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Active Photonic Routing for Computer Interconnects

- the Prospects for Photonic PCBs

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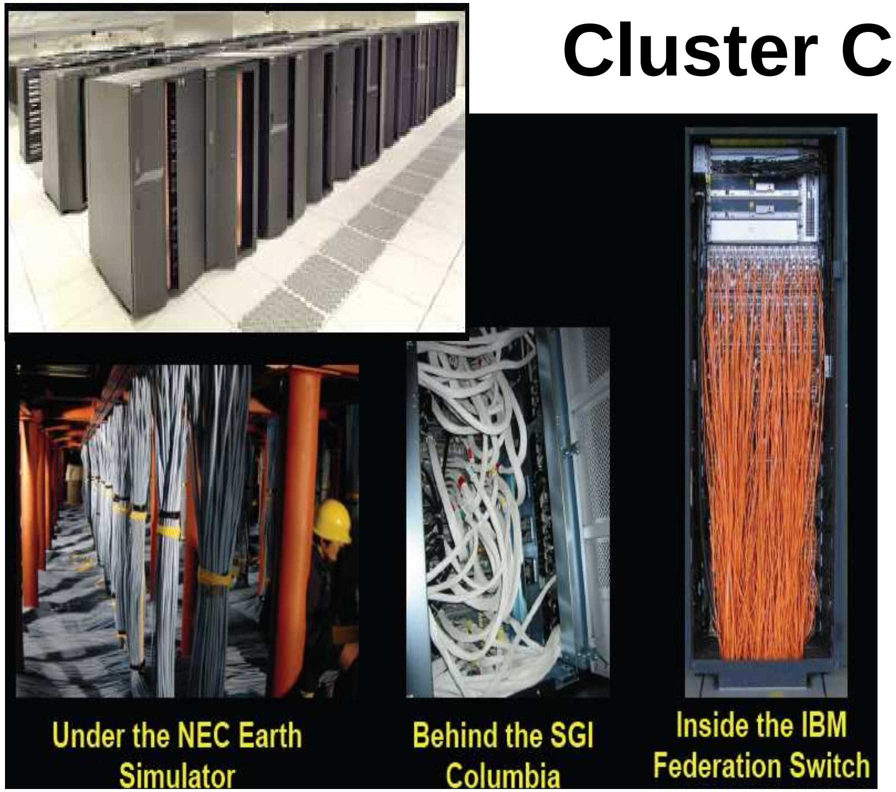
EPSRC, Cambridge Integrated Knowledge Centre

Cluster Computing Interconnects
The Challenge



Next Gen IBM Supercomputer -

Interconnect costs: $625M ($25/Gb/s)

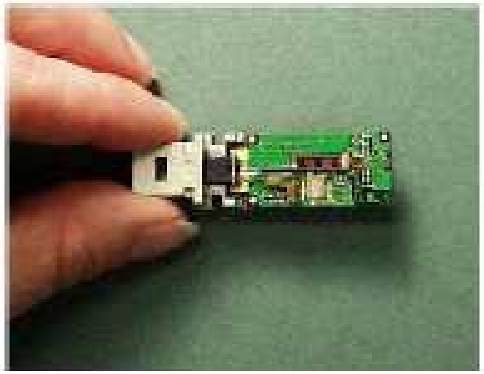
Targeted Interconnect costs: $25M (at $1/Gb/s)

- **Computer performance is a function of internal architecture, processor speed, external architecture, data and I/O access ...**
- **Cluster architectures provide value and require lots of interconnect**
  - **now the most common architecture for top 500 machine**

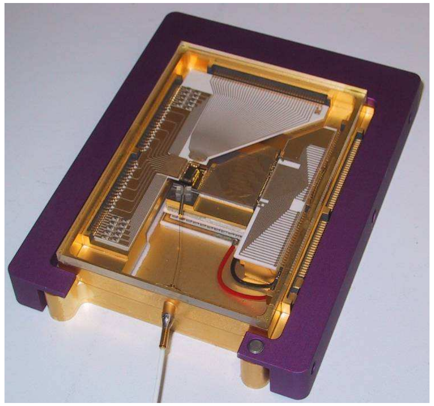
http://www.top500.org/lists/2005/06/PerformanceDevelopment.php

adapted from Alan Benner, IBM

Interconnect and Routing Options for Computer Networks
Modular Integration Sub-systems

