A Versatile 40 GBit/s Optical Transmitter Platform for NRZ, RZ and Carrier-Suppressed (CS) RZ Transmission Formats

G. Gilardi , L.Gobbi, A.Beretta, P.Milanese, S.Pensa, A.Nespola, S. Schmid, P.Andolfo, A.Vannucci
Corning OTI S.p.A , Viale Sarca 222, 20126 Milano, Italy
Vannuccia@corning.com
W. S. Lee, M. Martin
SHF Communication Technologies AG, Amalienstrasse 14, 12247 Berlin, Germany

In this paper we show optimization of both modulator and driving electronics in order to allow the commercial deployment of the first 40 G platform for NRZ, RZ and CS-RZ transmission for long haul application.

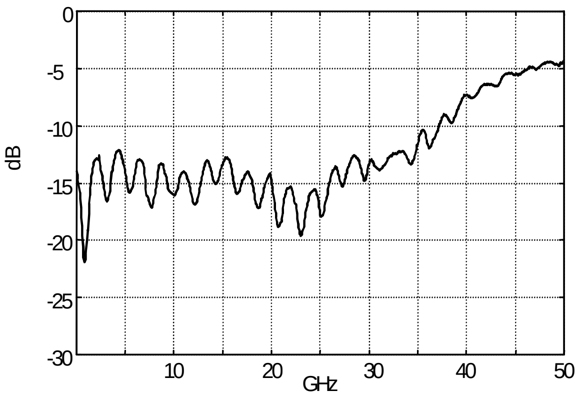
Keywords: $LiNbO_3$ modulators, 40 GBit/s, RZ and CS-RZ modulation format

Introduction

During the last two years of the photonic components "market slow down", the research has been working mainly on two issues: cost reduction and product innovation. For both aims a new race, towards 40 GBit/s transmission, is now open. All major system integrators and many small but highly technology oriented companies are developing 40 G solutions, both for SONET/SDH and WDM. The 40 GBit/s component technology has made essential progress and also at the transmitter level new and more effective coding techniques have been developed.
It is anticipated that NRZ will remain limited to short reach while advanced RZ-based modulation formats like CS-RZ, help to overcome the high sensibility of NRZ against chromatic dispersion and fiber non-linearities for long haul transmission links. The CS-RZ format adds a higher spectral efficiency to the robustness of RZ format and it is even more tolerant against SPM than standard RZ transmission.
In this paper we describe the performance of chirp free X-cut Lithium Niobate MZI modulators for long haul transmission and a versatile 40 GBit/s optical transmitter platform for NRZ, RZ and CS-RZ transmission formats. Very broad band modulators and drivers are matched to generate CS-RZ signals with exceptional low jitter enabling long haul 40 GBit/s transmission systems.

40 GBit/s Lithium Niobate modulator performance

LN X-cut based MZ modulators are designed with low loss RF coplanar electrodes grown on a silica buffer layer. Silica layer and coplanar micro strip electrodes are optimized for the velocity matching between the optical and the RF waves.
The small signal characterization of the modulator is shown in Figure 1 and 2.
State of the art 40 GBit/s X-cut LN modulators with an electro-optical bandwidth greater than 30 GHz as shown in Figure 2 together with a driving voltage lower than 6 V that is compatible with 40 GBit/s modulator drivers are currently available on the market.



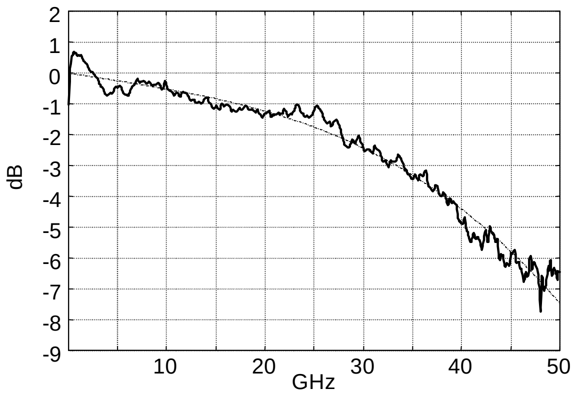


Figure 1: S11- Electrical return loss

Figure 2: S21-Electro-optical response

A 20 GHz clock modulator has been developed for CS-RZ pulse generation too. The modulator has been optimized both for the required RF operating frequency and a low Vpi at the 20 GHz clock frequency. This pulse generating modulator with a Vpi of 7 V at 20 GHz and 4 dB of optical insertion loss has been added as a first stage of the transmitter. The Vpi plot vs frequency has been measured and compared with the predicted values calculated from the electro-optical S21 of the modulator. Figure 3 shows the excellent agreement obtained.

