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Extending the Reach of DWDM ROF-PON Link with Optimization of Four Wave Mixing Effect with Comparative Analysis of Different Modulation Formats

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ABSTRACT

In present generation fiber optical accesses networks represented by Wavelength Division Multiplexed Passive Optical Network (WDM-PON) is an attractive solution to satisfy the worldwide growing demand for transmission capacity. In this paper we work on extending the reach of Dense Wave Division Multiplexing Radio Over Fiber–Passive Optical Network (DWDM ROF-PON). We use single parameter optimization scheme (SPO) for the designing of DWDM link having 32 channels and able to transmit the data with the speed of 40 GBPS. There is various problems like four wave mixing and dispersion. We discuss about the Four Wave Mixing (FWM) with various channel spacing. The dispersion is compensated with the use of dispersion compensating fiber (DCF). We also discuss about the various parameters like transmitting power, modulation formats, channel spacing, effective core area of fiber, and dispersion slope of fiber. We design a DWDM ROF-PON network and simulate with the help of the opti system 7.0.

Index Terms:— *Dense Wave Division Multiplexing (DWDM), Four Wave Mixing (FWM), Radio over Fiber (ROF), Passive Optical Network (PON), Dispersion compensating fiber (DCF), Opti system 7.0.*

I. INTRODUCTION

In the last few years, there has been vast increase of applications in telecommunications sectors that requires great amounts of bandwidth such as streaming audio, interactive multimedia, video conferencing which has made the capacity of the existing optical fiber network inadequate [1]. In order to increase the capacity of optical fiber communication system the most important phenomena is the emergence of dense wavelength division multiplexing (DWDM) [2, 3]. In WDM system information from many channels can be multiplexed and transmitted over a single optical fiber link. In such a way we use the higher bandwidth of optical fiber link by transmitting the huge amount of data through such multiplexed systems.

In recent trends radio over fiber (ROF) techniques may use for achieving the high data rates, low loss. ROF system also use ultra wide band provided by optical fiber. It uses optical fiber links to distribute radio frequency signals from a central location to remote antenna units (RAU'S). The main benefits of ROF are low attenuation loss, large bandwidth, immunity to radio frequency interference, reduced power consumption, multi operation and multi service operation, dynamic resource allocation.

In the present paper, we have examined the impact of four wave mixing (FWM) for ultra high speed 40GBPS WDM network over the optical fiber link [7, 8]. We also compensate the effect of dispersion with the help of DCF and increase the reach of DWDM ROF-PON system [4, 5, and 6].

II. Four Wave Mixing Effect

Four wave mixing (FWM) is the important factor having catastrophic effect on DWDM communication system [9, 10]. This non linear effect arises when two or more pulses transmit through same fiber.

Generally FWM effect occur if the three light pulses, having different wavelength & travelling through single fiber, interact together to generate a new pulse.

If the three wavelengths λ_A, λ_B & λ_C are propagating through single fiber, these wavelengths will interact according to equation (1) to generate new λ_D

$$\lambda_D = \lambda_A \pm \lambda_B \pm \lambda_C \text{ here } A \neq B \neq C \text{ [1] } (1)$$

In general, the number of crossing product K, for M number of input channel is given by equation (2)

$$K = N^2 /2*(N-1) \quad (2)$$

Equation (2) shows that non linear effect FWM increase as number of channel in DWDM system increase.

Interchange crosstalk effect is caused in DWDM system by FWM non- linearity. FWM effect can be reduced by using unequal channel spacing & by dispersion management.