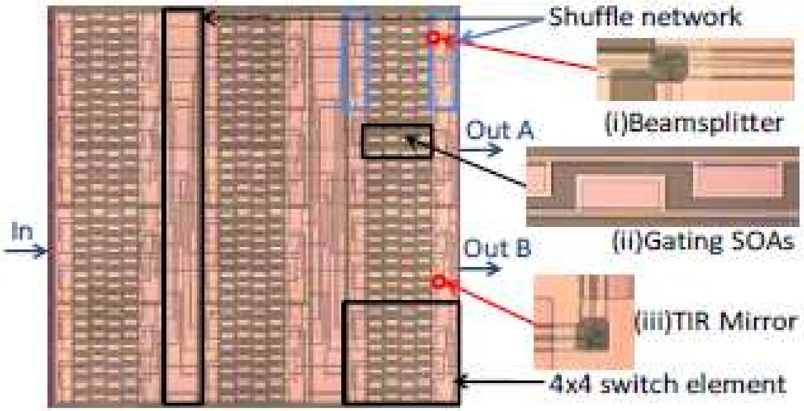


Source:
LA Buckman et al., IEEE PTL, Vol.14, pp 702-704, 2002



Infinera, OFC 2005

Luxtera Products



University of Cambridge, 2009

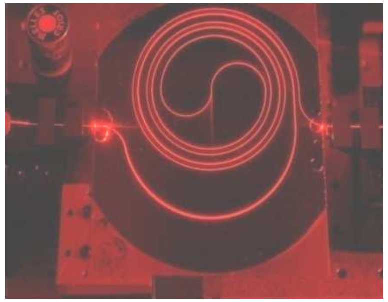
High speed optical modulator
realized in CMOS-SOI

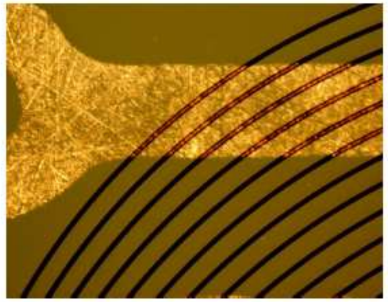
Is there another way?

Waveguides (and components) on the PCB?

- Optical Interconnects today
  - We buy modules
- Electrical Interconnects today
  - Mostly assembled from subcomponents – very cheap!
- Can we move Optics to mass manufacturing from sub-components?
  - Polymer waveguides on PCB?

Siloxane Polymer PCBs





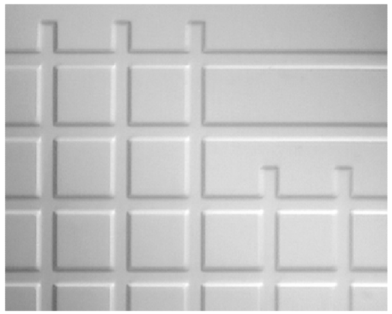
Siloxane materials engineered exhibiting suitable mechanical, thermal *and* optical properties (OE4140 and OE4141):

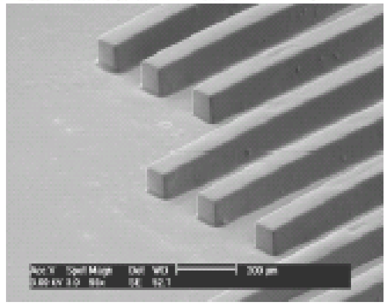
- **are flexible for use with PCBs (suitable for printing!)**
- **exhibit high processability**
  - **exhibiting high thermal and environmental stability:**

    withstand > 350 °C

    → can be integrated with PCBs

- **Low reported loss:**
  - **~ 0.05 dB/cm @ 850 nm**
  - **~0.006 dB/crossing using SMF launch**
- **Excellent crosstalk performance:**
  - **< -60 dB in intersecting waveguide**
- **High speed > 10 Gb/s operation**





