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Breves generator of pulses at different flow rates (40 GHz, 80 GHz and 160 GHz)

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Abstract

This work presents the realization by simulation a breves generator of pulse has different flow rates (40 GHz, 80 GHz, 160 GHz). In a first step, we have realized the source of short pulse train at 40 GHz by the non-linear compression of a sinusoidal flapping through a process of mixtures four multi-wave, using the Mach-Zehnder modulator and optic isolator simple. In a second step, the pulse train obtained is then fiberized to reduce the duty ratio of 1/5 to 1/16. In a third step the train obtained encoded then multiplexed to a throughput of 80 Gbit/s. In the last step, we present the re-coding and re-multiplexing again, in order to obtain a rate of 160 Gbit/s, in order to perform simulation a brief pulse generator, simple, easy implementation, is not expensive, in three outputs of different rates, stable and without jigs.

Keywords: optic *isolator, pulse train, Mach-Zehnder modulator, four wave multiplexing, temporal compression.*

1. Introduction

Laser sources emitting ultra-short pulses at very high repetition rates (>10GHz) are increasingly used in many applications such as clock generation, all-optical computers, the spectroscopy or testing components. Many works have been made to design impulse fibered sources that offer a great flexibility in terms of pace and time width [1].

Technically increased flows inevitably require the use of pulses of shorter and shorter, which can propagate in a stable way for high power injected into the fiber. From a fundamental point of view, propagation of ultra-short sets games linear effects and non-linear pulses such that the chromatic dispersion, the four-wave mixing, self phase modulation and the Brillouin and Raman effects [2].

Components such as gain switching laser (gain-switched laser) or of the mode-locked laser diodes (Locked Mode Laser Diode) are the main pulsed sources used for generating the optical pulse train, necessary in systems transmissions OTDM. However, these solutions are laboratory components, and most of them are expensive and not always commercially available [3]. But at least most CW laser fulfills this role easily and commercially available, on the other hand, the association of OTDM and WDM techniques can increase the overall throughput of the transmission systems [3]. Speeds exceeding Tb/s have been achieved. However, the incoherent nature of the pulses optical sources impose significant spectral spacing between channels in wavelength-division multiplexing [2]. These factors are the starting point of this work, the aim is to achieve a simulation of a generator has an optical transmission system in time division multiplexing, optical components based on low cost and commercially available.

The solution chosen for the optical pulse train generation will introduce constraints on its coherent nature. However, eliminating these constraints, the system has the advantage of a very narrow optical spectral efficiency. This allows OTDM techniques, with a much lower spectral channel spacing than those obtained with conventional solutions [1].

The system described here allows the transmission of data to an overall bit rate of 160 Gb/s after multiplexing. The components used are nevertheless suitable for a flow rate of 160 Gb/s, and their commercial availability allow to consider concrete applications and short-term designed system.

2. Theoretical study

2.1. Mounting of the generator

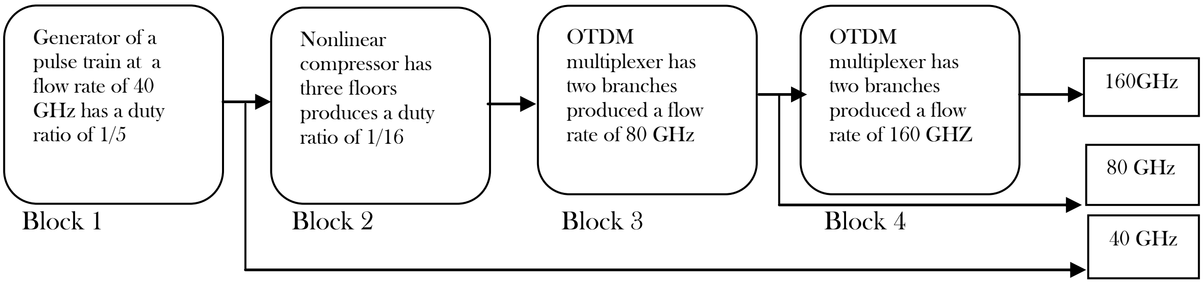

Figure1. Installation of the generator

The installation of the generator is simple, easy implementation is not expensive, consists of four blocks, three different repetition rates of outputs (40 GHz, 80 GHz and 160 GHz) stable and without jigs (see figure 1).