III. Simulation Model

In figure 1 the simulation model of DWDM ROF-PON network is shown. In which we generate the 32 input channels with the help of the WDM transmitter. WE also able to change the modulation format i.e. return to zero (RZ), not return to zero (NRZ) and no modulation format. Power variation should also be done with the help of the WDM transmitter. We have 32 channels with the frequency starting from 190 THz having frequency spacing of 200Ghz. The duty cycle of the signal is to be set on 0.5. After this the information coming from these 32 channels are multiplexed with the help of the ideal multiplexer and the multiplexed signal is transmitted through the single mode fiber having attenuation coefficient and dispersion slope 2db/km and 0.075ps/nm/km with the length of 75KM. The SMF is followed by EDFA-1(Erbium Dopped Fiber Amplifier) having gain and noise figure 15db and 6db respectively. After travelling 75Km the signal gets dispersed and the four wave mixing effects degrade the signal severely so compensate these effects by using dispersion compensating fiber (DCF). DCF have attenuation, dispersion and dispersion coefficient 0.5db/km, -85 ps/nm/km and -0.3ps/nm^2/km respectively having length of 30KM. After travelling the distance of 105 KM the signal again attenuate and the effect of attenuation is minimised with the help of the EDFA-2 having same parameters that of the EDFA-1. Now we again connect the SMF -2 having same parameters and length that of the SMF-1 and after this again followed by EDFA-3 having same parameters that of the EDFA-1. Now if we want to increase the transmitting distance then rotate the signal in the loop and increase the transmitting distance by increasing the number of loops. After travelling the distance of 150Km this multiplexed signal is demultiplexed with the help of the WDM DEMUX in to its 32 individual channels. Now this signal is passed through the Bessel optical filter tuned at the frequency of 200 GHz for the removal of noise optically from the optical signal. After this filtering process the optical signal is converted in the electrical signal with the help of the pin photo detector having dark current 10 nA and responsivity 1A/W. Now this electrical signal is passed through the Low pass Bessel filter of order 4 for the removal of noise content from the signal then this signal is send to the 3R generator and bit error rate (BER) analyser for the eye diagram analysis of the signal.

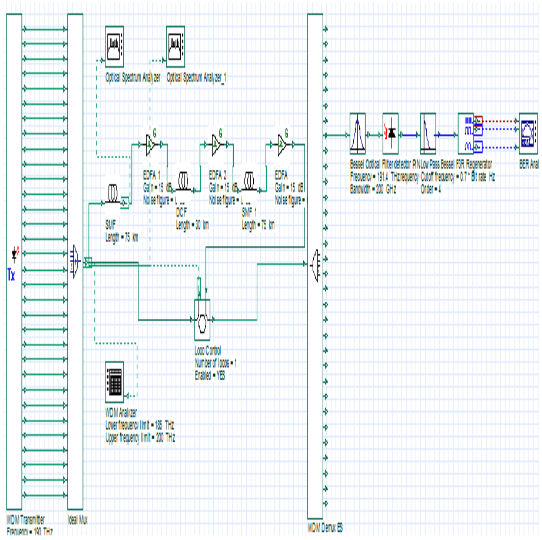


Figure 1. Simulation Model of DWDM ROF-PON

Simulation Parameters

The various parameters used for the simulation model are given in the table 1. These parameters are input power, transmitting distance, transmitting speed, DWDM channel spacing etc.

Table 1: Simulation Parameters

PARAMETER NAME	PARAMETER VALUE
Bit Rate	40 Gbps
Transmission Distance	150 Km
Sequence Length	64
Capacity	32 Channels 40 Gbps
Samples/Bit	256
Input Power	3 dBm
DWDM Channel Spacing	200 GHz
Duty Cycle	0.5

Table 2: Fiber Specifications

Fiber	Attenuation (dB/Km)	Dispersion (ps/nm-km)	Dispersion Slope(ps/ nm^2-Km)	Effective Core Area (μm^2)
SMF	0.2	17	0.075	70
DCF	0.5	-85	-0.3	22

IV. RESULTS & DISCUSSION

Analysis of FWM Effect on Various Channel Spacing

Simulation model given on the figure 1 is simulated and the effect of Four Wave Mixing effect is analyzed on the basis of various channel spacing. The various parameters used in this simulation process are input power 0dBm, channel spacing 25GHz, No modulation format, Line width 0Hz, Effective core area of SMF 70μm^2. Figure 2, 3, are input and output spectrum of the signal which shows that the maximum side lobe power is -36dBm after travelling the distance of 75KM. Figure 4, 5, 6 gives the analysis of the signal on the channel spacing of 100 and 200GHz. Table 3 shows the various side band power on various channel spacing after analyzing that table we conclude that the effect of FWM is increase when the channel spacing decreases. We observe the best results when the channel spacing is 200GHz.

