

# Dynamic Power Considerations in a Complete 12×12 Optical Packet Switching Network

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**Abstract** The optical power characteristics of a complete 12×12 Data Vortex optical packet switching network are measured and analyzed. Dynamic range and cascaded noise effects are quantified as indicators of network scalability and robustness.

## Introduction

The realization of a complete 12-port optical packet switching (OPS) interconnection network containing 36 switching elements based on the Data Vortex architecture was recently reported [1]. Within the system, optically transparent switching nodes route photonic packets on-the-fly as they traverse the network topology. This design allows for data packets to remain in the optical domain throughout their entire lifetime within the switching network, with both conservation of optical power and minimal optical signal distortion.

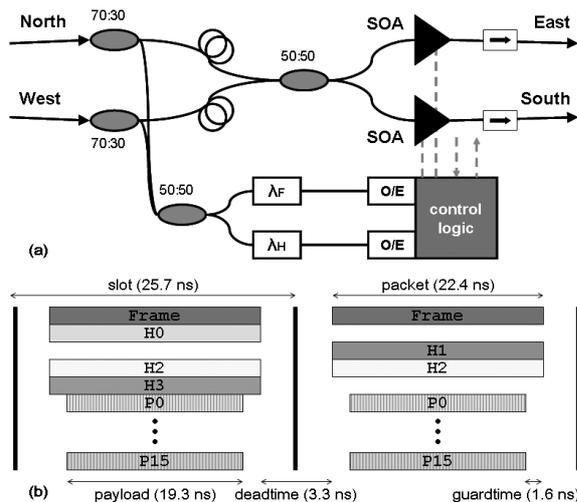


Fig 1 (a) Schematic of implemented transparent optical packet switching node (b) Diagram of multiple-wavelength optical packet format

The packet format used for the Data Vortex switching network allows for multiple-wavelength encoding of payload information while reserving particular wavelengths for routing address headers (Fig 1b). These headers are encoded as being constantly '1' or constantly '0' throughout the entire duration of an individual packet. This allows for simple and straightforward decoding by the 2×2 switching nodes; only a detector and an optical filter are required to decode these bits. Simple discrete logic gates, integrated on a PCB, utilize two of the header bit values to determine the packet's routing destination. Then, one of two SOAs is turned on, allowing the packet to pass from one of the two output ports (Fig

1a). The gain of the SOA is set to compensate for coupler and connector losses incurred by the packet, and the packet is ejected from the switching node with power nearly identical to its input levels [2],[3].

The balance of optical power within the multiple-wavelength optical packet is critical to system functionality. If the optical power of the payload and header signals is too low, the signal-to-noise ratio of the payload signals may fail to meet the error-free detection limit, and routing errors may also result. Because the noise introduced by each switching node is cumulative, characterizing the noise floor increase is also important. In the opposite extreme, power levels which are too high lead to saturation of the SOA switching elements, which can in turn substantially degrade signal quality via nonlinear crosstalk. The dynamic range of average optical signal power levels over which error-free operation can occur is an important indicator of the stability and scalability of the packet switching system.

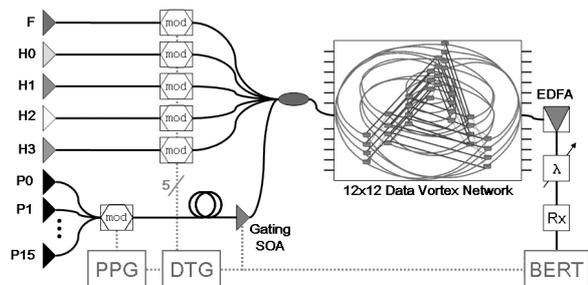


Fig 2 Schematic of experimental setup with the appropriate packet generation and detection subsystems

## Experimental Setup

The specific details of the 12-port optical packet switching network, and of the 36 component switching nodes are discussed in [1]–[3]. In order to generate packets of the correct format, 16 WDM payload channels are modulated with a continuous PRBS at 10 Gbps, and decorrelated with a length of optical fiber by about 450 ps/nm. The continuous data stream is then gated by an SOA to form the packet payload, and coupled with the appropriate routing header and frame wavelengths. The power level of the optical packet can be adjusted by setting the gain of the

gating SOA (Fig 2). Finally, the complete packets (Fig 1b) are injected into one of the system input ports.