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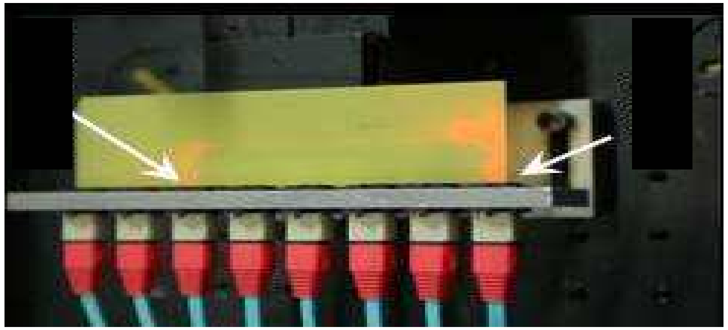
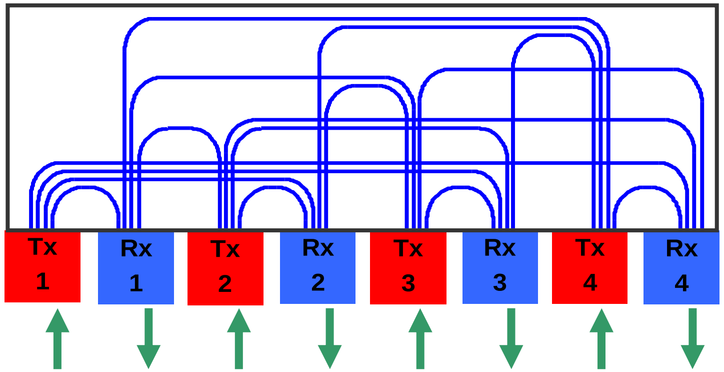
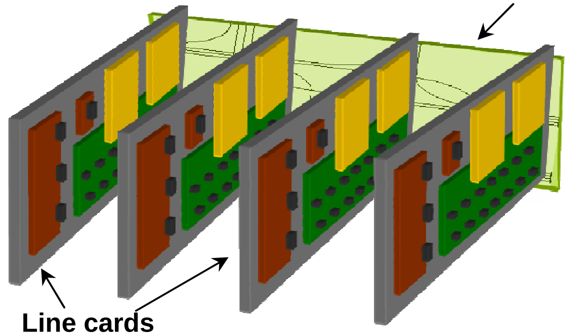
Polymer Optical Backplane Architecture





Ribbon fibres connect at board edges and run to line cards

Standard ribbon fibre link backplane to transmit and receive arrays mounted on line-cards



Schematic of conventional electrical backplane with pluggable line cards

Requirements:

