Optical Packet Switching using Space Switch Arrays

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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]

Keywords:
Optical Switch,Q-Factor,BER

1. INTRODUCTION
Computer and telecommunication networks, especially the internet, are changing the world dramatically and will continue to do so in the foreseeable future. The Internet had phenomenal success in the past 20 years, growing from a small research network to a global network that we use since it provides very flexible bandwidth-intensive networking applications, such as data browsing on the World Wide Web (WWW), java applications, video conferencing, interactive distance learning, on-line games, etc. However, being primarily based on packet services, it is a variable-delay, variable-bandwidth network that provides no guarantee on quality of service *(QoS)*. 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. If optical signals could be switched without conversion to electrical form, both of these drawbacks would be eliminated. 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 the switching speed, and thus network throughput, and a decrease in the operating power. 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. With respect to switching and routing, OTNs are grouped into two major categories:

1. *Opaque/Translucent Networks* - The routing and switching is performed electronically, thereby requiring signal regeneration, which in turn involves multiplexing/de-multiplexing and amplification before the signal is launched to the next node.
2. *Transparent Network*- it does not need signal regeneration, and all optical switching, routing, and amplification is implemented and transport is achieved between the nodes as if the nodes were transparent.

All-optical space switch arrays (OOO cross-connects) are the most important elements of a transparent network. They switch data without any conversions to electrical form. The core of an OOO cross-connect is an optical switch that is independent of data rate and data protocol, making the cross-connect ready for future data-rate upgrades. Other advantages of OOO cross-connects include reductions in cost, size, and complexity.

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 in telecom, datacom, and the simulation schematic of the 4 x 4 space switch. Routing is realised by applying currents to turn on the relevant gates along the route. In the absence of a current, the signal is suppressed to a very low level (about –50dB), which effectively reduces crosstalk.

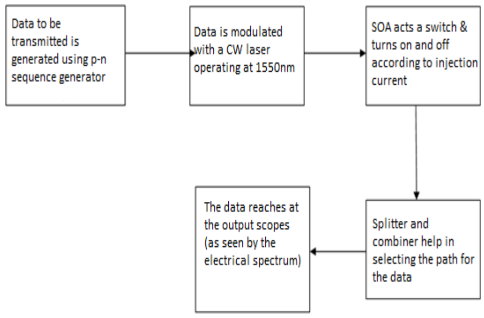


Fig1:-Data flow in a Space Switch Array

The simulation diagram for 4X4 space switch array is shown in Fig. 2. The performance of 4X4 space switch array was analysed 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]

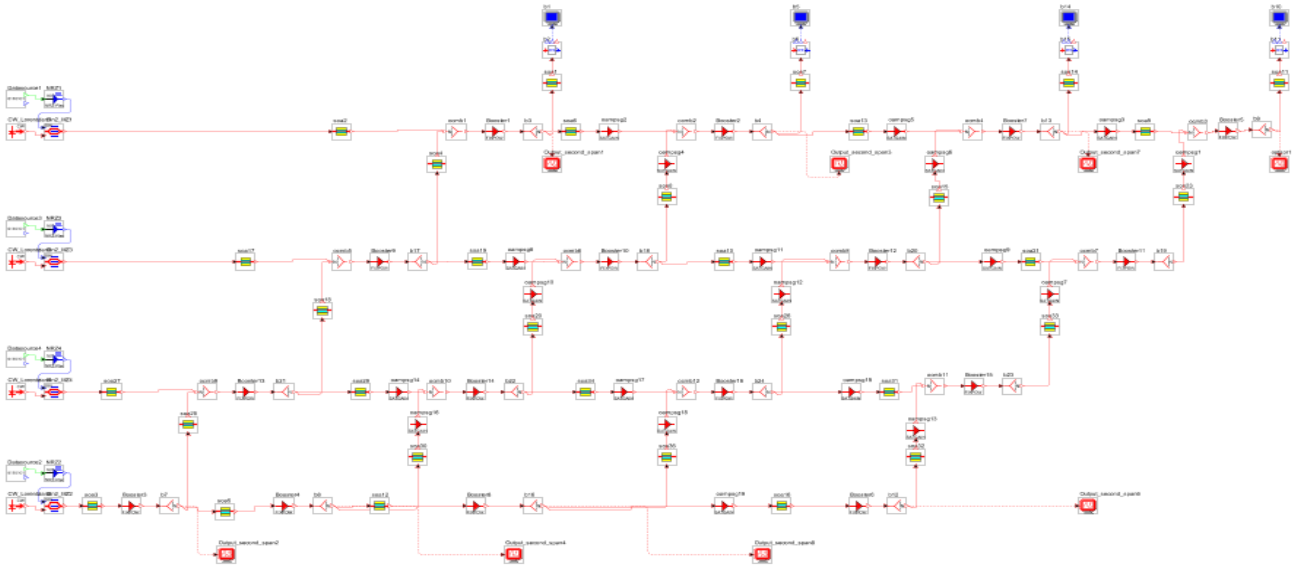
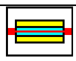
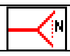
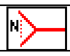
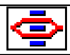
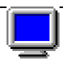