Table 3: Maximum Side Band Power with Respect to Various Channel Spacing

Channel spacing (GHz)	25	100	200
Approximate Maximum Side Band Power(dBm)	-42	-50	-56

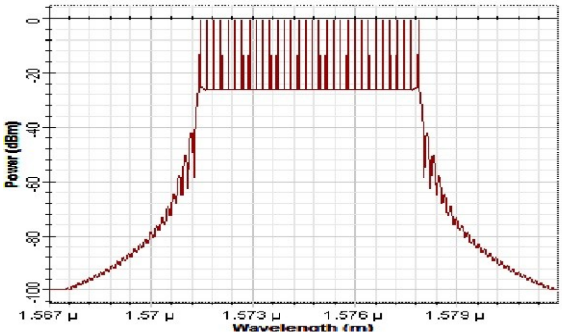


Figure 2: Input Spectrum of SMF of 75 Km Length (25GHz Channel Spacing)

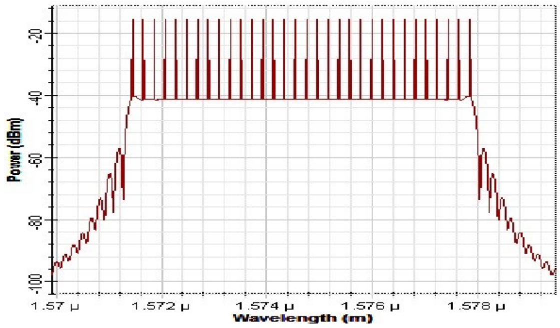


Figure 3: Output Spectrum of SMF of 75 Km Length (25GHz Channel Spacing)

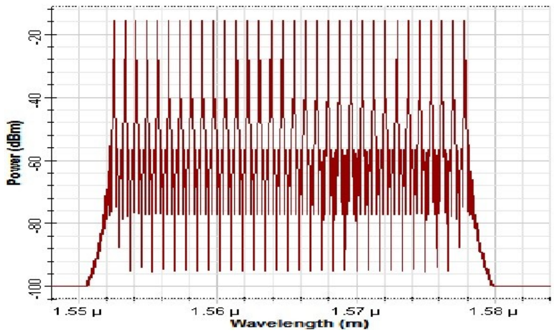


Figure 4: Output Spectrum of SMF of 75 Km Length (100GHz Channel Spacing)

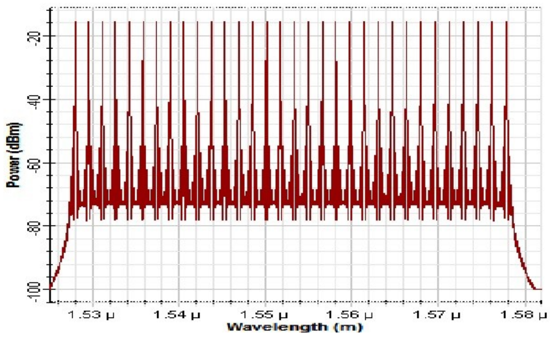


Figure 5: Output Spectrum of SMF of 75 Km Length (200GHz Channel Spacing)

Analysis of FWM Effect on Various Input Powers

Now we again simulate the model shown in figure 1 by taking the following parameters such that channel spacing 200GHz, Effective core area 70µm^2, Line width 0Hz, No modulation format. By simulating the model we analyze that the FDM effect is minimized by minimizing the power. The various side band powers are shown in table 4. But we can't reduce the power at certain limits because below that limit other component can't be run.

Table 4: Maximum Side Band Power with Respect to Various Channel Spacing

Input Power (dBm)	-10	0	10	20
Approximate Maximum Side Band Power(dBm)	-65	-56	-45	-34

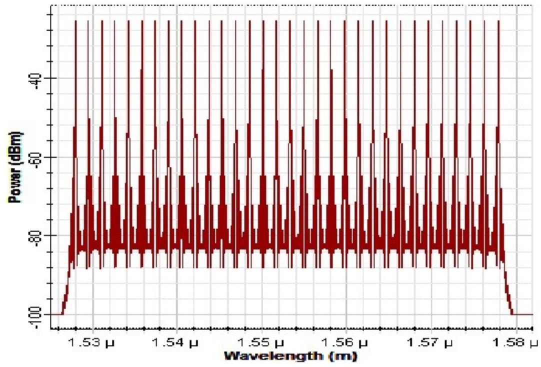


Figure 6: Output Spectrum of SMF of 75 Km Length (-10 dBm Power)

