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Viable Solution for Next Generation Passive Optical Network 2 (NG-PON 2) Supporting 40Gbps Downstream DQPSK and 10Gbps Upstream OOK

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Abstract

This paper demonstrates a simple and viable solution for high data rates challenge in access network by supporting 40Gbps in the downstream with Differential Quadrature Phase Shift Keying (DQPSK) and 10Gbps in the upstream with ON-OFF Keying (OOK) modulated signal. Channel dispersion is compensated by using fiber Bragg grating (FBG) dispersion compensation. The proposed system is analyzed through optisys software with standard values and recommendations of Next Generation Passive Optical Network 2 (NG-PON 2) for high data rate. Transmission performance of the proposed system has been investigated and simulation results shows the BER and power of downstream and upstream are quite better as the power at standard receiver sensitivity BER i.e. 1x10-9 is -32.5dB at downstream and -42.5dB at upstream.

Keywords*: Differential Quadrature Phase Shift Keying (DQPSK), ON-OFF Keying (OOK), fiber Bragg grating (FBG), Next Generation Passive Optical Network-2 (NGPON-2), Bit Error Rate (BER), High data rate*

1. Introduction

Advancement in Optical access network is necessary to deal with the increasing demand of high data rate. At present, Passive optical networks are deployed at 10Gbps data rate for the consumers with voice and multimedia services simultaneously [1-2]. It is essential to increase the data rate up to 40Gbps which cope up the demands of consumers and viable as next generation passive optical network (NG-PON 2) [3-5]. In order to increase the data rates of passive optical networks, advanced modulation formats have been proposed and implemented to decrease the effect of non-linearity's and dispersion effects [6]. Several modulation formats have been proposed by researchers in downstream and upstream such as NRZ, RZ, MD-RZ [7], CSRZ, MDRZ, DPSK [8], RZ-DQPSK/OOK [9], Differential Phase Shift Keying (DPSK)/OOK [9], Carrier suppressed return to zero CSRZ-DQPSK/OOK [9-11], NRZ-DQPSK/ASK [12, 13], DPSK/ IRZ [14,15]. But either above modulation techniques has been implemented over 10Gbps only (i.e. very low data rate) or proposed techniques have been implemented at very short fiber length, high cost, design complexity and high energy consumption. In this paper, we proposed an architecture which is 40Gbps DQPSK modulation in downstream and 10Gbps OOK modulation in upstream having fiber length of 10Km at both streams using FBG dispersion compensation. FBG dispersion compensation is used as it is simple, has low insertion loss and no nonlinearity and ability to provide tunable dispersion compensation compared to other dispersion compensation [16-18]. Important parameters of FBG are reflection coefficient (r_g), phase (ϕ_g) and bandwidth whose equations are given below [19] :

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$$r_g = \frac{A_b(0)}{A_f(0)} = \frac{ik_g \sin(q_g L_g)}{q_g \cos(q_g L_g) - i\delta \sin(q_g L_g)} \quad (1)$$

$$\phi_g = -arctan\left[\frac{Im(r_g)}{Re(r_g)}\right] \quad (2)$$

$$\Delta\lambda = \frac{2\lambda_B^2}{2\grave{n} L_g \pi}\sqrt{\left(K_g L_g\right)^2 + (\pi)^2} \quad (3)$$

Where A_b and A_f are spectral amplitudes, $\delta$is the detuning, Kg is the coupling coefficient, $q_g^2 = \delta^2 - k_g^2$ and Lg is the FBG length. Proposed system is fulfilling the requirement of NG-PON 2 in terms of high data rate.

2. Description of Simulation

Simulation results have been carried out of high data rate NG-PON. Figure 1 shows the simulated model of high data rate NG-PON having Optical line terminal (OLT), Optical network unit (ONU) and optical fiber having 10Km length between OLT and ONU. CW LASER is used as a carrier source having launch power = 0dBm (1 Watt) works at 1550nm, Electrical data stream is generated from pseudo random generator (PRBS) having data rate 40Gbps which is precoded differentially and modulated with optical carrier signal through two Lithium Niobate Mach-Zehnder modulator (LiNb MZM) which are connected in series as shown in Figure 2. Modulated signal transmitted through optical fiber having attenuation co-efficient of fiber is 0.2dB/km as shown Table 1. FBG dispersion compensation is used after the signal is transmitted from 10 km span of optical fiber to eliminate the effect of dispersion and nonlinearities in fiber before demodulation.