2.1.1. Block 1

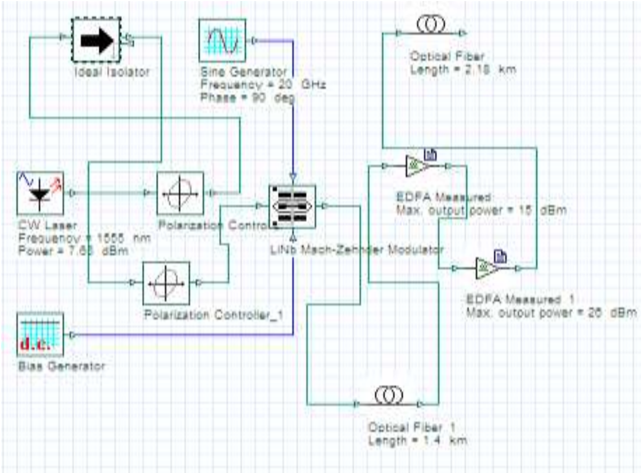

Figure 2. Optical source of breves pulse at 40 GHZ

This block (see figure 2) is a source of breves pulse at a flow rate of 40 GHZ, with a duty ratio of 1/5 (temporal pulse width/pulse period of this), consists of a laser source (CW laser) issued continuous power equal a 7.65 dBm has a wavelength 1555 nm, that power passes through the first polarization controller which optimizes the power level at the output of the isolator, this isolator has the role to completely remove the Brillouin effect, the second polarization controller is used to adjust the bias on the axis of Mach-Zehnder modulator, the latter driving a generator at very high frequencies of 20 GHZ (see figure 6), is obtained at the output of the modulator a pulse train of 40 GHz (see figure 7 and figure 12), was pre-amplified by EDFA1 then amplified by EDFA2, the resulting pulse train is injected into the first fiber, this product a rhythmic pulse train at 40 GHz by nonlinear compression of a sinusoidal flapping through a process mixture of four multi-wave [4],[5],[6], stable and without jigs, has a duty ratio of 1/5 (see figure 8 and figure 13).

2.1.2. Block 2

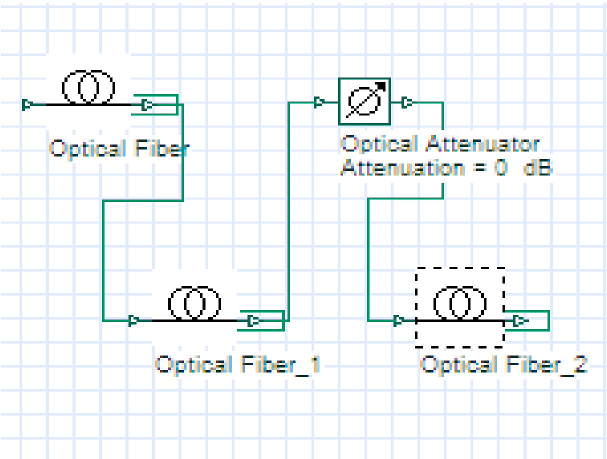

Figure 3. The compressor non-linear

This block (see figure 3) presents a nonlinear compressor, to decrease the duty ratio of 1/5 to 1/16, is composed of three floors, each floor performs a type of fiber to specified parameters (fiber length L, chromatic dispersion D, nonlinear coefficient Kerr γ) (see figure 9 and figure 14).