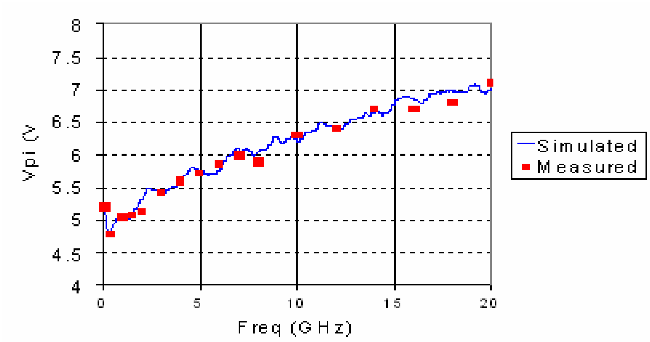


Figure 3: V_{π} vs Freq

Transmitter architecture

Figure 4 shows the basic transmitter architecture comprising a cascade of two chirp-free X-cut Lithium Niobate modulators. Both the pulse generation and data modulators have PM fiber at both inputs and outputs.

These modulators feature single-ended drive. The pulse generating modulator is driven by a narrow band GaAs RF amplifier with a pass band from 18 to 27 GHz. At mid-band the RF amplifier exhibits a voltage gain of 34 dB and the maximum output power was limited to 28 dBm to avoid overdriving the modulator. The output of the clock driver exhibits harmonic suppression of better than 30 dB below the clock signal, when driven with a 20 GHz signal for RZ pulse generation.

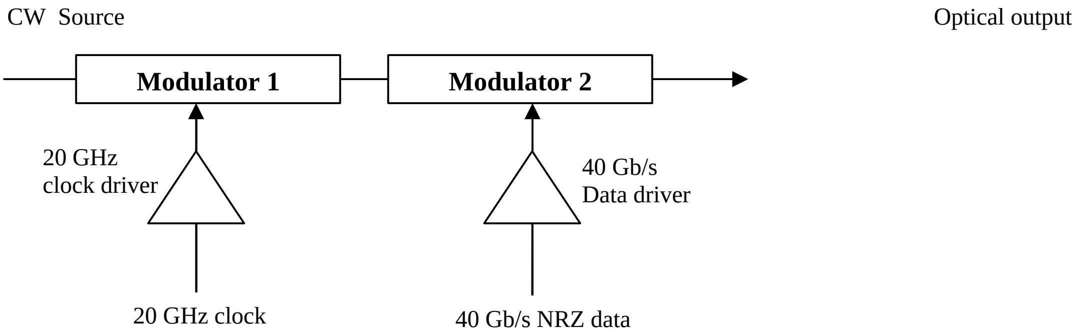


Figure 4: Basic transmitter schematic

The data modulator is driven with a broad band power amplifier [1] with 3 dB bandwidth of typically 42 GHz. Moreover 26 dB mid-band gain with a very low group delay ripple (peak-peak) has been achieved. This multi-stage amplifier is based on GaAs PHEMT MMICs.

To obtain the optimum transmitter performance, the frequency response of the modulator driver amplifier is designed to have a positive gain slope to compensate for the frequency response of the modulator. The increase in amplifier gain is typically 2 to 3 dB up to the -3 dB bandwidth of the modulator. Under this ‘matching’ condition, the added timing jitter of the amplifier is typically 500fs <RMS> and Figure 5 shows the optical waveforms for NRZ operation.

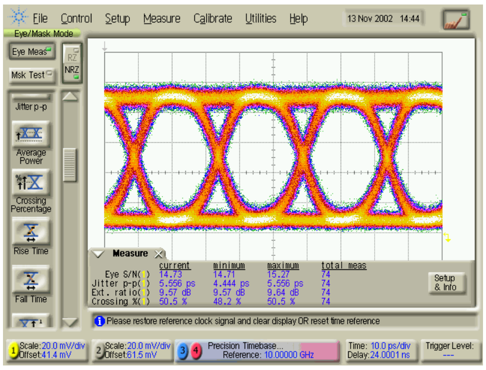


Figure 5: 40 GBit/s NRZ output signal

For RZ operation, the pulse modulator is biased to the maximum transmission point of the MZ response curve. The resultant optical pulse width (FWHM) is in the range of 10-12 ps. For CS-RZ operation, the modulator bias is set to the null of the MZ curve with a corresponding pulse width that is typically 15 ps. Figure 6 shows the measured optical pulse response and the corresponding spectral characteristics.

