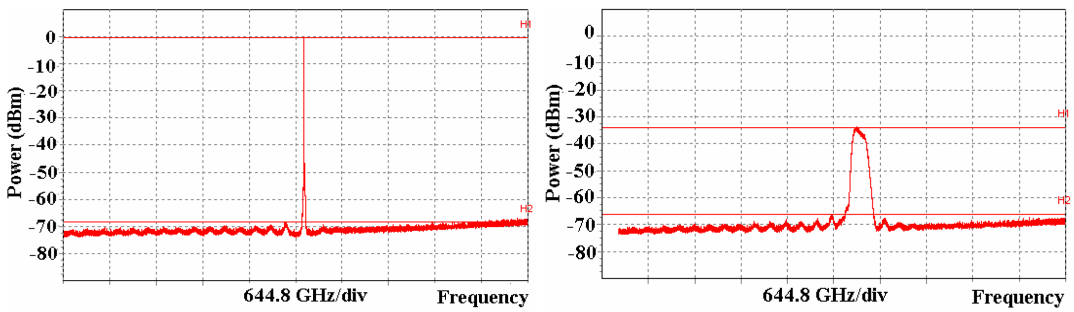

Fig. 3. Spectra from (a) CW and (b) Modulated DFB laser

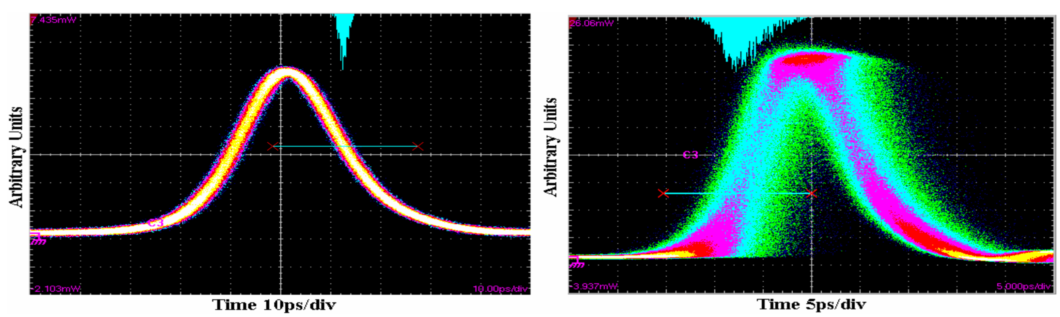

Fig. 4. Gain switched pulses from (a) DM and (b) DFB laser