2.1.3. Block 3

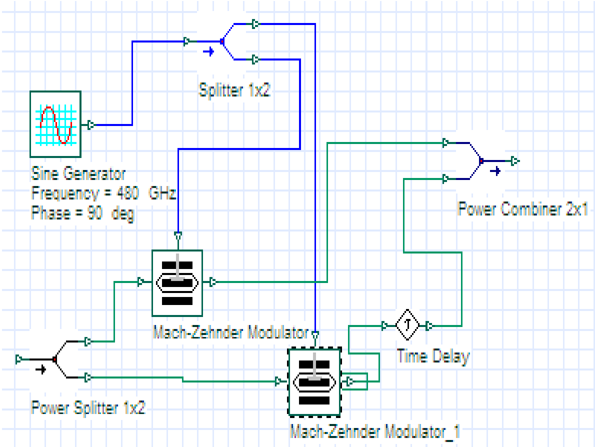

Figure 4. The first OTDM multiplexer

This block (see figure 4) is an OTDM multiplexer [7], rhythmical to the flow of the previous block has 80 GHz repetition of frequencies, consists of two branches, each branch delays the pulse train relative to the previous branch a duration τ well determined (see figure 10).

2.1.4. Block 4

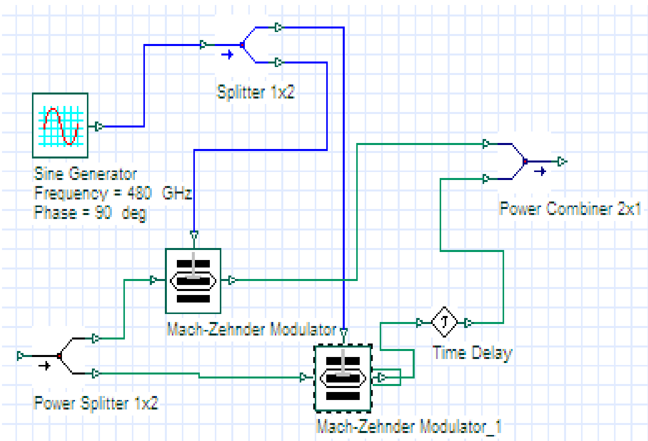

Figure 5. The second OTDM multiplexer

The latter block (see figure 5) is a second multiplexer by the OTDM method, he even flow rate of the previous block a repetition rate of 160 GHz, contains two branches, one of the two branches delays the pulse train relative to another a duration τ (τ= the period of the pulse/the number of branches), (see figure 11).

2.2. Nonlinear Schrodinger equation

A light pulse of slowly varying envelope A(0,t), which propagates in an optical fiber can be described by the generalized nonlinear Schrödinger equation[8],[9],[10]

$$\underbrace{\frac{\partial A}{\partial z}}_{\text{Propagation}}+\underbrace{i\left(\frac{\beta_2}{2}\frac{\partial^2 A}{\partial t^2}-\frac{\beta_3}{6}\frac{\partial^3 A}{\partial t^3}\right)}_{\text{Chromatic dispersion}}+\underbrace{\frac{\alpha_L}{2}A}_{\text{losses}}-\underbrace{i\gamma|A|^2A}_{\text{Effect of Kerr}}+\underbrace{i\gamma T_r\frac{\partial|A|^2}{\partial t}A}_{\text{effect of Raman}}+\underbrace{\frac{\gamma}{\omega_0}\frac{(\partial|A|^2A)}{\partial t}}_{\text{Stiffening}}=0 \quad (1)$$

Theoretically, the dispersion effects are expressed by the Taylor expansion in Taylor series of the propagation constant around the carrier frequency of the following:

$$\beta(\omega)=\frac{\omega}{c}n(\omega)=\beta_0+\beta_1(\omega-\omega_0)+\frac{\beta_2}{2}(\omega-\omega_0)^2+\frac{\beta_3}{6}(\omega-\omega_0)^3+\cdots+\frac{\beta_m}{m!}(\omega-\omega_0)^m \quad (2)$$

With $\beta_m=\left(\frac{\partial^m\beta}{\partial t^m}\right)_{(\omega=\omega_0)}$ ou $\beta_3=\left(\frac{\partial^3\beta}{\partial t^3}\right)_{(\omega=\omega_0)}$ (3) is the chromatic dispersion of order 3.

