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IMPROVED OPTICAL PACKET SWITCHING USING SPACE SWITCH ARRAYS

Disha Khanna[1], Anuradha Kuckian[1], Ipsita Mishra[1], Dr. Lochan Jolly[1]

[1]Department of Electronics and Telecommunication, Thakur College of Engineering and Technology, Kandivali(East), Mumbai, India

Abstract. Simulations of a 4 x 4 optical packet space switch array based on optically amplified suppressed interference switches (OASIS) were carried out. The OptSim simulator was used to model the structure, to assess the behavior and performance of this switch array. Parameters such as Q factor and bit error rate (BER), jitter were calculated. Implications of cascadability of this switch array are investigated which improves the quality and capacity of the existing networks. Transparent space switch array is an enabling technology for implementing OPS.[1] ·Switch configuration for both 10Gbps and 40Gbps systems has been proposed.

Keywords: Optical Switch, BER, Filter, SOA.

1 Introduction

Computer and telecommunication networks, especially the internet, are changing the world dramatically and will continue to do so in the foreseeable future. New services are being added to the pure data delivery framework of yesterday. Such high demands on capacity could lead to a "bandwidth crunch" at the core wide-area network, resulting in degradation of service quality.[2]

To overcome this eventuality, intensive research is being carried out in the field of all-optical networks**.** A field that has emerged in this research is optical packet switching, which is a special application within the field of photonics and combines the high capacity of optical technology with the flexibility of well-established packet switching. It is regarded as a very promising candidate for all-optical networks in order to withstand the battle against increasing bandwidth demand and complexity of future networks

Optics, as used in communications, is therefore a fast-paced technology sector, in particular supported by advances in nanophotonics. Up to now, the switching burden in such systems has been laid almost entirely on electronics. In every switching node, optical signals are converted to electrical form (O/E conversion), buffered electronically and subsequently forwarded to their next hop after being converted to optical form again (E/O conversion). As data traffic starts to dominate the communication networks, the traffic even on the long-haul network becomes more data oriented (i.e., less predictable). In the long term, optical packet switching (OPS) could become a viable candidate because of its high-speed, fine-granularity switching, flexibility and its ability to use the resources economically.

As the network capacity increases, electronic switching nodes seem unable to keep up. Apart from that, electronic equipment is strongly dependent on the data rate and protocol and thus, any system upgrade results in the addition and/or replacement of electronic switching equipment. The main attraction of optical switching is that it enables routing of optical data signals without the need for conversion to electrical signals and, therefore, is independent of data rate and data protocol. The transfer of the switching function from electronics to optics will result in a reduction in the network equipment, an increase in switching speed and thus, network throughput. In addition, the elimination of E/O and O/E conversions will result in a major decrease in the overall system cost, since the equipment associated with these conversions represents the lion's share of cost in today's networks [3].

The success of present and future optical transport networks hinges on the efficient optical signal switching and routing. Without reliable and efficient optical switching optical transport networks (OTNs) simply cannot function. Hence we are proposing a 4X4 switch configuration which will give BER of around 10^-40, if implemented.

2 Theory

Data to be transmitted is generated using p-n sequence generator is given to CW laser operating at1550nm.Then the signal is given to SOA which acts as a switch according to the junction current. The select or combiner is used for selecting the path and the data reaches at the output port. OptSim is an advanced optical communication system simulation package designed for professional engineering and cutting-edge research of emerging optical systems.

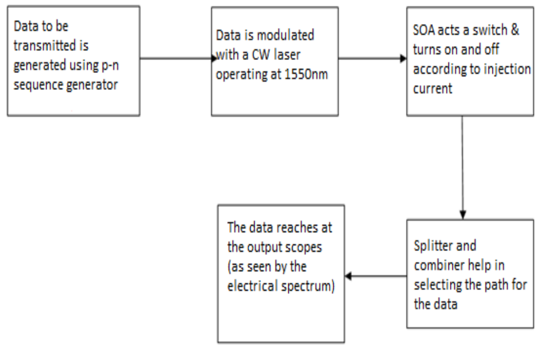


Fig.1. Data flow in a Space Switch Array

The simulation diagram for 4X4 space switch array is shown in Fig.2. The performance of 4X4 space switch array was analyzed using an input data rate of 10Gbps and the Eye Diagrams were observed at four output nodes. Eye Diagrams thus obtained were studied and the corresponding output parameters were noted.

