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OPTICAL PACKET SWITCHING BASED ON TURBO SWITCHES USING SPACE SWITCH ARRAY

Suhail Ashraf
M.Tech CSE, CCNA
suhibhat@gmail.com
(Assistant Professor Department of CSE, SSM College of Engineering & Technology, Pattan J&K)

***Abstract:** Optical packet switching based on turbo switches using space switch array is Simulation of a 4 x 4 optical packet space switch array based on Turbo-Switches were carried out on 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. Transparent space switch array is an enabling technology for implementing OPS.*

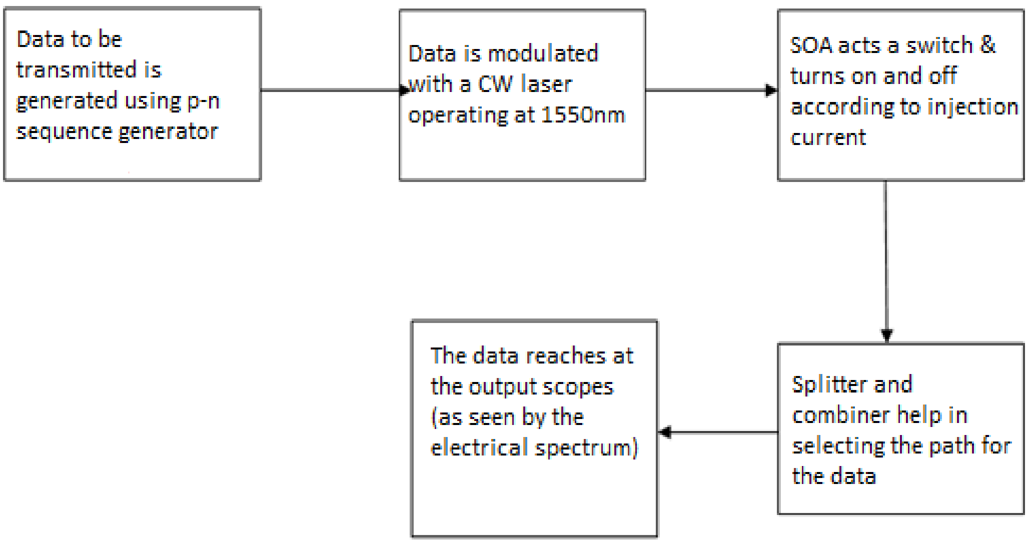
Introduction

Optical Packet Switching based on turbo switches using space switch array is one of the most emerging fields for researchers and industry communities. 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. 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. 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.

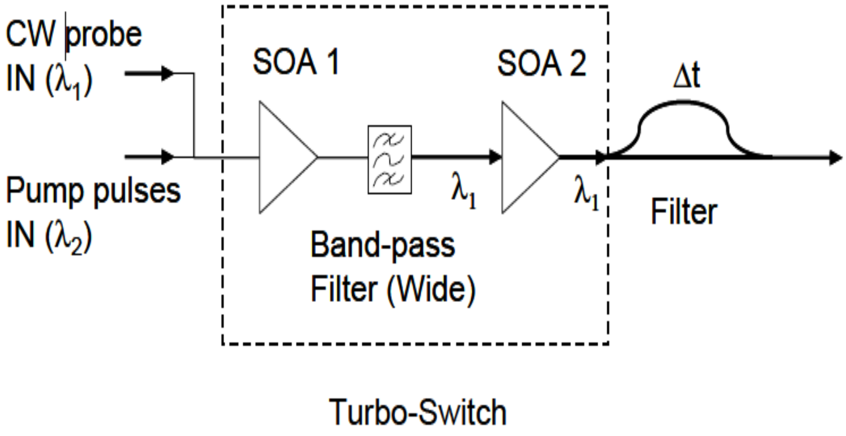
With respect to switching and routing, OTNs are grouped into two major categories:

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. 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, data comm, and the simulation schematic of the 4 x 4 space switch. Routing is realized 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.



Data flow in Space Switch Array



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

The simulation diagram for 4X4 space switch array is shown in Fig. 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.