Fig.2- Simulation of 4X4 switch array space

3. STUDY OF COMPONENTS AND DIAGRAMS USED

The first step taken towards implementation was to familiarize with the components that were to be used for the simulations. Various components viz. Semiconductor Optical Amplifiers (SOAs), Optical Splitters and Combiners, CW lasers, Modulators and Data Sources were studied and their functionalities relevant to the project that is undertaken, were clearly understood. A brief explanation of the various components, their representation in OptSim and their functions is given below in table1.

Table1:- Components used in simulation

<table>
<tr><th>Components</th><th>Representation</th></tr>
<tr><td>Semiconductor Optical Amplifier (SOA)</td><td></td></tr>
<tr><td colspan="2">Function
• The input signal stimulates the transition of electrons down to valence band & emission of photon with same energy & same wavelength as the input signal. Amplified optical signal is thus obtained
• Significant optical phase shift in an SOA during gain recovery to rapidly alter the intensity at the output port of an interferometer thus enabling switching</td></tr>
<tr><td>Optical Splitter</td><td></td></tr>
<tr><td colspan="2">Function
• Splits the light beam depending on their wavelengths due to change in refractive index of the material because of electric field.</td></tr>
<tr><td>Optical Combiner</td><td></td></tr>
<tr><td colspan="2">Function
• A passive device in which power from several output fibers is distributed among a smaller number (one or more) of input fibers.</td></tr>
<tr><td>MZ Modulator</td><td></td></tr>
<tr><td colspan="2">Function
• Optical device in which a signal-controlled element displaying electro-optic effect is used to modulate a beam of light.
• Modulation may be imposed on the phase, frequency, amplitude, or polarization of the modulated beam.
• Modulation bandwidths extending into the gigahertz range are possible with the use of laser-controlled</td></tr>
<tr><td>Electrical Scope</td><td></td></tr>
<tr><td colspan="2">Function
• Simulates an oscilloscope for electrical signals. Collects data for diagrams such as amplitude, Eye Diagram, histogram at the optimum sampling instant and power spectrum</td></tr>
</table>

4.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, Fig 4, Fig 5 and Fig 6 show the Eye Diagrams for the output signal at scope1, scope2, scope3 and scope4 respectively.Table 2 shows the parameter values of the corresponding Eye Diagrams of scope1, scope2, scope3 and scope4 respectively.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 and hence 4x4 space switch array can be used for transmitting data rate of 10Gbps.