After having successfully achieved optimum BER and quality it can be used to design optical communication systems. Simulation can be done to determine their performance given various component parameters to guarantee the highest possible accuracy and real-world results.

OptSim represents an optical communication system as an interconnected set of blocks, with each block representing a component or subsystem in the communication system. As physical signals are passed between components in a real world communication system, "signal" data is passed between component models in the OptSim simulation. Each block is simulated independently using the parameters specified by the user for that block and the signal information passed into it from other blocks. This is known as a block-oriented simulation methodology. These blocks are graphically represented as icons in OptSim. Internally, they are represented as data structures and sophisticated numerical algorithms.[4]

In the OptSim simulation, SOAs are used to implement the gates within the switch unit. SOA offers nanosecond switch times and produces gain changes according to the level of current applied to it. SOAs are used as switching elements, offering data-rate and packet-format transparency.[5] Semiconductor optical amplifiers (SOAs) are widely studied as nonlinear elements for high bit rate all-optical switching applications, such as wavelength conversion and regeneration.[6-8] The SOA device simulation results that are produced by OptSim include signal waveform plots and Eye Diagrams at any point within the optical communication system and bit error rate (BER) plots vs. various parameters within the system such as the received optical power.[9]

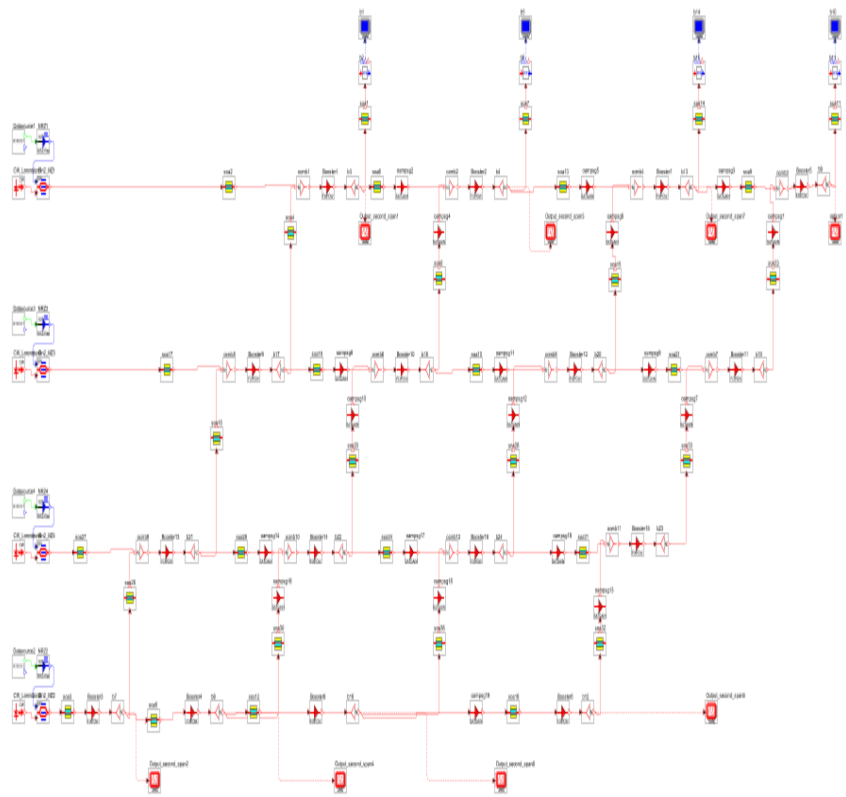


Fig.2. Simulation of 4X4 space switch array

3 Result & Discussion

The simulation uses Non Return to Zero (NRZ) PRBS signals at the data rate of 10Gb/s. The data stream modulates a laser with CW power of 0.1mW at a central frequency of 1550nm.

Boosters were used in the simulation of 4x4 space switch arrays and the Eye Diagrams of the output signal at all the four scopes were analyzed for the data rate of 10Gbps. Fig 3 shows the Eye Diagram for the best case output signal. The minimum and maximum values of BER for 4x4 space switch array are 4.57584e-006 and 0.00339607 which are within the acceptable range for enabling correct reception of data and hence 4x4 space switch array can be used for transmitting data rate of 10Gbps.