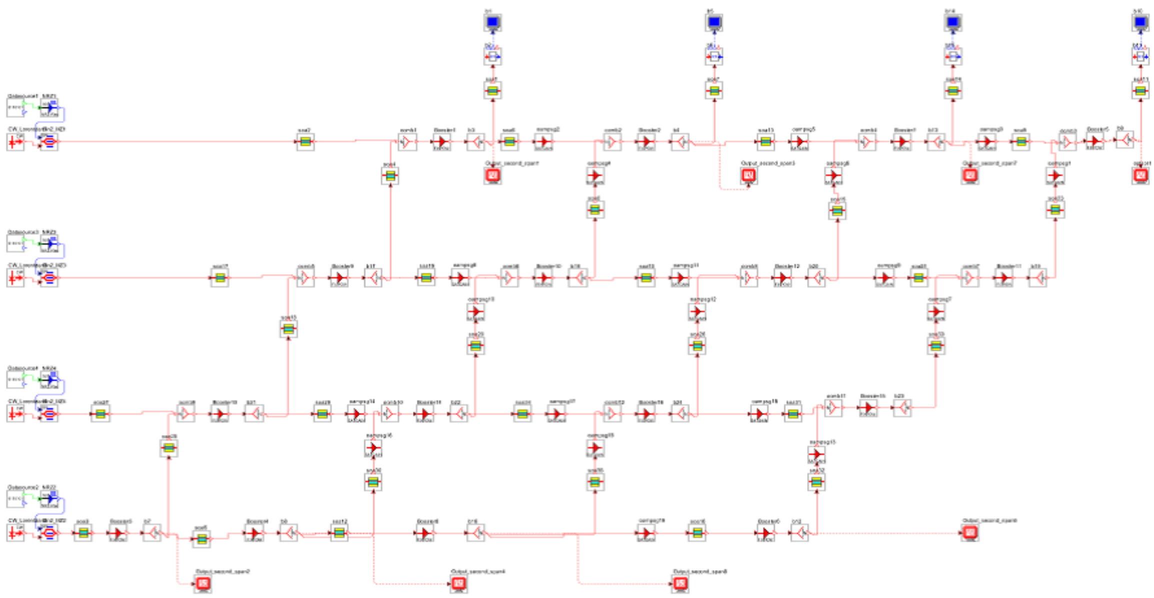
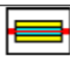


Fig.- Simulation of 4X4 switch array space

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.

<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>
</table>

Design of a free space optical switch demonstrator for a VCSEL-based photonic packet switch

Free space chip-to-chip optical interconnections might be considered as a means of increasing the scalability of large electronic IP switches. In one category of hardware implementation some channel selection takes place in the optical interconnect, which employs optical fan-out, selection of channels followed by optical fan in. We have discussed a version of the architecture in which liquid crystal over silicon devices were used as input transducers to modulate the optical channels and to reconfigure the interconnect. The slow speed of the modulators (100 kHz) meant that massive parallelism was necessary in the optics (107 channels) to achieve a capacity of a Tb/s. The fan-in optics for such systems appear to be formidable. One possible solution is to use a much smaller number of higher data rate optical channels using VCSELs. This assumes that the problems of integrating the VCSEL array and suitable photo detectors with high-density silicon CMOS circuitry can be solved, but it reduces the optics to manageable proportions. It is

our estimate that switch modules with capacity approaching 1 Tb/s could be constructed with 16 x 16 array of polarisation-stable VCSELs operating at around 2 Gbits/s with a fan-out of 16. Switches comprised of such modules might be scalable into the Pb/s region. In the implementation considered here, the links will be reconfigured using a miniature free space optical interconnect based on liquid crystal (LC) shutters. An earlier system of this kind (for fibre to fibre switching) reconfigured 64 channels in 17µs. Here we aim to reconfigure 16 channels in 1µs to minimise queuing on the input plane of the switch.

System design and device experiments

In a previous experimental setup, we performed an optical link measurement between a single VCSEL out of a 5x5 VCSEL array and a single photodetector from an 8 x 8 array. At 1.0 mW output power, the maximum frequency at which we could achieve 10-9 BER was 600 MHz. In order to improve on this performance, we have commissioned a re-design of the pcb mounting for the VCSEL array. Four 2 x 2 arrays will be wire bonded to a Kyocera chip carrier which will be, in turn, soldered to a multilayer pcb. High frequency performance will be gained by impedance matching the microstrip lines right up to the chip carrier, and by keeping wire bonds short. We anticipate multi-GigaHertz performance. The VCSEL arrays are single-mode at 855nm (CSEM, Switzerland) with a FWHM divergence angle measured of 14.5°, and the 8x8- siliconphotodetector array (Hamamatsu Photonics, Japan) has a 3-dB cut-off frequency at 1 GHz and a sensitivity of –14 dBm. The same microstrip design concept has been used for the Hamamatsu chip. A 40-dB gain amplifier complements the detector.

