Low phase noise laser source packaged in a low power consumption module for all optical sampling applications

A. Shen (1), S. Chongkam (2), G. Liger (2) J. da Silva (2), and S. Formont (3)
(1) Alcatel-Thales III-V Lab, a joint lab from Alcatel-Lucent Bell Labs France and Thales Research & Technology,
1, avenue Augustin Fresnel, 91 767 Palaiseau Cedex, France
(2) ERTE, 14, rue de la Truie qui file, 91 400 Saclay, France
(3) Thales Air-borne Systems, CN 675, 2 Avenue Gay Lussac, 78 851 Elancourt Cedex, France.
alexandre.shen@3-5lab.fr, jdasilva@erteweb.fr, stephane.formont@fr.thalesgroup.com

Abstract: Using low power consumption photonic modules containing a low timing jitter optical laser source and an optical gate, we demonstrated potential all-optical sampling of a radio signal carried at >5GHz with a 6 bits resolution.
OCIS codes: (140.4050) : Mode-Locked Lasers; (140.5960) : Semiconductor Lasers;

1. Introduction

Quantum dash based mode locked laser diodes (QDa-MLLD) have been developed in recent years in view of such applications as high bit-rate transmitter through optical time-division multiplexing [1], generator of millimeter wave signals at high frequencies [2], and also as a photonic device for all-optical clock recovery at 40 Gbit/s and beyond [3]. Extremely narrow beat tone spectral line has been observed from such Qda-MLLDs, and reported [4], which leads to very low phase noise laser pulse sources. Thus, it is extremely interesting to use such an optical source to implement all-optical sampling, namely for all-optical analog to digital conversion, which has stringent requirements for the sampling pulse source. For example, a radio signal carried at 60GHz would need a sampling pulse source with a timing jitter better than 10fs to achieve 8 bits sampling resolution, which is not feasible nowadays, and a signal carried at 2GHz would require a timing jitter better than 310fs for the same resolution, which seems to be technically possible.

In this paper, we report on the experimental results demonstrating the feasibility of the optical sampling system, in which the QDa-MLLD pulse source has been packaged into a low power consumption module, and where a semiconductor optical amplifier Mach-Zehnder modulator (SOA-MZ) has been used as the all-optical gate.

2. QDa-MLLD module and SOA-MZ optical gate

The sampling laser source module (fig. 1) comprises a QDa-MLLD, whose fabrication and characterization have been reported elsewhere [4-5], mounted on an electronic card which integrates a DC current source, and the thermal regulation feedback loop. Both current and operating temperature can be monitored and modified. A SMA connector gives the possibility of active mode locking at 10GHz. The whole module is electrically powered by a commercial AC to DC converter, and the overall power consumption is less than 18W.

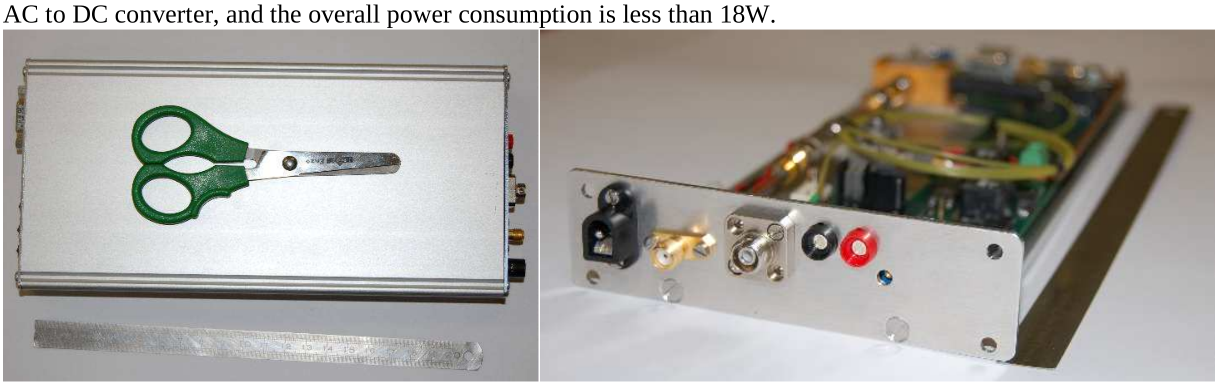

Fig. 1. Photograph of the implemented module: QDa-MLLD laser source overall picture (left), inside picture showing the electronic card (right)

In the passive mode locking mode, the electrical spectral line-width has been measured, and its value of 8kHz is amongst one of the lowest reported. In an active mode locking scheme, the single side band (SSB) phase noise spectrum can be measured, and such a spectrum is shown on figure 2. At 10GHz, with an input radio-frequency power of 25dBm, the laser output shows a very low level of phase noise, which corresponds to less than 370fs timing jitter (integrated at off-set frequencies between 100Hz and 10MHz): this can lead to better than 7bits resolution sampling of radio signals carried at 2GHz, for example.