While β_2 reflects the fact that two neighboring frequencies see a different group velocity. It is commonly called (dispersion coefficient of group velocity GVD):

$$\beta_2=\left(\frac{\partial^2\beta}{\partial t^2}\right)_{(\omega=\omega_0)}=\frac{1}{V_g^2}\frac{\partial V_g}{\partial\omega}=\frac{1}{c}\left[2\frac{\partial n}{\partial\omega}+\omega\frac{\partial^2 n}{\partial\omega^2}\right] \quad (4)$$

However, the scientific community telecommunications prefers the use of another parameter D (ps/(nm.km)). The two parameters are related by the following relation ship: $D=-\frac{2\pi c}{\lambda^2}\beta_2$ (5)

The length of the fiber corresponds to the distance at the end of which the initial pulse of a time width 1/e, T_0 has expanded a √2 factor is expressed as a result:

$$L_D=\frac{T_0}{|\beta_2|} \quad (6)$$

Electric field incident and modulates around a carrier has ω_0, modifie by his mere presence the index of the medium through which it passes, this change results from the Kerr effect and is dictated by the power profile

$$P(z,t)=|A(z,t)|^2 \quad (7)$$

As indicated by the equation : $n=n_0+\frac{P(z,t)}{A_{eff}}$ (8)

n_0 : normal refractive index, n_2 is the nonlinear refractive index, A_{eff} is the effective area of the fiber.

The Kerr coefficient γ is expressed by the following equation: $\gamma=\frac{\omega_0 n_2}{cA_{eff}}$ (9)

The phase shift from the self phase modulation given by the following expression:

$$\varphi_{NL}=\gamma|A(0,t)|^2z \quad (10)$$

This reflects a shift

$$\delta\omega(t)=-\frac{\partial\varphi_{NL}}{\partial t}=-\gamma\frac{\partial|A(0.t)|^2}{\partial t}z \quad (11)$$

Fiber length for which the nonlinear effects become important is expressed by the following equation :

$$L_{NL}=\frac{1}{\gamma P_0} \quad (12)$$

criterion L_D = L_{NL} can describe the soliton pulse [11], proposed in 1973 by Hasegawa and Tapper in the form of a hyperbolic secant as a result :

$$A(z,t)=N\sqrt{P_0}\,\mathrm{sech}\left(\frac{t}{T_0}\right)\exp\left[\frac{iP_0z}{2\gamma}\right] \quad (13)$$

With N is the order of the soliton, T_0 time width 1/e of the pulse and P_0 the peak power of the soliton connected to the parameter of the optical fiber, gift:

$$P_0=\frac{\beta_2}{\gamma T_0^2} \quad (14)$$

3. Characteristics and values of components parameters

From the equations (1,..,14), has achieved the following components parameters and values:

Table 1. Fiber parameters and value

fiber	Parameters	Symbol	Value
Fiber 1 DCF (Dispersion compensating Fiber)	Fiber length	L_1	1.4 Km
	Chromatic dispersion	D_1	-100 ps/(nm.Km)
	Nonlinear Kerr coefficient	γ_1	1.3 $W^{-1}.Km^{-1}$
Fiber 2 SMF (Standart Fiber)	Fiber length	L_2	2.18 Km
	Chromatic dispersion	D_2	17 ps/(nm.Km)
	Nonlinear Kerr coefficient	γ_2	1.7 $W^{-1}.Km^{-1}$
Fiber 3 NZ-DSF (Non-Zero Dispersion Shifted Fiber)	Fiber length	L_3	1.29 Km
	Chromatic dispersion	D_3	-1.5 ps/(nm.Km)
	Nonlinear Kerr coefficient	γ_3	1.3 $W^{-1}.Km^{-1}$
Fiber 4 HNLF (High Non-Linear Fiber)	Fiber length	L_4	1 km
	Chromatic dispersion	D_4	-0.45 ps/(nm.Km)
	Nonlinear Kerr coefficient	γ_4	10 $W^{-1}.Km^{-1}$
	Dispersion slope	S	0.01 ps/(nm^2.Km)
	Coeffecient losses	α_L	1.64 dB/Km
Fiber 5 SMF 28 (Standard	Fiber length	L_5	0.145 Km
	Chromatic	D_5	17.5