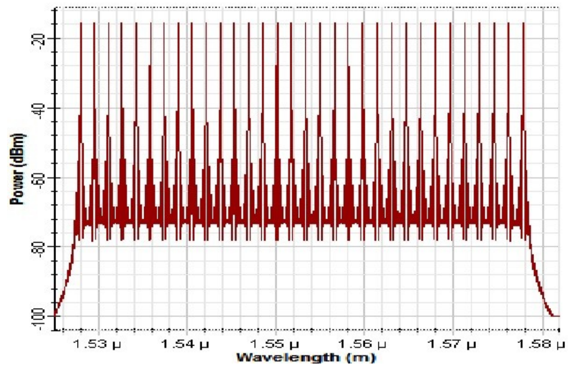


Figure 7: Output Spectrum of SMF of 75 Km Length (0dBm Power)

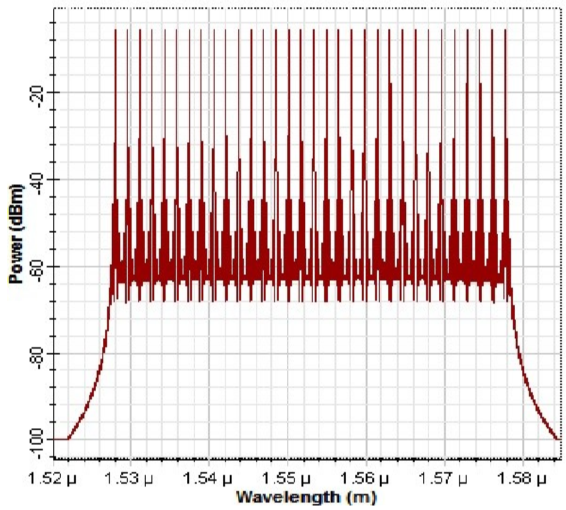


Figure 8: Output Spectrum of SMF of 75 Km Length (10 dBm Power)

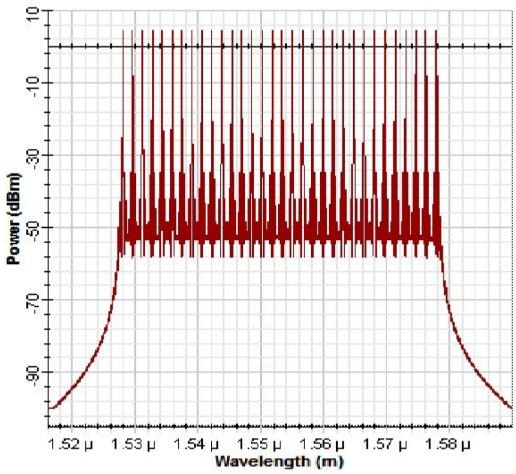
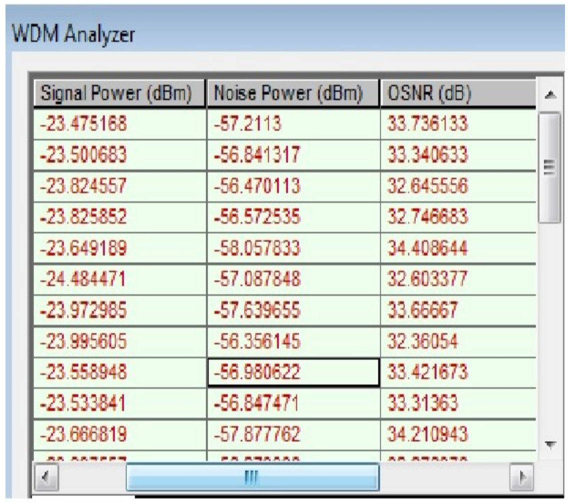


Figure 9: Output Spectrum of SMF of 75 Km Length (20 dBm Power)

Analysis of FWM Effect on Various Modulation Formats

RZ and NRZ modulation formats are used for the analysis of FWM effect by taking the parameter input power 0dBm, channel spacing 200 GHz, effective core area 70 µm^2, laser line width 0Hz. The signal is analyzed after travelling the distance of 75 Km with the help of WDM analyzer it gives the SNR 33.73 and 29.78 for the RZ and NRZ modulation formats respectively. From this analysis we conclude that the RZ modulation format is well suited for the long distance communication.