The optical gate module contains a SOA-MZ modulator. The fabrication and characterization of the SOA-MZ have been reported elsewhere. Similarly to the MLLD module, all the biasing current sources and the temperature controller have been integrated on an electronic card. The overall power consumption is less than 25W.

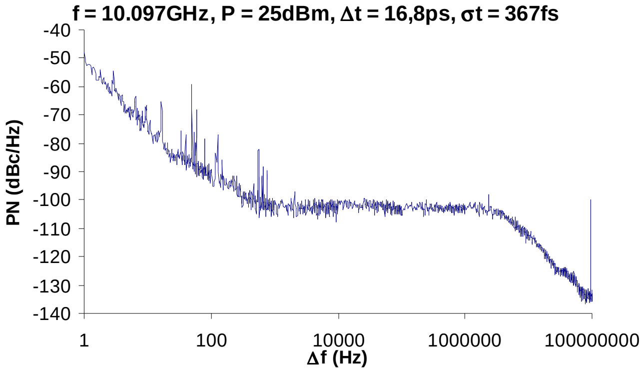

Fig. 2. SSB spectrum of the QDa-MLLDF module in a active mode locking scheme

3. Description of the experiment

Figure 3 sketches the experimental set-up, which is basically a contra-propagation wavelength conversion scheme.

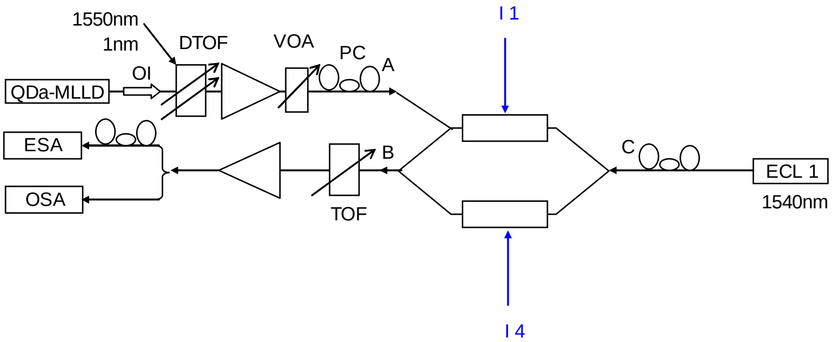

Fig. 3. Experimental set-up.
DTOF: doubly tunable filter; PC: Polarization Controller; TOF: tunable filter; OSA: Optical Spectrum Analyser; ESA: Electrical Spectrum Analyser; VOA : variable optical attenuator; ECL: External cavity laser.

Optical filtering is needed to obtain 5ps pulses which are injected into the upper arm of the optical gate. Amplification is necessary to get sufficient power through the SOA in the upper arm of the MZ, since passive waveguides loss has to be overcome. The signal at the output port of the SOA-MZ has however to be filtered so that the sampling signal is retrieved: only the wavelength converted signal is useful to constitute the sampled signal, and even in the contra-propagative scheme, the filter stops the parasitic reflected signal of the sampling pulses. The set-up shown on figure 3 allows the dynamic characterization of the optical gate. In real sampling experiment, the CW signal provided by the ECL has to be replaced with the signal to be sampled.

4. Main results and discussion

Figure 4 sketches the optical spectrum at the output of the SOA-MZ gate after the filtering. The right hand side zoom shows the initially CW signal from the ECL (at 1540nm) is now modulated by the sampling signal at 1550nm. By measuring the electrical spectral line power as a function of the sampling signal mean power, we can estimate the characteristics of the optical sampling. Figure 5 shows 38dB dynamic of the optical gate, when the SOA bias currents have been optimized at I1=218mA and I4=138mA. An extinction ratio of 38dB can lead to a N = 6 bits sampling resolution, and along with the σ_t=370fs timing jitter of the optical sampling source (biased at 300mA), such an all optical sampling scheme can lead to the digital conversion of an analog signal whose maximal frequency is 6.7GHz, given by the following formula: $f_{max} = 1/ (2 \pi \sigma_t 2^N)$.