Received signal comprises in-phase (I) and quadrature-phase (Q) of DQPSK modulated signal, which are separately extracted from PIN detector circuit after processed through + 45º and - 45º phase shifter circuit as shown in Figure 3. For the efficient design, centralized LASER source technique is employed for re-modulation and the received downstream signal is used as an optical carrier of same wavelength and re-modulates the upstream at 10Gbps OOK modulated electrical data as shown in Figure 4.

Table 1. Simulated Model Parameters

	Parameter	Values
Transmission Section	Power of Laser	0dBm
	Frequency of Laser	193.1 THz
Fiber	Fiber Length	10Km
	Dispersion slop	0.075 ps/nm^2/km
	Effective core area	80 um^2
	Non Linear index-coefficient	2.6x10^{-20}
	Attenuation Coeff:	0.2 dB/km
	Dispersion	16.75 ps/nm/km
Receiver Section	Filter Cutoff Frequency	0.75*bit rate Hz

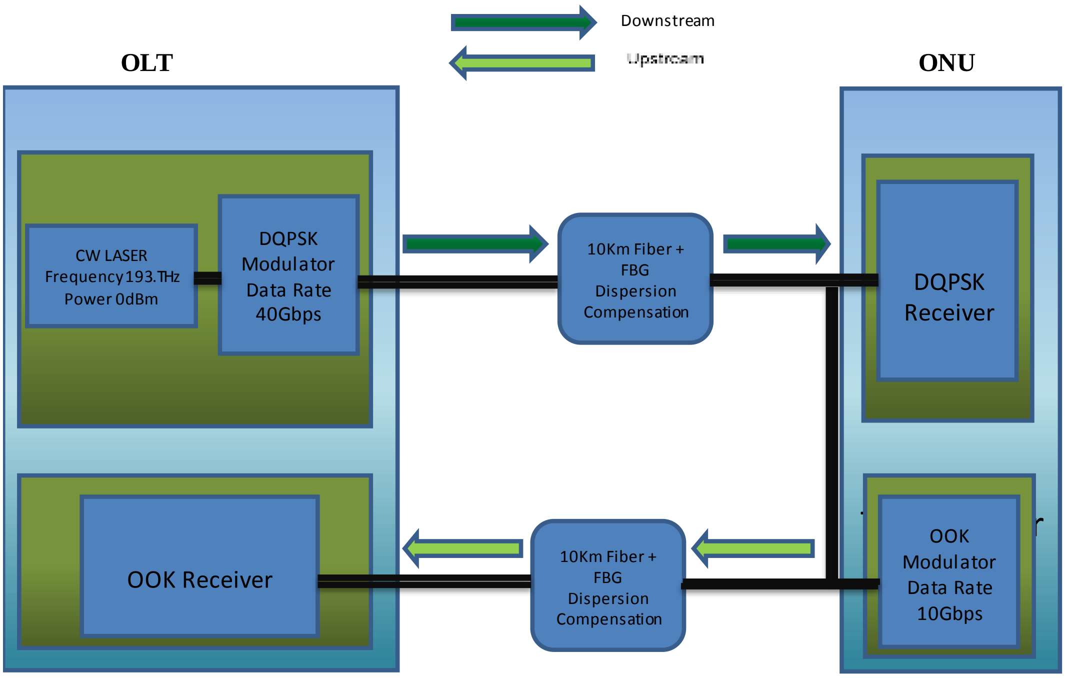

Figure 1. 40Gbps Next Generation Passive Optical Network (NG-PON) with FBG

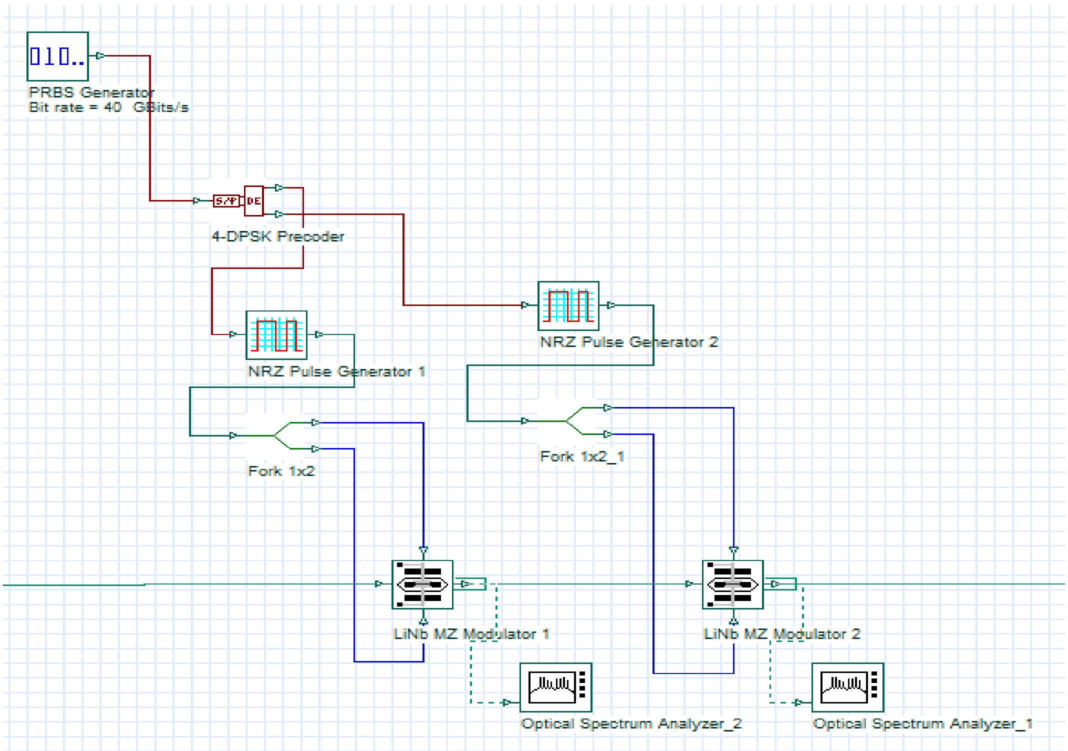