passive routing
scalable architecture
low loss and crosstalk

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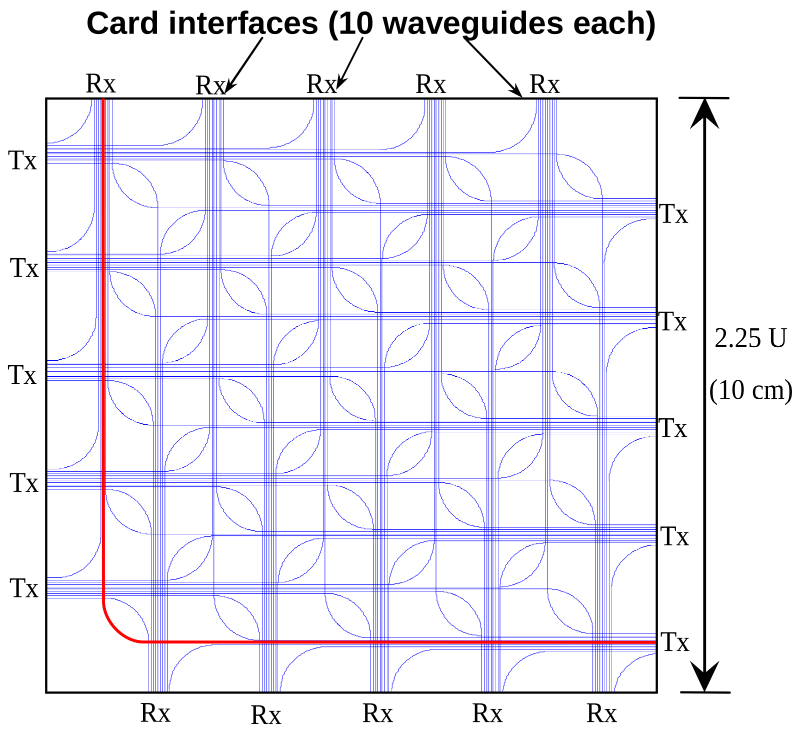
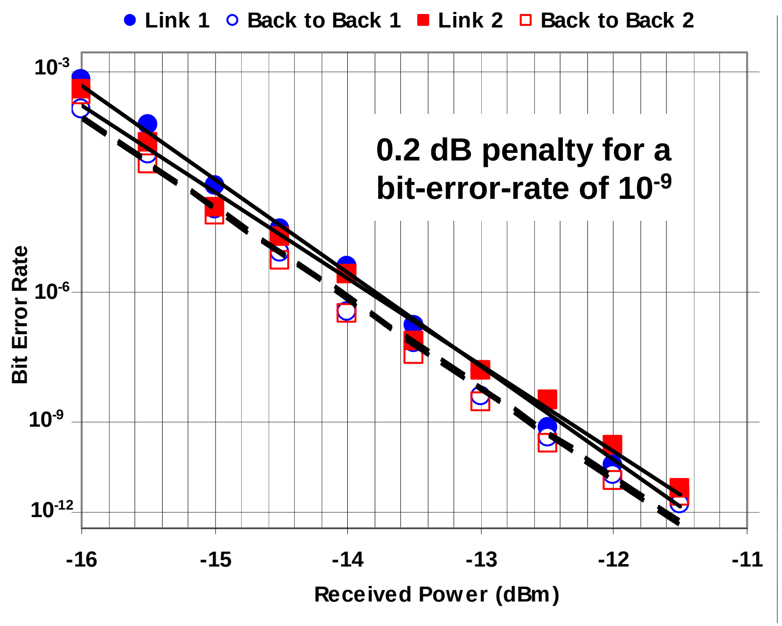
Demonstrated 10 Card Optical Backplane



Schematic of 10-card backplane layout

Error-free 10 Gb/s and real Gigabit Ethernet traffic data transmission demonstrated



- 100 waveguides
- single 90° bend per waveguide
- 90 crossings or less per waveguide

Input Type	Insertion Loss	Worst-case Crosstalk
50 μm MMF	2 to 8 dB	< -35 dB
SMF	1 to 4 dB	< -45 dB

Terabit capacity enabled by 100 waveguides each capable of 10 Gb/s operating in multicast mode