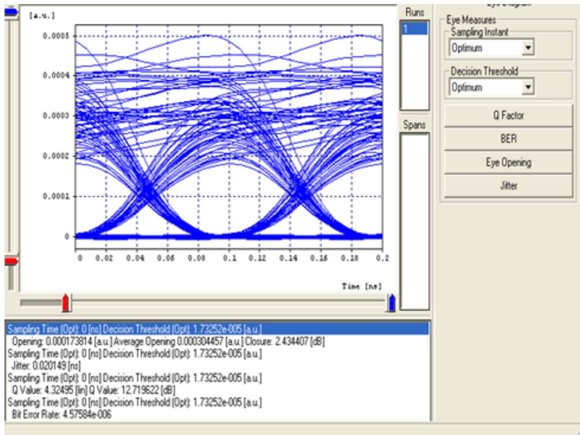


Fig.3.Output signal Eye Diagram for 4x4 space switch array.

From our study and from the simulations obtained we observe that as the number of cross connects are increased, there is a progressive increase in errors in the received data as can be seen in the Eye Diagrams. Therefore, it can be inferred that interference and cross-talk becomes dominant with cascading of the switching elements and hence using only SOAs for switching has its limitations.

Fig.4 and Fig.5 show the optical spectrum of received signal in the 4x4 space switch array at data rates of 10Gbps and 40Gbps respectively.

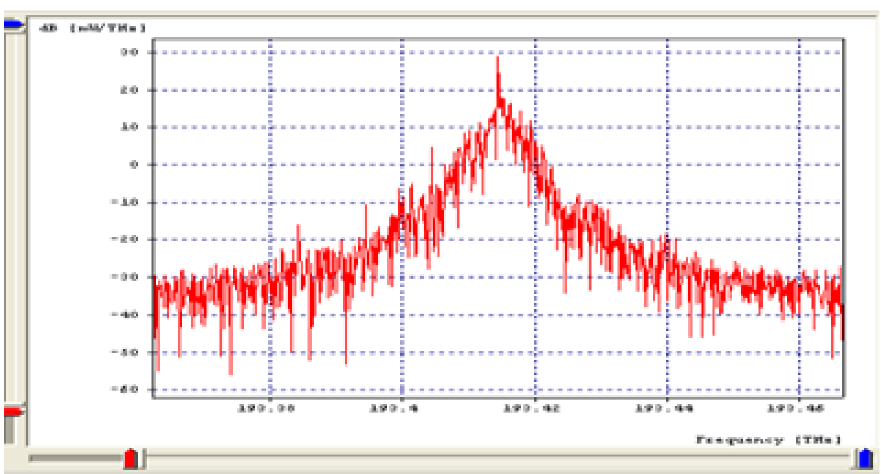


Fig.4. Optical spectrum for 4x4 space switch array at data rate of 10Gbps.

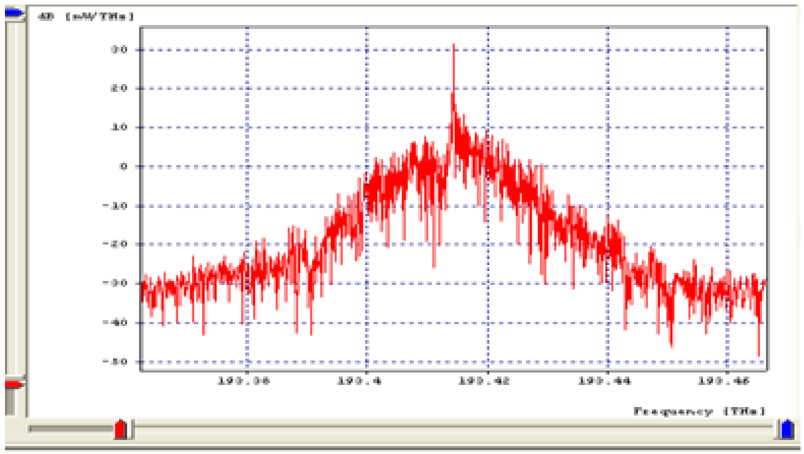
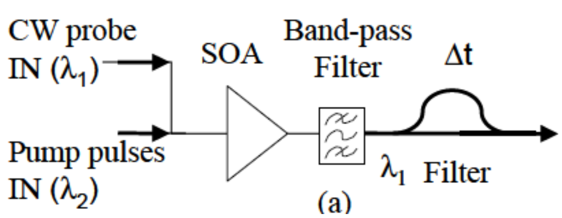


Fig.5. Optical spectrum for 4x4 space switch array at data rate of 40Gbps.