Figure 2. DQPSK Modulator Data Rate 40Gbps

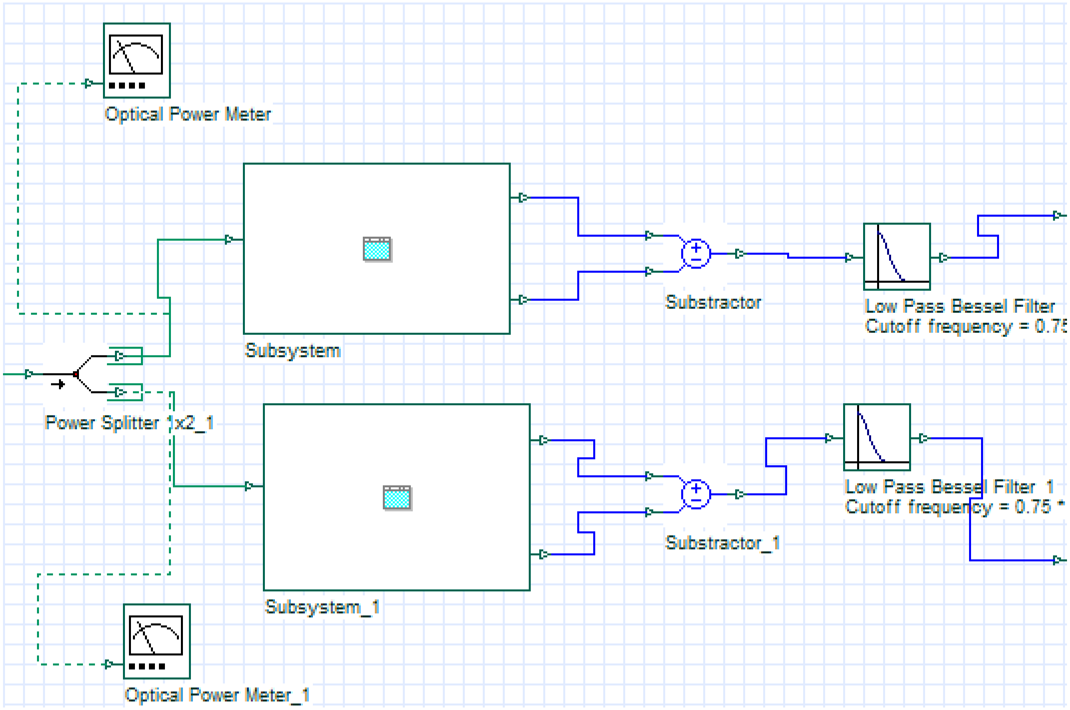

Figure 3. DQPSK Receiver

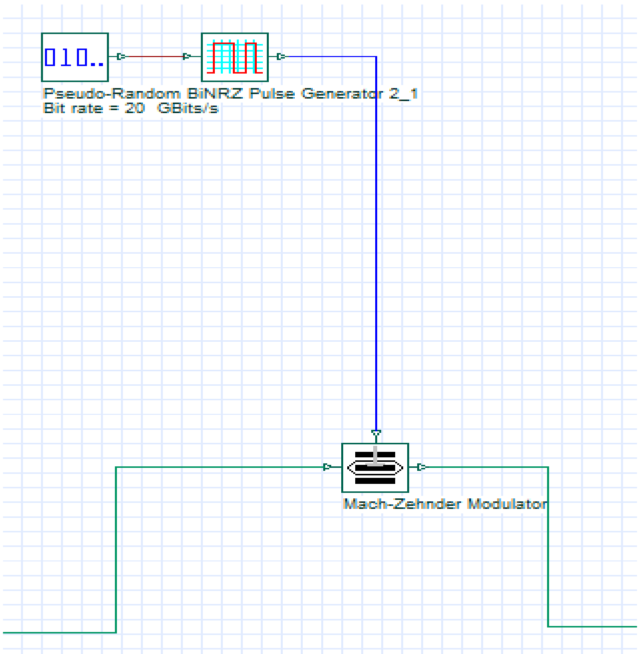

Figure 4. OOK Modulator Data Rate 10Gbps

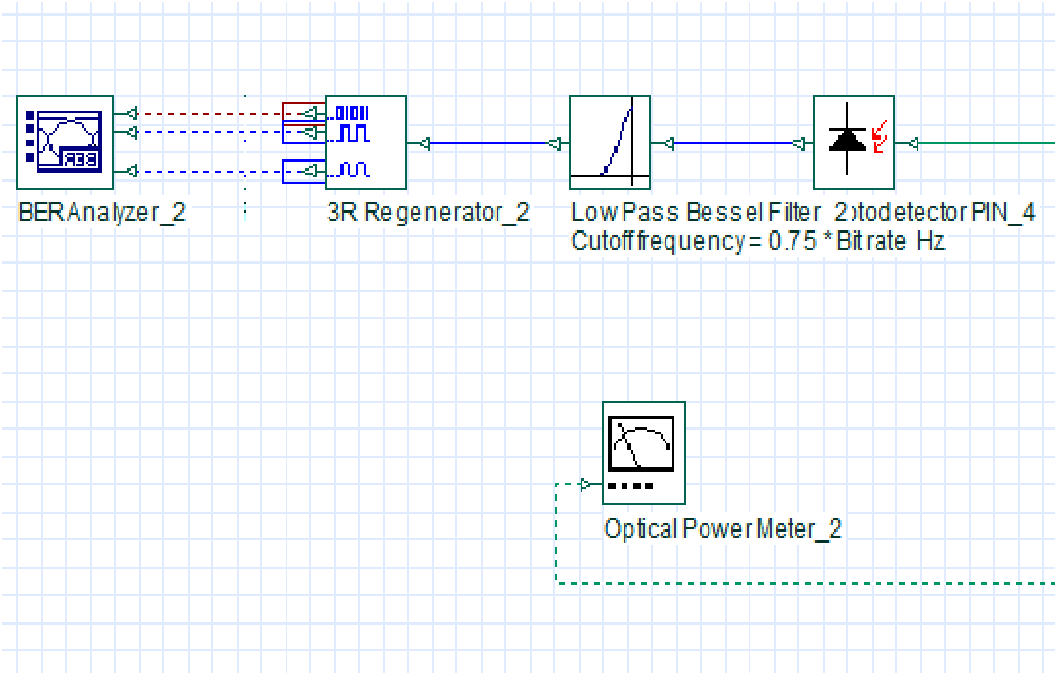

Figure 5. OOK Receiver

Then upstream data from ONU is transmitted back towards OLT through optical fiber length of 10km and Ideal dispersion compensation FBG then detected single Photo detector is used as a OOK modulated upstream as a receiver at OLT as shown in Figure 5.