WDM Analyzer

Signal Power (dBm)	Noise Power (dBm)	OSNR (dB)
-23.475168	-57.2113	33.736133
-23.500683	-56.841317	33.340633
-23.824557	-56.470113	32.645556
-23.825852	-56.572535	32.746683
-23.649189	-58.057833	34.408644
-24.484471	-57.087848	32.603377
-23.972985	-57.639655	33.66667
-23.995605	-56.356145	32.36054
-23.558948	-56.980622	33.421673
-23.533841	-56.847471	33.31363
-23.666819	-57.877762	34.210943

Figure 10: Output of WDM Analyzer at the Distance of 75 Km Length (RZ Modulation Format)

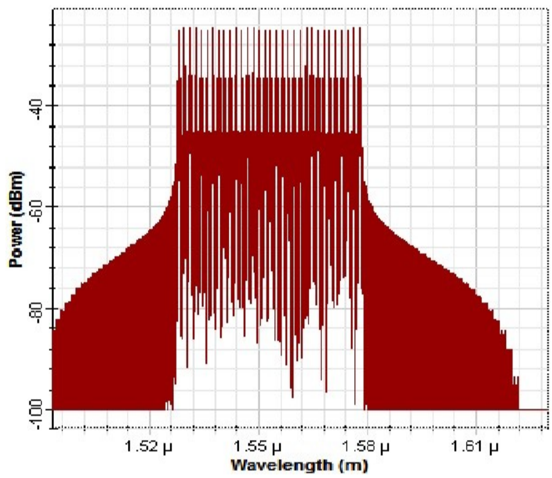
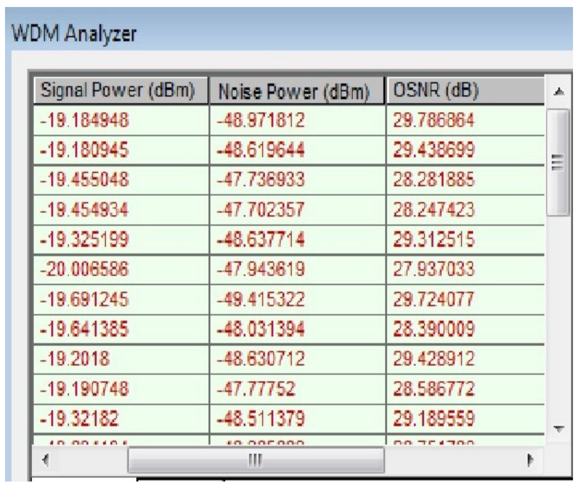


Figure 11: Output Spectrum of SMF of 75 Km Length (RZ Modulation Format)



WDM Analyzer

Signal Power (dBm)	Noise Power (dBm)	OSNR (dB)
-19.184948	-48.971812	29.786864
-19.180945	-48.619644	29.438699
-19.455048	-47.736933	28.281885
-19.454934	-47.702357	28.247423
-19.325199	-48.637714	29.312515
-20.006586	-47.943619	27.937033
-19.691245	-49.415322	29.724077
-19.641385	-48.031394	28.390009
-19.2018	-48.630712	29.428912
-19.190748	-47.77752	28.586772
-19.32182	-48.511379	29.189559

Figure 12: Output of WDM Analyzer at the Distance of 75 Km Length (NRZ Modulation Format)

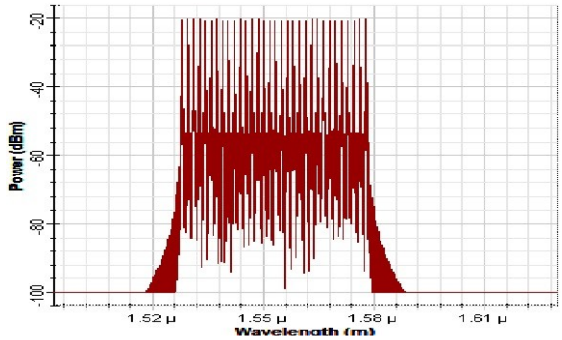


Figure 13: Output Spectrum of SMF of 75 Km Length (NRZ Modulation Format)

Analysis of FWM Effect on Various Cross Sectional Areas of Fiber

In this analysis the used parameters are input power 0dBm, lasser line width 0 Hz, channel spacing 200GHz, no modulation format is selected and the length of the fiber is taken 75 Km. By varying the effective core area of fiber on 64 µm^2 and 80µm^2 then we from the table 5 the FWM effect is increases when we decrease the effective core area of SMF. The FWM effect is shown in the figure 14, 15 for the effective core area of 64µm^2 and 80µm^2 respectively.