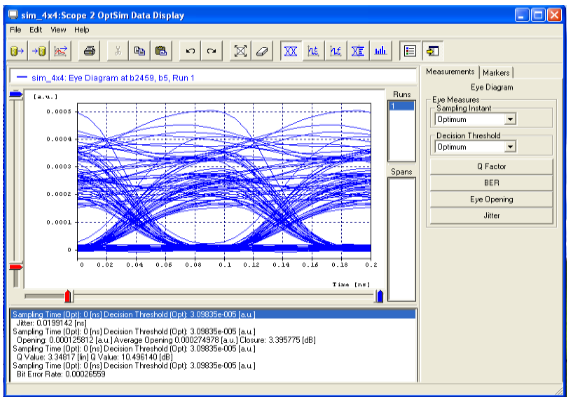


Fig 3: Scope1 output signal Eye Diagram for 4x4 space switch array

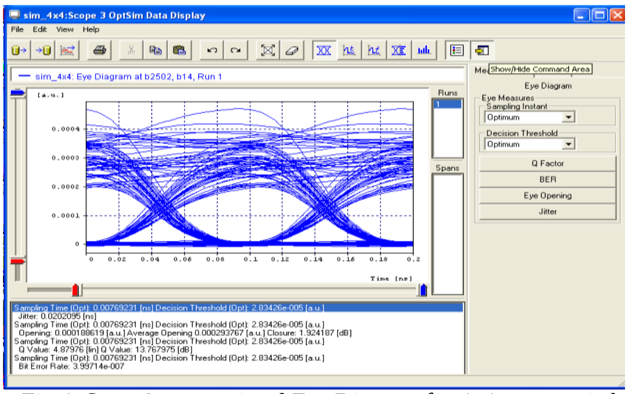


Fig 4: Scope2 output signal Eye Diagram for 4x4 space switch array

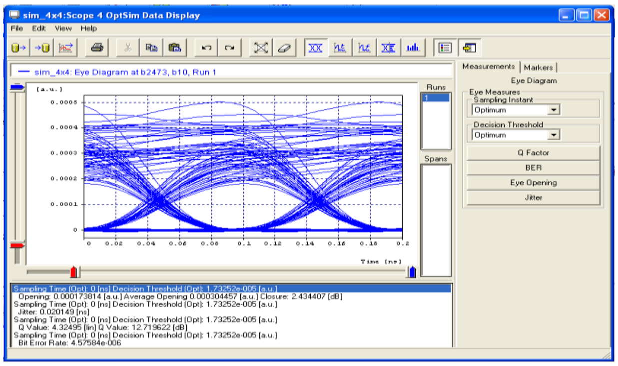


Fig5: Scope3 output signal Eye Diagram for 4x4 space switch array

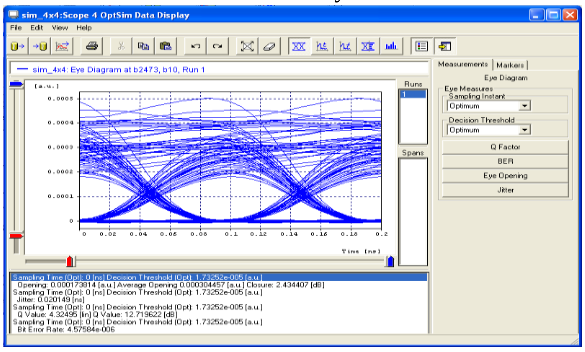


Fig 6: Scope4 output signal Eye Diagram for 4x4 space switch array.

Table 2: Parameter values from the Eye Diagram of scope1,2,3,4 of4x4 space switch array

Scopes of 4x4space switch	Scope1	Scope2	Scope3	Scope4
PARAMETERS				
Opening (dB)	**0.01243**	**0.00013**	**0.00019**	**0.00017**
Closure(dB)	**4.45275**	**3.3958**	**1.92419**	**2.43441**
BER (dB)	**0.00339**	**0.00027**	**3.9971 4e-007**	**4.5758 4e-006**
Q-factor (dB)	**2.76198**	**3.34817**	**4.87976**	**4.32495**
Jitter (ns)	**0.02032**	**0.01991**	**0.02021**	**0.02015**

From our study and from the simulations obtained we observe that as the number of cross connects are increased, there in 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 7 and Fig 8 show the optical spectrum of 4x4 space switch array at data rates of 10Gbps and 40Gbps respectively.