Fiber)	dispersion		ps/(nm.Km)
	Nonlinear Kerr coefficient	γ_s	1.3 $W^{-1}.Km^{-1}$

Table 2. Components parameters and values

Component	Parameter	Symbol	Value
Laser source	Wave length	L	1555 nm
	Power	P	7.65 dBm
Mach-Zehnder Modulator 1	Extinction ratio	U_{ext}	21.5 v
	Bias voltage	V_b	11 v
Mach- Zehnder Modulator 2	Extinction ratio	U_{ext}	33 v
EDFA amplificator 1	Maximum output power	$P_{s.max}$	15 dBm
EDFA amplificator 2	Maximum output power	$P_{s.max}$	26 dBm

4. Simulation and test tools

4.1. Simulation tools OPTISYSTEM

Faced with the growing complexity of developed architectures and systems, the simulation tools have become important. They are increasingly used in order to optimize the parameters involved in the realization of a system. They allow to take a prevision of the expected results experimentally. Also, now they allow to use during a simulation, example OPTISYSTEM [12],[13].

4.2. Results of simulation

From the values and components parameters (see Table 1 and Table 2), has achieved the following results:

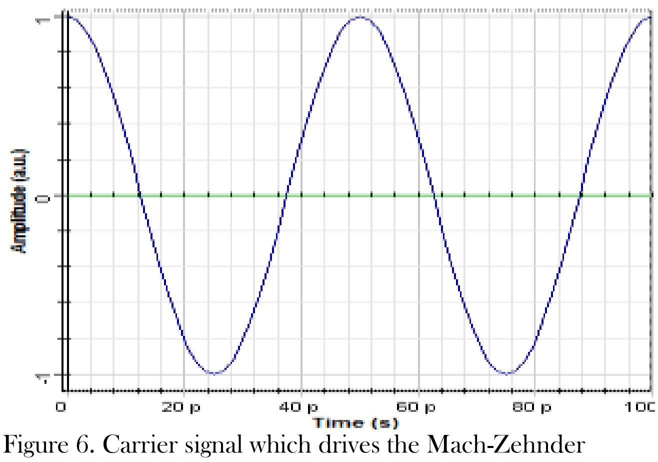

Figure 6. Carrier signal which drives the Mach-Zehnder modulator

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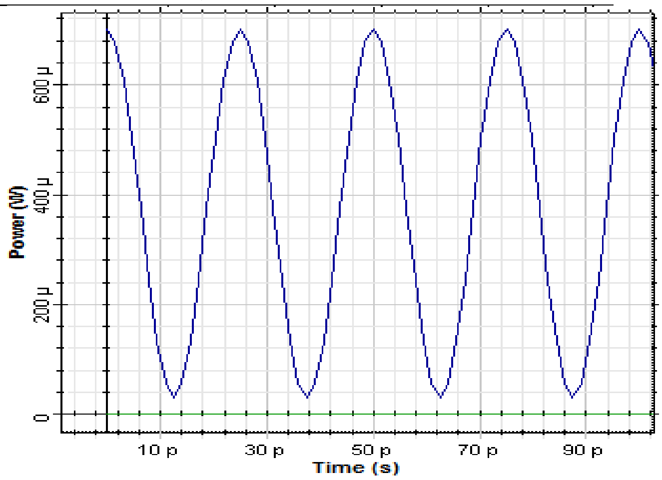

Figure 7. The pulse train at the output of the Mach-Zehnder modulator (the frequency is doubled).