The Optical spectrum shows that the results degrade for 40 Gbps data rate and hence an improvement in the system is required for data rates greater than 10 Gbps.

5 Improved Design for 40 Gbps System

When data trains are used to switch these devices, the slow SOA lifetime leads to patterning in the gain and phase response of the SOA [7]and hence in the output from the interferometric switch. In order to prevent such patterning, a faster response speed is generally required. Recently, various linear spectral filtering schemes. [6-8] have been reported which greatly increase the observed response speed.



(a) Use of a pass-band filter and DISC filter to pass parts of the modulated CW probe spectrum

Fig. 6[16]

The above mentioned idea was used to design the switch

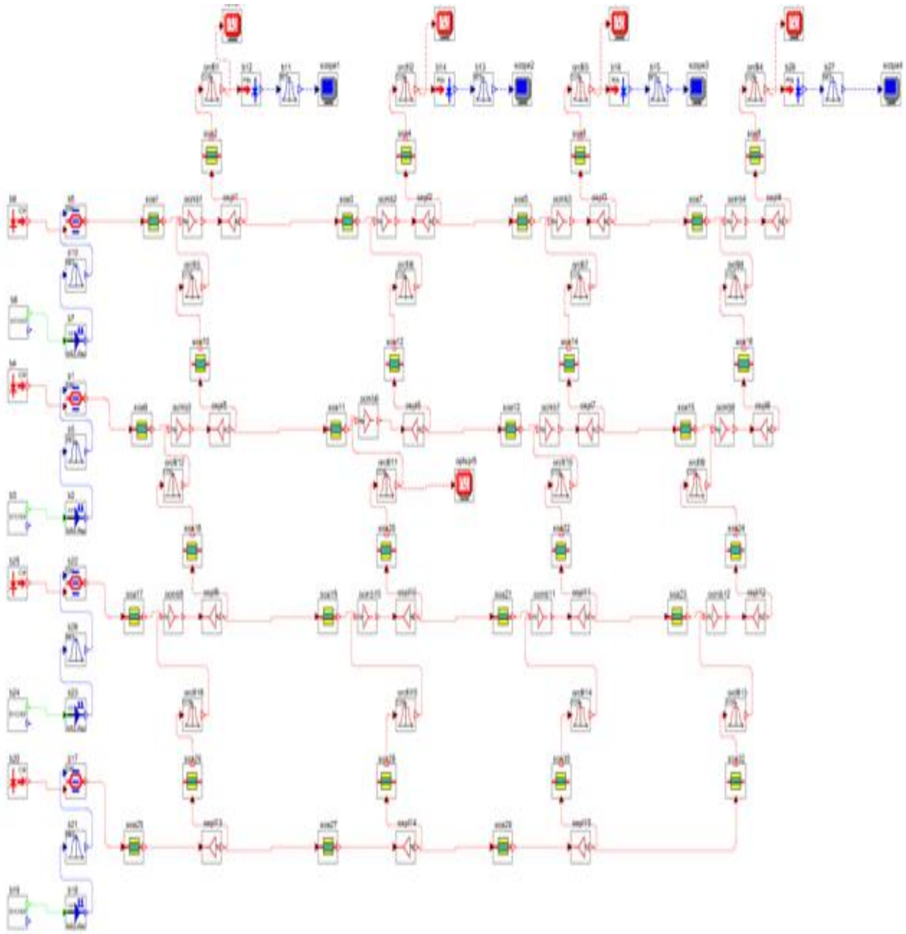


Fig.7. Improved Switch Configuration

configuration given in Fig. 7. The basic operation of a switch is to route data packets arriving at its input on various wavelengths, to a particular output node. To achieve this objective, narrowband raised cosine filters have been used. These filters are tuned to different center wavelengths and the bandwidth of each filter is chosen such that input from only one laser arrives at a node. The wavelengths at which data was transmitted from the CW Lorentzian laser are 1550nm, 1551nm, 1552 nm and 1553 nm. Due to this, the filter that precedes a node actually decides the wavelength that is to be selected for that particular node. The bandwidth of each filter in 0.9 nm and the center wavelengths of the four filters correspond to one of the transmitted wavelengths so that all the data is received albeit at different pre-determined nodes. The data packets, thus, reach the desired node following the predefined routing path defined primarily by the bandpass filters.

The use of filters instead of the conventional splitter and combiner arrangement for switching helps in the reduction of dispersion losses. This can be validated by the sharp peaks obtained at the respective wavelengths, in the output optical scopes (Fig.9, Fig.10 and Fig.11). This in turn allows a very significant improvement in the Eye Diagram obtained after conversion into electric signal.