The layout of the switch is shown in Fig 1. Four 2 x 2 sub-arrays of VCSELs are fanned out in a classic 4f arrangement with the grating in the mid-plane. Each 2 x 2 sub-array has a dedicated 4f arrangement. At the image plane of each 4f system, 4 2 x 2 sub-arrays are formed. Because these are within the aperture of a micro-optical system, aberrations are reduced compared to larger offaxis multiple imaging arrangements. The fast shutter plane, which is placed in the image plane of the 4f systems, blocks all but one of the 2 x 2 sub-arrays in each aperture. The fan in, which is accomplished by a lenslet array with a single compound lens, reconstitutes a 4 x 4 array using the 4 2 x 2 sub-arrays which have been selected by the shutter array.

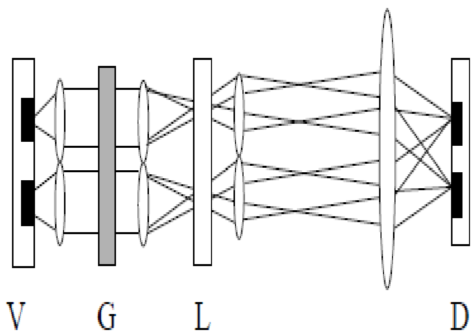


Fig 1 The optical system of the demonstrator (V-plane of VCSEL arrays; G-Diffractive grating;

L-Liquid crystal shutter array; D-plane of detector arrays)

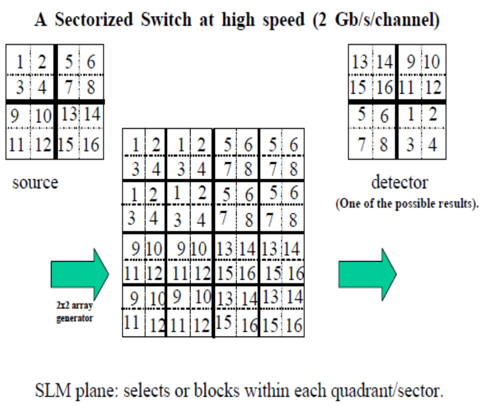


Fig. 2. The channel paths through the system of Fig. 1

The optical system complements the electronic switches which can be associated with each sub array on the input and the output. Therefore, the optics is providing a global connectivity which is reconfigurable and scalable. We call this global connectivity sectorised switching, and the concept is illustrated in Fig. 2. The optical switching in the shutter plane selects the sectors. For example, a 4 x

4 shutter array of which the 4 central pixels are transmissive will create the arrangement of sectors in the detector plane shown in Fig. 2. Here, we just show one of the possible combinations of the output. There are 4! possible arrangements for the sectors in the detector plane. The fan-out/fan-in losses associated with this system scale as the fan-out rather than the number of input channels. One purpose of the demonstrator will be to help assess the limits of sectorised switching. We believe that this design concept is scalable up to a Tb/s switch module. Higher switch capacities will require the optical interconnection of such modules. V G L D In order to specify the shutter array, we have constructed liquid crystal test cells with several types of liquid crystal. In our previous measurements [5], we used an experimental electroclinic mixture FELIX-R1305(Clariant, Japan) which is no longer available. Thus, we have used another experimental electroclinic mixture FELIX-R1306 (Clariant, Japan) which can be supplied subsequently. This mixture has a SmA phase between 31.9 □C and 65.8 □C. We measured a field induced tilt angle of 11□□with 1 □s electro-optic response time at 45 □C using an electric field of 20V/□m across a 1.0 □m cell. The Contrast Ratio (CR) (TON /TOFF) of the shutter is highly dependent on the OFF-state transmission (TOFF) of the LC between a polariser/analyser pair. The quality of alignment of the LC is important for achieving low TOFF. The CR and the loss specifications will be achieved, by operating the link with nearly crossed analyser. If the angle of the analyser from the crossed position is 3 deg and we use a field of 20V/□m across the LC cell, then the ON-state loss will be 7.5 dB and the CR will be 66. We measured the CR as 58, which is close to the calculated value. Although electroclinic liquid crystals are a good choice for fast switches due to the low viscosity of director rotation, special measures have to be taken in order to ensure that current flow into the cell does not induce chemical degradation of the liquid crystal when a DC voltage is applied across the cell over a considerable time. We plan to reduce DC currents by introducing a passivation layer of silica over the ITO electrodes.

Conclusion

The main objective is to improve the performance of the current system by implementing some modification of the current switching elements. One such arrangement, known as Turbo-Switch which uses two SOAs and a filter as the basic switching element can be implemented. The recovery time of a Turbo-Switch is less as compared to SOA and hence higher switching speeds can also be achieved.

Results

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 and hence in the output from the inter ferometric 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. 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.

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