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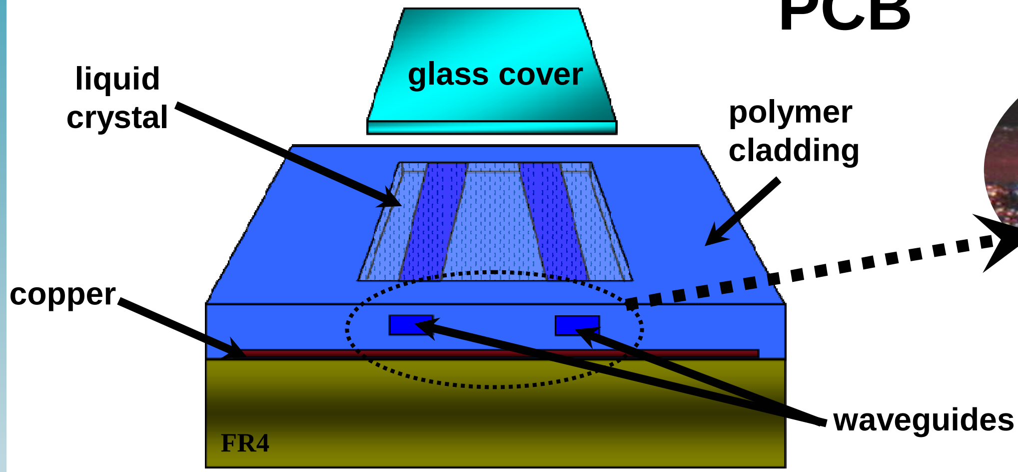
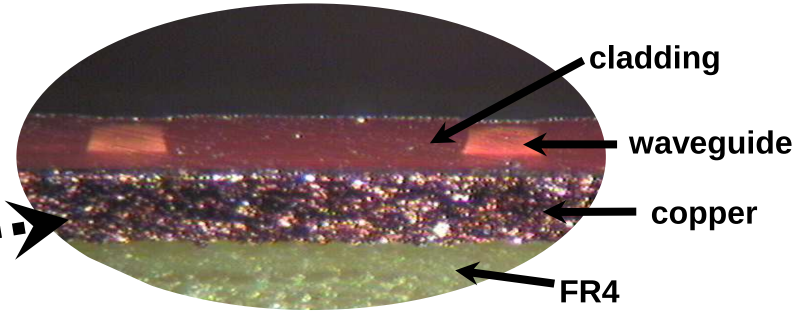
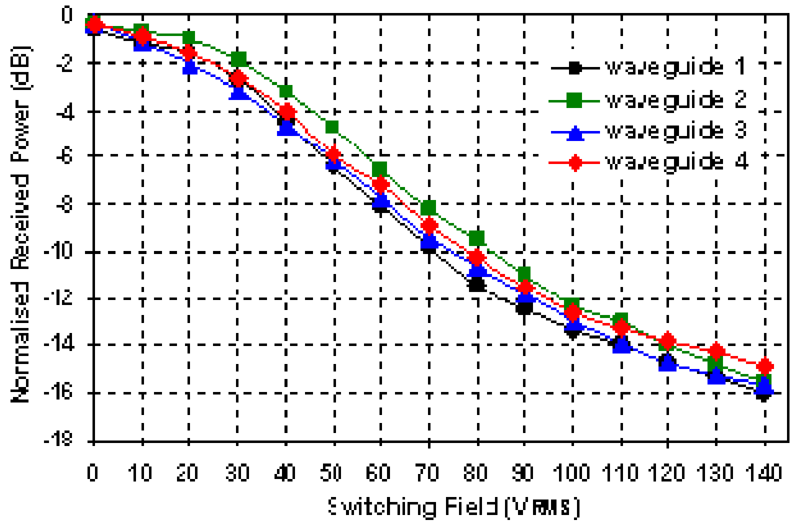
Active Routing: Integrated LC/polymer Switch on FR4 PCB





- Mixture of two nematic liquid crystals: Merck ZLI-1840 and 1550
- Bulk planar alignment of the liquid-crystal parallel to the waveguides using a rubbed polyimide layer on the underside of the ITO top contact
- 850 nm operating λ (though easily varied)
- 0.5 dB excess loss and 15 dB switching
- Excellent repeatability ~0.5 dB across 4 waveguides



Ack T Wilkinson, S Morris, O Hadeler Cambridge University

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Final Comments

- **Photonics in period of transition with enormous potential for new low cost high performance *user-designed* optical systems**
- **Polymer siloxane materials satisfy necessary requirements for low-cost and large-scale integration of *waveguides and active and passive components* into PCBs**

Points for Discussion:

***1. Are Printed* Electro-optical PCBs a promising technology for use in high-speed short-reach optical interconnection applications where light is retained in the PCB?**

2. Are there opportunities for integrated active polymer *(laser/modulator/detector)* components?

Thank You