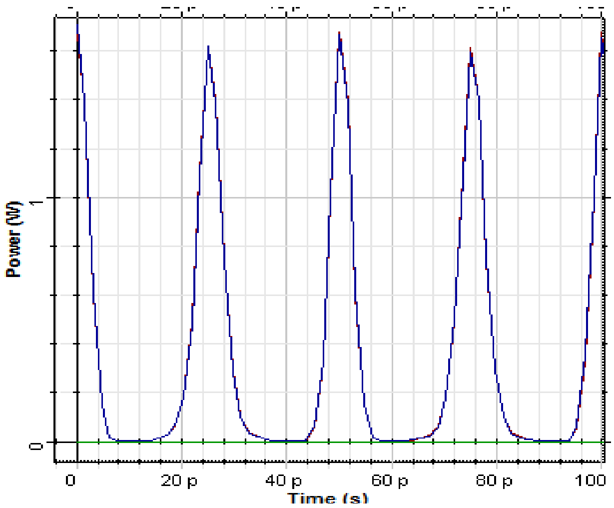

Figure 8. The pulse train at the output of the first block at a rate of 40 GHz has a cyclic ratio of 1/5.

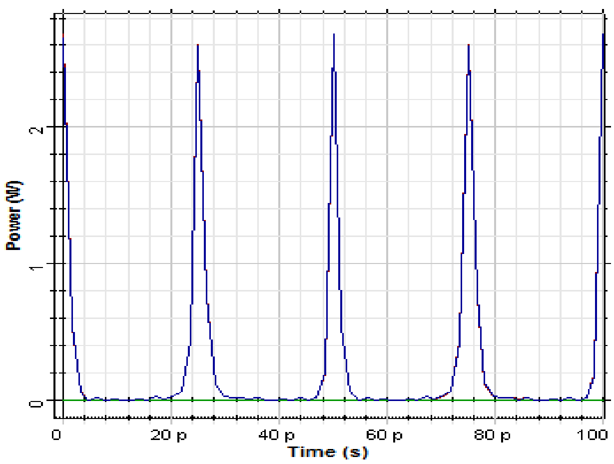

Figure 9. The pulse train at the output of the second block at a rate of 40 GHz has a duty ratio of 1/16.

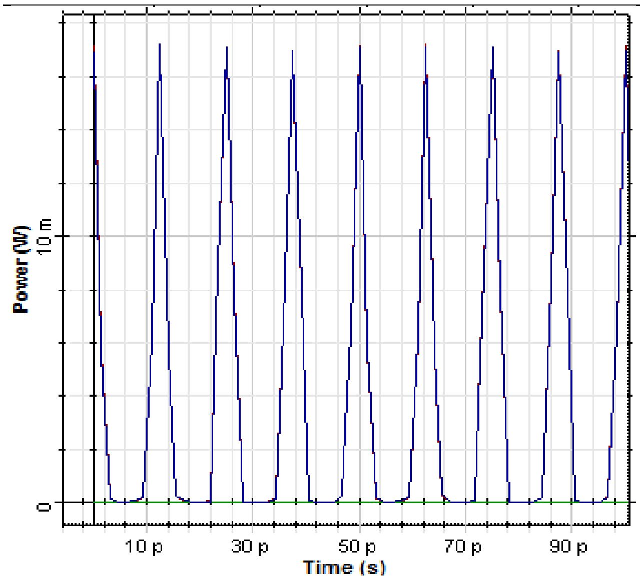

Figure 10. The pulse train output of the third block has a flow rate of 80 GHz, OTDM method is the bitter pre-multiplexing.