OThU3.pdf

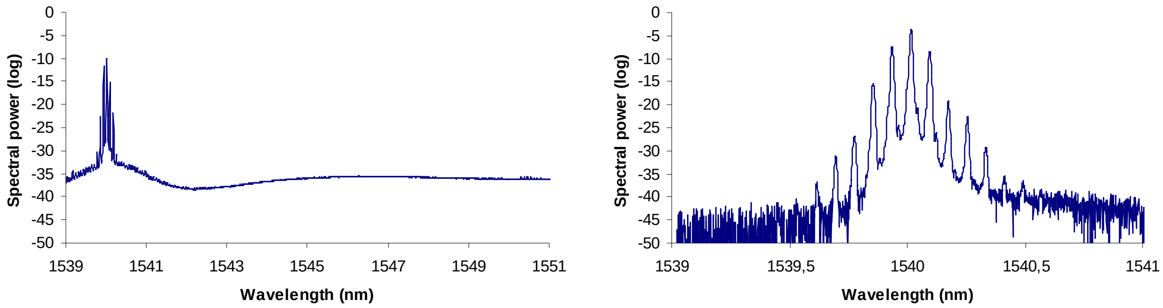

Fig. 4. Wavelength converted signal characteristics: optical spectrum after filtering (left), and a zoom at 1540nm (right).

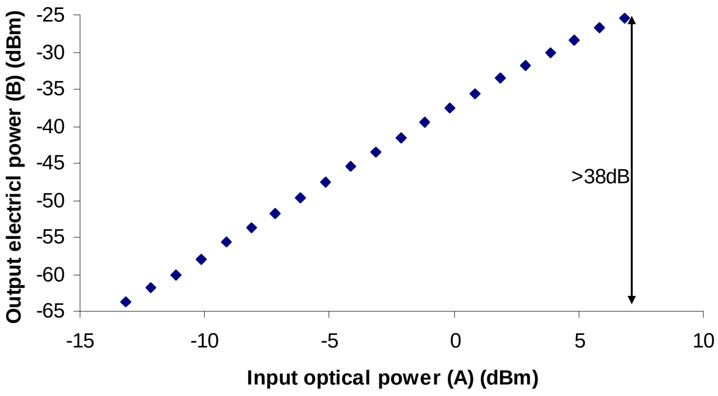

Fig. 5. Characterization of the dynamic of the optical sampling

5. Conclusions

In this paper, we report on the experimental results demonstrating the feasibility of an all-optical sampling system, in which all the photonic devices have been packaged in modules. A QDa-MLLD has been packaged into a compact module, which integrates a current source and an automatic temperature regulator. The MLLD exhibits a very low phase noise, corresponding to less than 370fs timing jitter. When combined with a 38dB dynamic SOA-MZ optical gate, such a system can lead to 6 bits resolution sampling of an analogue signal whose maximal frequency is 6.7GHz, which can be typically a 1.7GHz bandwidth radio signal carried at 5GHz. This opens the way to all optical high speed analog to digital conversion.

Acknowledgements

This work is partly financed by the ANRT program TONICS.

References

[1] S. Arahira et al., "160-Gb/s OTDM Signal Source With 3R Function Utilizing Ultrafast Mode-Locked Laser Diodes and Modified NOLM", IEEE Photonics Technol. Lett., vol. 17, pp. 992 – 994, 2005.

[2] T. Ohno et al., "A 240-GHz active mode-locked laser diode for ultra-broadband fiber-radio transmission systems", OFC, paper PDP13, Anaheim 2005.

[3] J. Renaudier et al, "First experimental demonstration of clock recovery meeting ITU requirements at 40 GHz based on a 1.5-µm Quantum-Dots Fabry-Perot self-pulsating semiconductor laser", post-deadline paper, ECOC, Glasgow, UK, 2005

[4] A. Shen et al., "Ultra-Narrow Mode-Beating Spectral Line-Width of a Passively Mode-Locked Quantum Dot Fabry-Perot Laser Diode", ECOC, Cannes, France, 2006

[5] A. Shen et al., "Nearly Fourier-transform limited tunnel injection quantum dash modelocked Fabry-Perot laser module for tuneable pulse generation", Post-Deadline Paper 2.6, ECOC, Berlin, Germany, 2007