3. Discussion of Results

Figure 6 and 7 shows the optical spectrum of DQPSK (downstream) and OOK (upstream) at carrier frequency of 193.1 THz (1550nm wavelength).

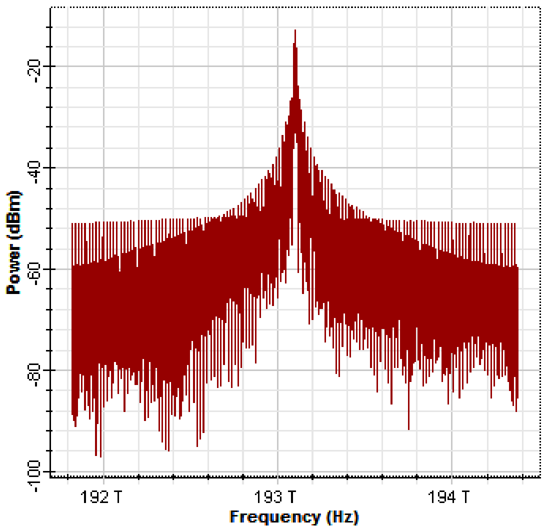

Figure 6. Optical Spectrum of DQPSK

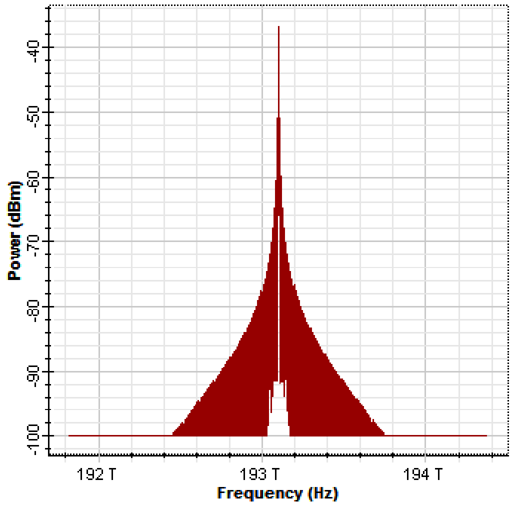

Figure 7. Optical Spectrum of Re-modulated OOK

Eye diagrams of downstream and upstream are shown in figure 8 and 9, open and wide eye has few errors in transmission but it is acceptable as BER and power of downstream and upstream are 3.41961×10^{-046} and 4.10171×10^{-018} and -8.168dB and -34.347dB respectively which is quite better as the power at standard receiver sensitivity BER i.e. 1×10^{-9} is -32.5dB at downstream and -42.5dB at upstream. It can also be seen that the loss margin (i.e. receiver power without attenuator 3.41961×10^{-046} minus standard receiver power sensitivity 1×10^{-9}) of the proposed system at downstream and upstream is 22.832dB and 8.153dB which is feasible and efficient for high data rate passive optical network. Figure 10 and 11 shows the simulation results obtained on back to back and 10Km fiber length DQPSK downstream and OOK upstream. Transmission power penalty for DQPSK downstream at 1×10^{-9} i.e. standard Bit Error Rate (BER) is 1dB only whereas for OOK is 0.5dB.

From the results, it can be seen that the proposed system is feasible and efficient for high data rate NG-PON.