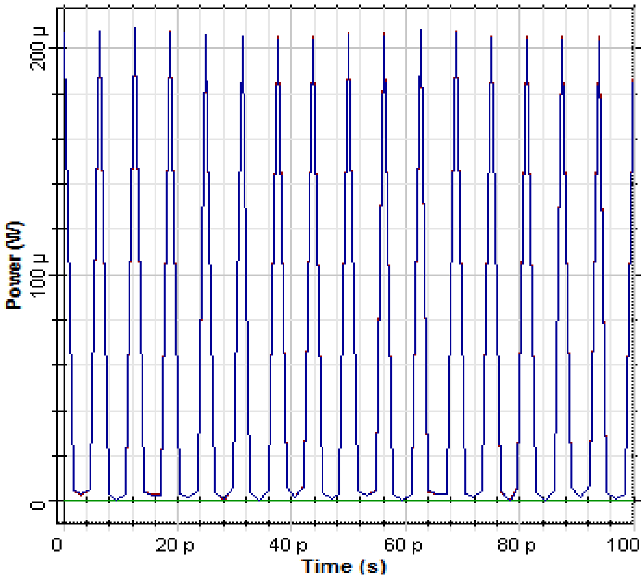

Figure 11. The pulse train at the output of the last block has a flow rate of 160 GHz.

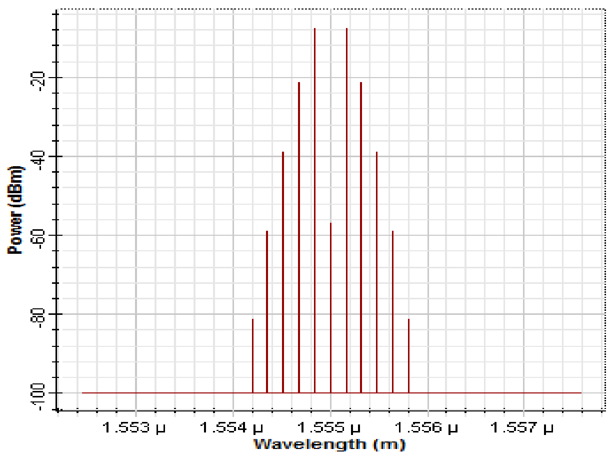

Figure 12. Signal spectrum of the signal at the output of the Mach- Zehnder modulator in the first block.

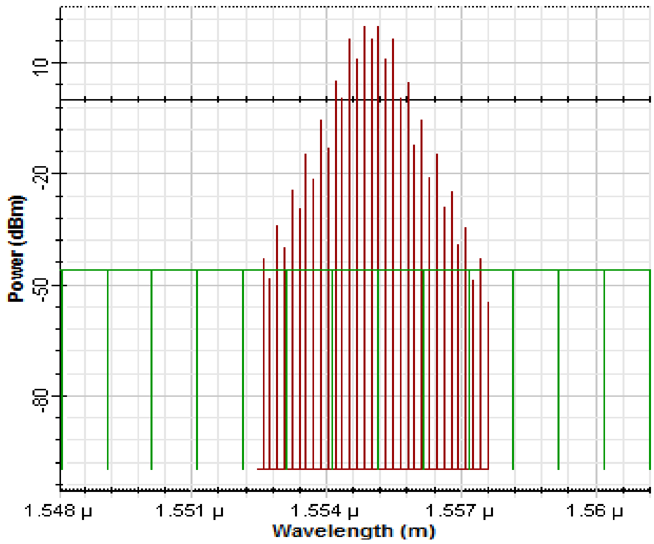

Figure 13. Signal spectrum at the output of the first block, it is noted enrichment of the spectrum by the effect of the curtailment sinusoidal beat by mélange of four-wave process.