In order to characterize the system, a routing path which contains 5 switching nodes is used. For a Data Vortex topology of size  $12 \times 12$ , the mean and median number of node hops is 5 [1], so this choice is appropriate. This 5-node path is also representative of the variety of routing decisions that are available within the network. In order to increase the overall load of the network, “dummy” packets, which are addressed to other output ports, are also injected into the network.

Upon exiting the system from a particular output port, packets are amplified with an EDFA, and the appropriate wavelength is selected with a tunable filter. Bit error rate measurements are then made on each packet payload wavelength by utilizing the gating feature of a standard BERT (Fig 2).

### Experimental Results

A series of experiments to investigate the optical power levels within the 12-port switching network are performed. First, the injected packets’ optical power spectrum was compared to that of the ejected packets, in order to confirm the almost perfect transparency of the implemented OPS architecture (Fig 3). The net gain of each switching node is kept below 1.0 dB, resulting in a 5-hop total gain mismatch range of less than 4.9 dB for all 16 payload wavelengths. Small imperfections in the gain balance are due to the wavelength dependence of the SOAs and couplers within the switching nodes [4],[5].

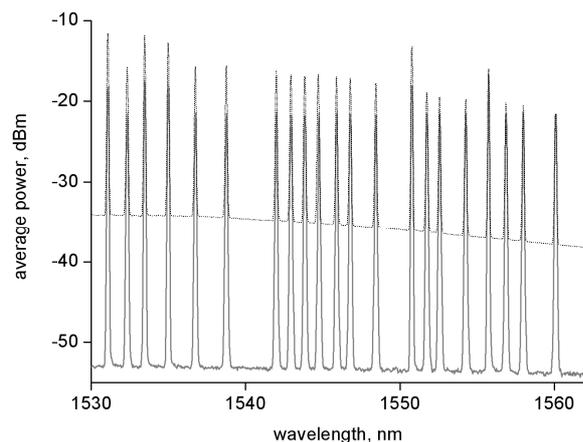


Fig 3 Plot of input packet optical power spectrum – and output packet optical power spectrum -- with header wavelengths annotated

On average, each node incurs a 2.7 dB penalty to the OSNR. The SOA switching elements of each node also introduce approximately -20.5 dBm of ASE noise, distributed across a large span (roughly 1450 nm to 1600 nm), so that the optical noise density over the

middle of the C-band increases by about 3.5 dB / 0.1 nm for each node (Fig 3).

Further, the total receiver power penalty of the 5-hop path on the 16 payload channels at a BER of  $10^{-9}$  is measured to be about  $2.6 \pm 0.5$  dB, depending upon the signal wavelength. This value is quite reasonable, especially considering that 21 separate wavelengths (5 routing headers and 16 payloads) are present in all 5 SOAs, in addition to the accumulating ASE noise.

Lastly, the dynamic power range of the 16 payload wavelengths was measured. By varying the gain of the gating SOA (Fig 2), the signal power of all of the payload wavelengths can be adjusted, without disturbing the header wavelengths. The range of power levels for which all payload wavelengths could maintain a BER of  $10^{-12}$  or better is found to be at least 1.1 dB. Although each individual channel’s flexibility is more than 1.5 dB on average, the aggregate multiple-wavelength packet requires error-free transmission of all wavelengths simultaneously (Fig 4).

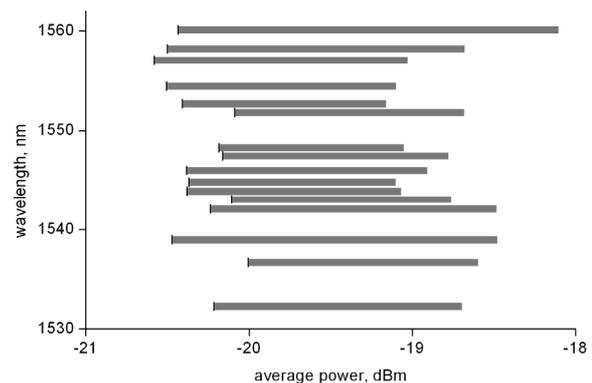


Fig 4 Plot of error-free ( $BER < 10^{-12}$ ) optical power range of each payload wavelength

### Conclusions

Measurements concerning optical power within a fully functional  $12 \times 12$  Data Vortex optical packet switching fabric illustrate the architecture’s flexibility, robustness, and scalability. The optical transparency of the switching nodes is confirmed, and their noise characteristics are quantified as well. The routed data transparency is shown to allow for a dynamic range of the packet power, which suggests the feasibility of even larger network designs.

### References

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