Apart from filters to perform routing, another configuration has been implemented, which uses a bandpass filter (BPF) and SOA arrangement, to further improve the quality of signal received at the output. In this configuration, a BPF is used after an SOA to reduce chirp effect and reduce the switching time of SOA (or ON-OFF time) to the order of picoseconds.[16]

5 Results For Improved Design

On simulation using OptSim, the following eye diagram was obtained for the best case output signal and an output BER of around 10^-40 was achieved. This is a major improvement over the previous design. The wavelengths at which the data was transmitted gave sharp peaks in the optical output scopes indicating that only the data on the desired wavelength was obtained at a particular output while the rest were rejected by the filters thereby performing the action of a switch.

The Eye Diagram is shown below.

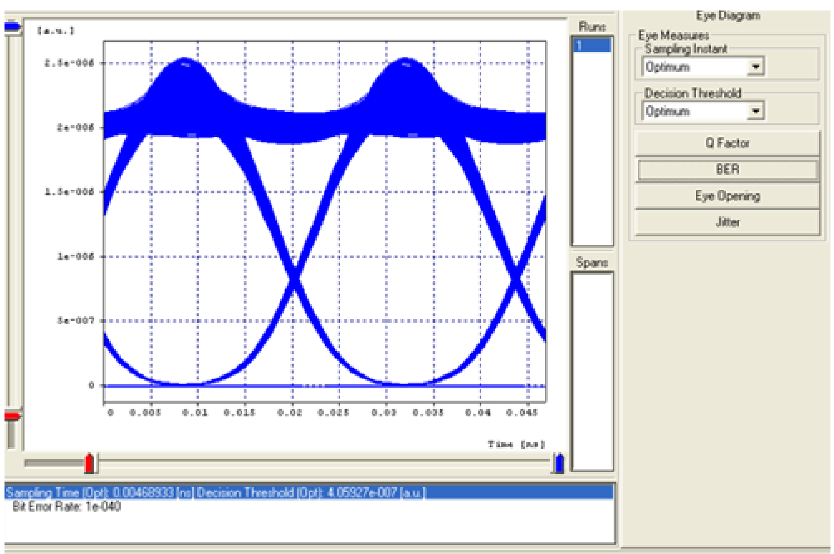


Fig.8. Eye Diagram and BER at output

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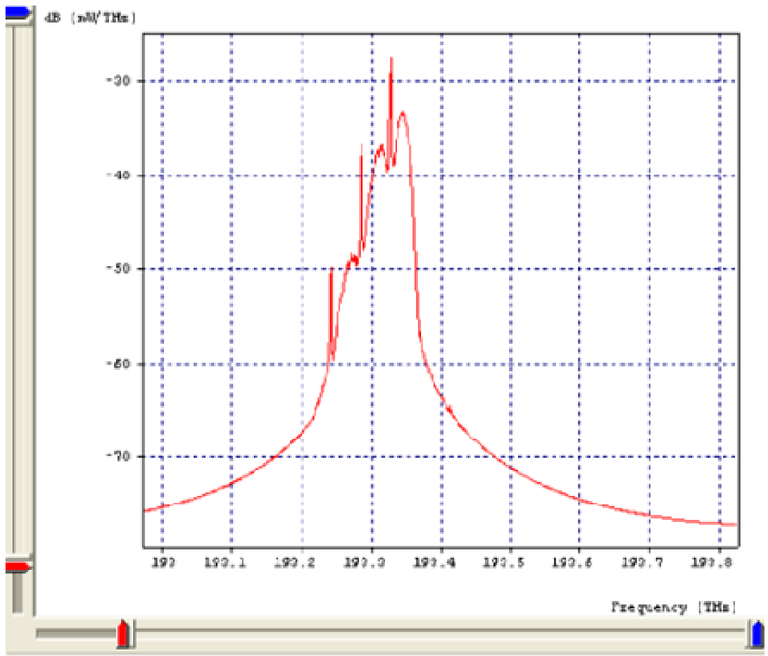

Fig.9. Optical signal at Output 1 (data received at 1550nm)