Table 5: Maximum Side Band Power with Respect to Various Effective Core Areas

Effective Core Area(µm^2)	64	80
Approximate Maximum Side Band Power (dBm)	-47	-41

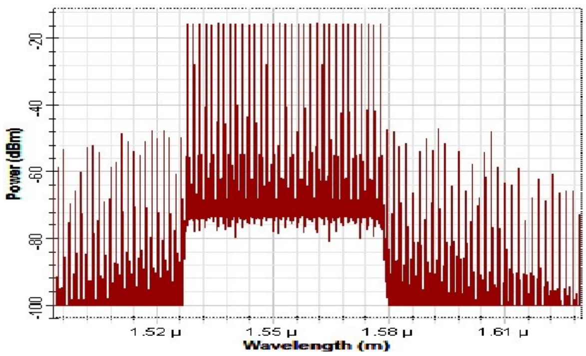


Figure 14: Output Spectrum of SMF of 75 Km Length (Effective Core Area 64µm^2)

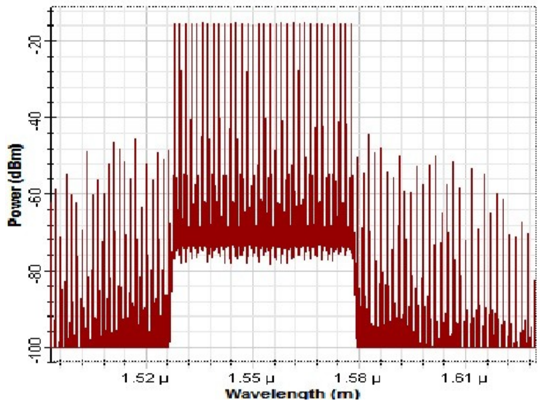


Figure 15: Output Spectrum of SMF of 75 Km Length (Effective Core Area 64µm^2)

From the above analysis we find some of the optimize parameters on which our system gives the optimum performance. So we put that parameter values such as RZ modulation format, 200GHz channel spacing, 70µm^2 effective core area, 3dBm input power, 0Hz line width of the laser and simulate the system then we get the better eye diagram and Q value from the system which is approximately equal to 38.607 the eye diagram is shown in figure 16.

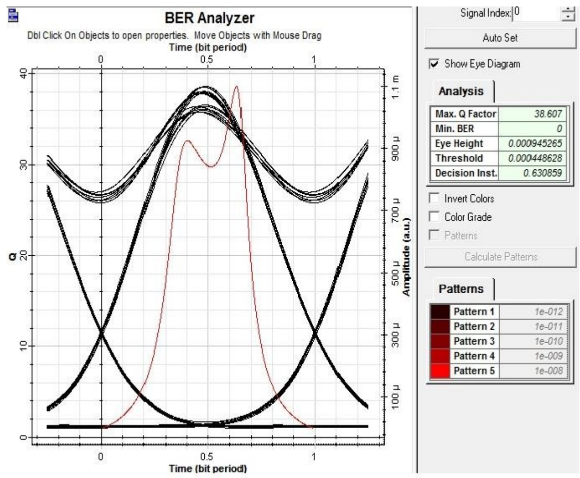


Figure 16: Eye Diagram of the Signal at the distance of 150 Km

V. Conclusion

Above analysis conclude that 32 channel DWDM system gives the optimum performance if the input power is set on 3dBm, modulation format is RZ, channel spacing between the various channels will not less than 200GHz, Effective core area of SMF is 70µm^2, laser line width is 0Hz. After using these parameters we simulate the system then our systems performs then the previous one we increase the reach of the DWDM system by 30kms more than the previous one and the power requirement is also lesser then that of the previous model and now our Q value of the system is 38.607 which is greater than the previous value which is 36.24.

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