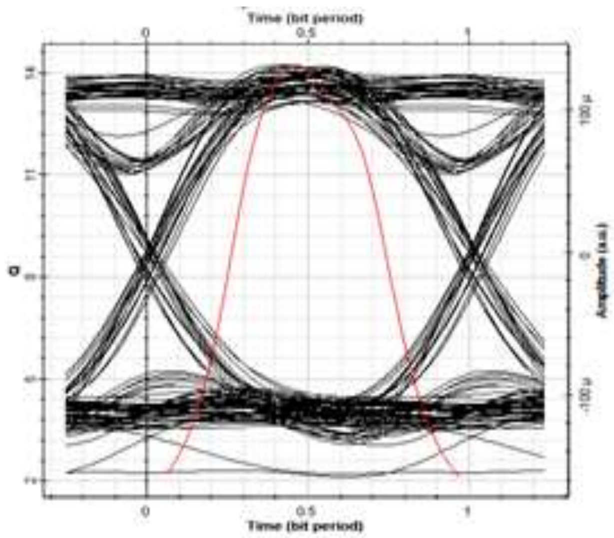

Figure 8. Eye Diagram of Downstream DQPSK Signal

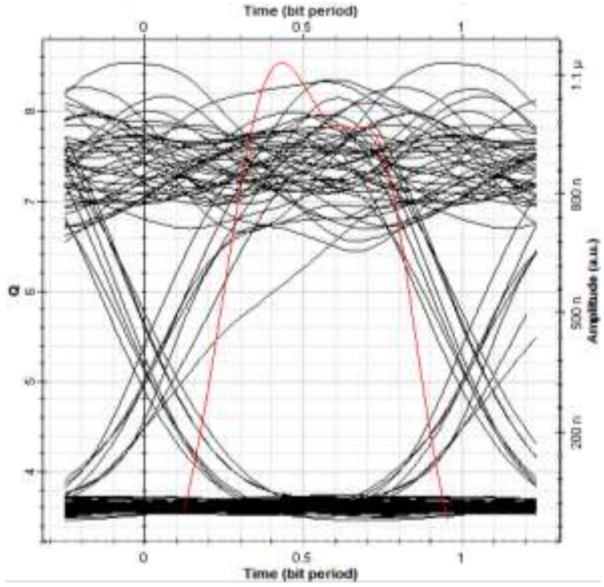

Figure 9. Eye Diagram of Upstream OOK Signal

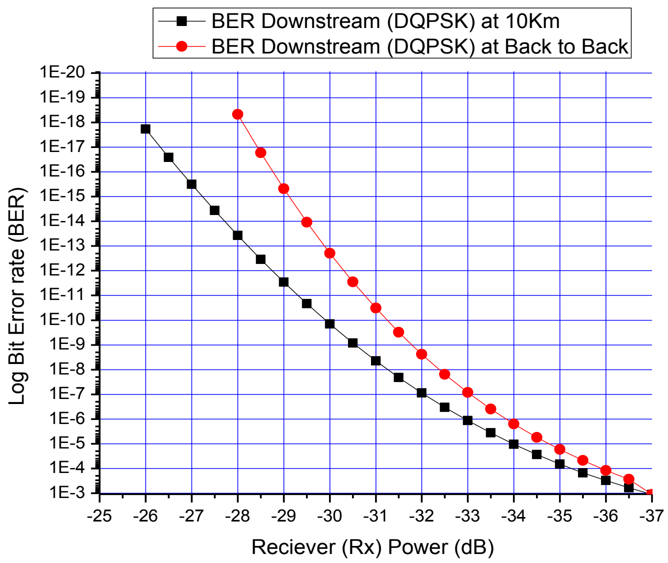

Figure 10. Rx Power vs BER

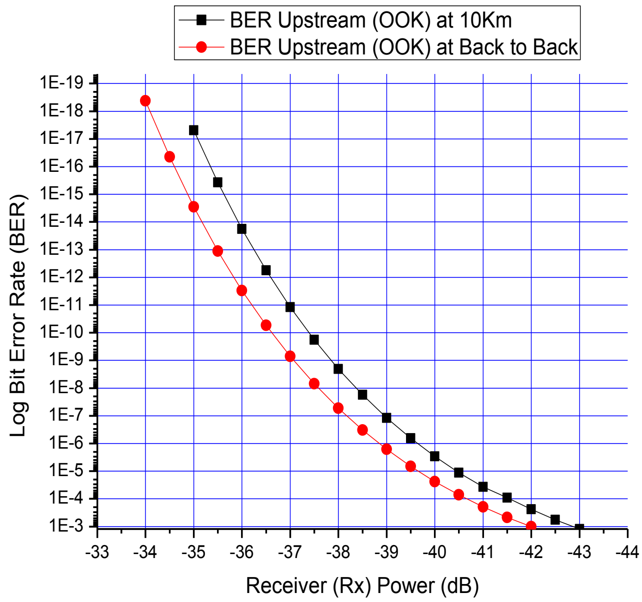

Figure 11. Rx Power vs BER

3. Conclusion

In the proposed setup, 40Gbps DQPSK modulated downstream and 10Gbps OOK modulated upstream have been investigated. The simulation results of the proposed scheme validate that data transmission for 10 km fiber span has been successfully achieved with very low transmission power penalties in both directions. Therefore it is recommended as a viable solution to cope up the high data rate demand of NG-PON 2.

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