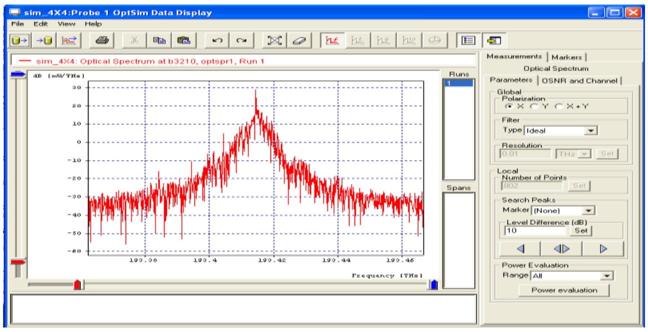


Fig 7: Optical spectrum for 4x4 space switch array at data rate of 10Gbps

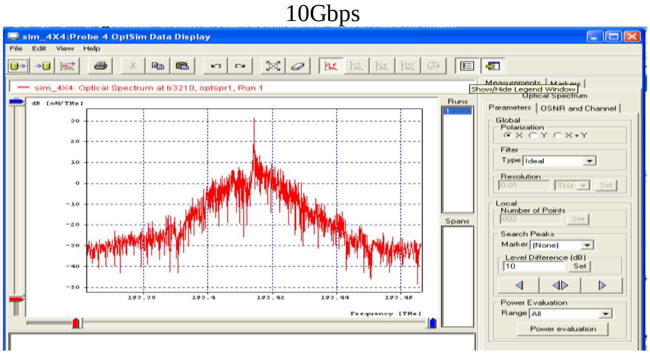


Fig 8: Optical spectrum for 4x4 space switch array at data rate of 40Gbps

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. Scope for Improvement:

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. Another scheme giving a faster response incorporates a second SOA in the so-called Turbo-Switch arrangement, in which the second SOA may be loosely regarded as a filter [10, 11]. Whilst these approaches help to increase the operating speed of the optical switching, they do not reduce the actual recovery time of the gain of the SOA. To achieve this, other techniques such as a holding beam [12] and optimisation of the SOA structure [13-16] may be used.

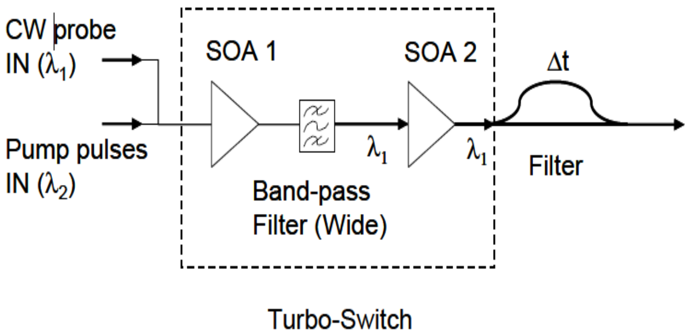


Fig 9: A Turbo-Switch scheme. A DISC filter is placed after the turbo switch for wavelength conversion

The Turbo-Switch arrangement is shown in Fig. 9 . The CW probe has gain and phase modulation imposed upon it by the response of SOA1 (see Fig. 9). The wide band-pass filter (~5 nm) used here blocks the pump, but is sufficiently wide to pass the entire modulated spectrum of the CW probe.[17]

5. CONLCUSION

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 needs to be done. One such arrangement, known as 'Turbo-Switch' which uses two SOAs and a filter as the basic switching element can be implemented in future. The recovery time of a Turbo-Switch is less as compared to SOA and hence higher switching speeds can also be achieved.

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