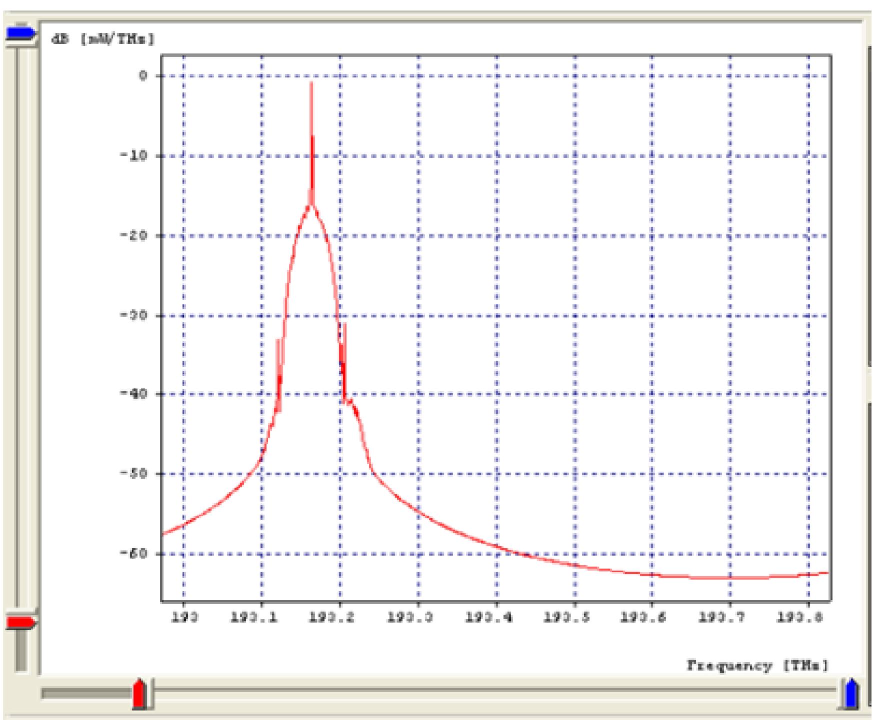

Fig.10. Optical signal at Output 3 (data received at 1552nm)

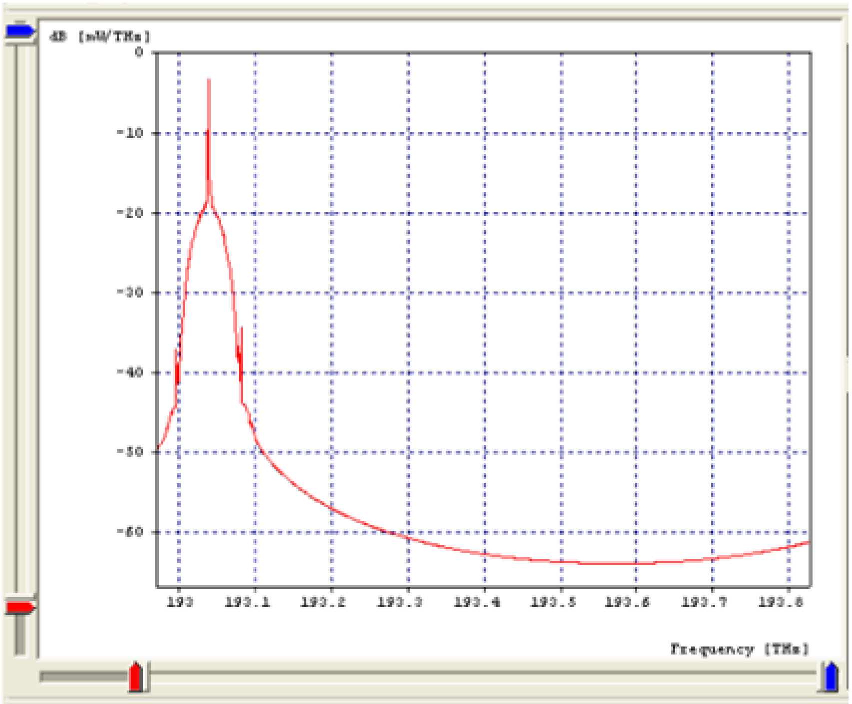

Fig.11. Optical signal at Output 4 (data received at 1553nm)

6 Conclusion

While the 4X4 switch array performs satisfactorily for a small number of nodes, better performance will be expected from switches if they are to be employed in the actual scenario. Hence modification of the current switching elements has been done to achieve a 5-fold improvement in BER in the 40Gbps system using SOA-BPF arrangement. Also switching at four different wavelengths was done using a pre-defined routing path.

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