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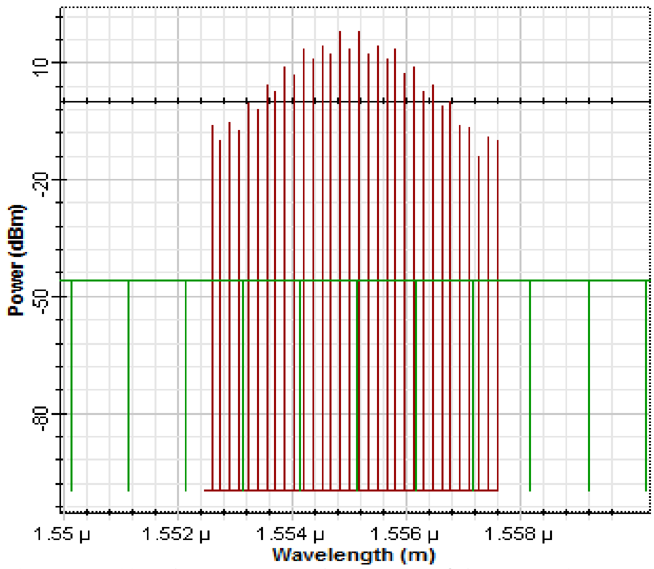

Figure 14. Signal spectrum at the output of the second block.

5. Discussion

Coupling two continuous diodes whose frequency difference is equal to the repetition rate desired, the main advantage of this technique is to achieve repetition rates up to 2 THz [4], [5] which exceeds bandwidth electronic systems (lower 50 GHz). During this, in the absence of special precautions, the spectral instability of the two diodes (line width between 1 and 5 MHz) causes a fluctuation of the repetition rate, and therefore, a significant time jitter on the intensity profile final. The intensity modulation of a single continuous diode then appears as a great alternative to generate a more stable beat (see figure 6 and Table 2). For against, in addition to the limit of bandwidth, this technique is expensive depending on the frequency f of the RF signal which drives the modulator. To find a compromise between cost and stability of the system, the control of the modulator has its point of zero transmission by the frequency f /2 of the RF, has allowed us to generate a sinusoidal flapping at the rate f qualify (frequency doubling) (see figure 7, figure 12 and Table 2).

The compression of a sinusoidal flapping by mixing four waves is relatively simple to implement for an ultra-short pulse train high speed (see figure 8, figure 13 and Table 1).

To increase flow at very high repetition rate, it has used the OTDM multiplexing method that is quick and simple, it has managed to decrease the duty ratio of 1/5 to 1/16 (see figure 9, figure 14 and Table 1), then multiply by two the resulting flow (see figure 10, Table 1 and Table 2), and late doubling again to get the pace at 160 GHz (see figure 11, Table 1 and Table 2), over the three flows generated mainly in research laboratories at the same time can be used.

6. Conclusion

In this work, and after the theoric study of the generator of a brief pulse train, of three output of flow rates different (40 GHz, 80 GHz, 160 GHz), and introduction of the non linear Schrödinger equation which describes the non linear evolution of the envelop slowly varying of the optical pulse during its propagation along the fiber.

In the first step we have realized by simulation a generator of brief pulse train at the rate of 40 GHz with duty ratio of 1/5, based on non linear compression technique of a sinusoidal flapping through the mixing process of a four multi-wave using Mach-Zehnder and the optic isolator already chosen.

In the second step we succeeded in reducing the duty ratio from 1/5 to 1/16 using the compressor assembling that we realized which is composed by three floors, each floor is a fiber with determined parameters.

In the third step the brief pulse train obtained from the second step coded then multiplied by two, using an assembling of the multiplexer that we realized by simulation, this assembling is composed of of two branches, one branch delays the pulse train of the other branch by a duration τ, we have used the OTDM method to obtain the flow rate at 80 GHz.

In the last step the latter pulse train also multiplied by two, using an assembling of the multiplexer that we realized by simulation, we have used the same OTDM method to obtain th flow rate at 160 GHz, in order to obtain a generator <u>multi-output</u>, <u>sample</u>, <u>easy implantation</u>, is <u>not expensive</u>, used in the <u>C-band Telecommunication</u>

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Author's contributions

Hamouda Amar: Participated in all experiments, coordinated the goal of the work and writing the manuscript.

Kaddour Saouchi: Participated to the design of the research plan and organized the study.

Taybi Mahmoud: Participated to the design of the research plan and organized the study.

Ethics

If there are any ethical issues please send an email to:
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