Multiple recirculations through Crosspoint switch fabric for recirculating optical buffering

Published in:
Electronics Letters

DOI:
10.1049/el:20052568

Published: 01/01/2005

Document Version
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the author's version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

Citation for published version (APA):

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.
Multiple recirculations through Crosspoint switch fabric for recirculating optical buffering


Multiple recirculations through an optical buffer using a fast-reconfigurable AVC based Crosspoint switch matrix is shown. A 10 Gbit/s payload is used and a small power penalty for each additional recirculation, up to 10 recirculations, is achieved.

Introduction: Contention resolution in optical switching can be addressed using both fibre delay lines (FDLs) and the wavelength domain [1]. FDLs can be implemented in either travelling (input or output buffering) or recirculating configurations [2]. Recirculating buffers require less physical fibre, and also provide flexibility in that shorter delay lines can be used and packets can be accessed upon each recirculation through the switch fabric. The main drawbacks of recirculating buffering using an electro-optic switch are the loss resulting from traversing the switch fabric multiple times and switch crosstalk that accumulates with multiple traversals of the signal. The former can be solved using in-loop optical amplifiers or a switch with gain, but it is more difficult to get rid of crosstalk.

The Crosspoint optical switch consists of two waveguide layers. Two active vertical couplers (AVCs) are formed at each cross-point of the switch by having an active waveguide stacked on top of both input and output passive waveguides. The switching mechanism of the Crosspoint is carrier-induced refractive index and gain changes in the AVCs [3]. In the ON state, the effective refractive index of the active upper layer is reduced by the presence of injected carriers to equal that of the lower waveguide thereby allowing coupling. The injected carriers in the active layer also provide gain for the signal resulting in a high ON/OFF contrast. 4 × 4 Crosspoint switch fabrics have been demonstrated so far, but are scalable without the inherent losses associated with broadcast and select schemes. It has also been shown that the Crosspoint switch output power can be dynamically controlled on a packet to packet basis for a large input power range [4], optical gain differences of less than 3 dB are attainable between the shortest and longest switch paths [5], and multicasting without optical split loss is possible [6].

![Fig. 1 Typical rise time of Crosspoint (in the order of 35 ns) and typical downtime of Crosspoint (less than 10 ns)](image)

In the Crosspoint switch, ultra-low OFF state crosstalk is achieved through the highly absorptive state of the active waveguide, together with the weakened coupling so that the stray signal is attenuated [7]. Crosstalk as low as −60 dB has routinely been demonstrated. Because of this low crosstalk, together with ultrafast switching speed as shown in Fig. 1, the Crosspoint switch provides an excellent electro-optic switch fabric to be investigated in the implementation of packet switched cross-connects for optical networks.

![Fig. 2 Experimental setup](image)

The input packets (with power level of 0 dBm) arrive every 793 ns fitting the delay length, and the payload is 60 ns of 2−1 PRBS data. The payload length is defined to keep a 1:5 switching duty cycle for the Crosspoint in order to avoid excessive thermal strain to the device. The buffered packet is switched into the FDL using switch C1. The recirculations through the buffer are handled by switch D1. The buffered signal is output by switch D2, and the unbuffered packets are switched by C3.

![Fig. 3 Close up of 10 Gbit/s 2−1 payload after 10 recirculations (Fig. 3a) pattern is clear with little signal quality degradation. Packets buffered 10 times, so 10 793 ns time slots between output packets from Crosspoint switch (8.7 µs between payloads) (Fig. 3b). Ten unbuffered packets directly switched to alternative output (Fig. 3c)](image)

The eye diagram Q-factor after recirculation is evaluated and the corresponding bit error rate is derived using $BER = (1/2) \text{erfc}(Q/\sqrt{2})$. It can be seen from Fig. 4 that the penalty after the first recirculation of a...
packet is approximately 6 dB. It is however interesting to note that increasing the number of recirculations does not result in a proportional penalty increase, as nine recirculations introduce only 3 dB further penalty over a single recirculation. The power penalty is due to both the spontaneous emission from the EDFA and the pattern effect of the switch. Fig. 4 also shows that the quality of the unbuffered packets output from C3 that are switched to the output immediately without travelling through the FDL have a low BER, comparable to the buffered packets. Thus signal integrity is maintained whether the packets are buffered or not.

Conclusions: We have demonstrated multiple recirculations through an optical buffer using an AVC based Crosspoint switch matrix. A 60 ns 10 Gbit/s payload was used, and signal integrity was maintained with a small power penalty for an increasing number of recirculations. While no crosstalk is observable in the multiple recirculation experiment although other packets are arriving and being switched simultaneously as the recirculation buffering is taking place, there seem to be two main contributors to the deterioration in the output eye quality. The first main contributor is OSNR deterioration due to amplified spontaneous emission. Because the main source of attenuation in the loop is the switch itself, and as its output OSNR is sufficiently high (35 dB), the main OSNR deterioration is due to the EDFA, which after a single pass is measured to have an output OSNR of ~25 dB. A second main factor is the pattern effect in the switch. On average, the initial input power of the optical signals to the Crosspoint switch is in the order of 0 dBm. Because an EDFA with a fixed gain is not balanced to unity, therefore it is likely that after a number of circulations the input power to the switch is only limited by the EDFA output saturation power, which may have exceeded saturation levels of the switch despite input coupling loss to the switch. The performance can therefore be improved by carefully balancing the loop gain to unity, and, in the future, by realising Crosspoint switch devices with net fibre-fibre gain.

Acknowledgment: This work was made possible by support of the South African National Research Foundation.

c⃝ IEE 2005 15 July 2005
Electronics Letters online no: 20052568
doi: 10.1049/el:20052568
R. Geldenhuys and F.W. Leuschner (Department of Electrical, Electronic and Computer Engineering, University of Pretoria, Pretoria 0002, South Africa)
E-mail: ronelle.geldenhuys@eng.up.ac.za
N. Chi and S. Yu (Department of Electrical and Electronic Engineering, University of Bristol, Woodland Road, Bristol BS8 1UB, United Kingdom)
I. Tafur Monroy, A.M.J. Koonen, H.J.S. Dorren and G.D. Khoe (COBRA Research Institute, Faculty of Electrical Engineering, Eindhoven University of Technology, NL-5600 MB Eindhoven, The Netherlands)
Z. Wang (Tianjin University, Tianjin, People’s Republic of China) (currently on leave)

References