These optical pulse waveforms were measured using a 70 GHz bandwidth detector coupled into a 70 GHz electrical sampling head. Precision time base operation was used to show the real timing jitter performance. The significant reduction in the timing jitter of the RZ and CS-RZ optical signal was obtained with the re-timing operation of the low jitter clock signal used to generate the initial optical pulses. Special care to design for an extremely small group delay ripple even in the low frequency regime below 1 GHz was one of the key factors to this success.

RZ operation

CS-RZ operation

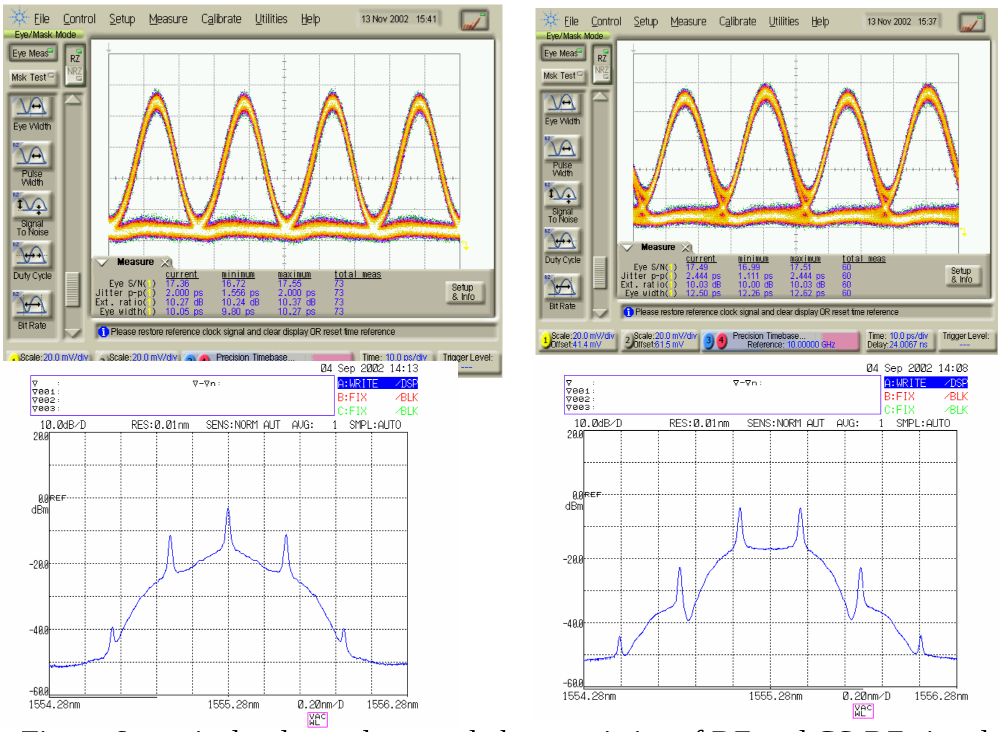


Figure 6: optical pulse and spectral characteristics of RZ and CS-RZ signal

The narrower optical spectral width achieved with the CS-RZ signal compared to RZ is also evident in the spectral plots of Figure 6. This reduced spectral width, together with the optical phase inversion between consecutive pulses, are key attributes towards the realization of a robust high capacity 40 GBit/s transmission for the next generation cost effective optical networks.

The obtained results for jitter and signal to noise ratio are of so far unseen quality. It is not longer the transmitter section putting limits to 40 G optical transmission. This is a real milestone on the way towards 40+ G optical systems.

Conclusions

In this paper the electro-optical characterization of a zero chirp $LiNbO_3$ modulator at 40 GBit/s with the RZ and the CS-RZ coding for the ultra-long haul applications are shown. The results demonstrate that by lowering the transmitter jitter, related to the development of the proper electronics, the system performance has been optimized. The state of the art double modulator and the related driver amplifiers allows the commercial deployment of the first 40 G platform for NRZ, RZ and CS-RZ transmission for long haul application. Now a chirp free 40 GBit/s transmitter solution is available to systems integrators.

References

1. W. S. Lee and M. Martin, ‘High performance broadband optical modulator driver amplifiers to power the optical network’, Technology and Services section, Business Briefing, Global Optical Communications 2002