Optical Polymer Dielectric Waveguides on Printed Circuit Boards – high speed, short distance interconnects

- The established technology of using copper tracks to transmit electrical signals between electronic components mounted on printed circuit boards (PCBs) has been very successful.
- The copper track technology has evolved so PCBs can contain multiple layers of copper tracks connected vertically to each other by copper vias on both rigid and flexible PCBs.
- However, as speed of digital communications on PCBs approaches 10 Gb/s the copper tracks begin to show failings such as
  - High propagation loss
  - Strong radiation of electromagnetic waves outside the enclosure – electromagnetic interference (EMI)
  - Strong reception of electromagnetic waves within the enclosure by other neighbouring tracks causing cross talk interference
  - The impedance of the copper vias no longer matches that of the track at all frequencies resulting in reflections
- The copper technology has responded to overcome these challenges by the use of
  - Injection of high power pulses into the copper tracks
  - Pulse shaping with pre-emphasis
  - Adjustment of the frequency characteristics of the link by equalisation or adaptive equalisation
  - Low loss PCB material
  - Redrilling buried via stubs to control impedance
  - Multiple tracks at lower bit rates in bus connections
- However, these methods are costly, time consuming and are not scalable to even higher faster speed interconnections.
- The disruptive technology of infra-red laser communication through polymer dielectric waveguides offers an attractive route to overcome these problems and is scalable to much higher bit rates
- However, it research is necessary to bring this technology to a maturity having low cost and high performance where PCB manufacturers will embrace it.

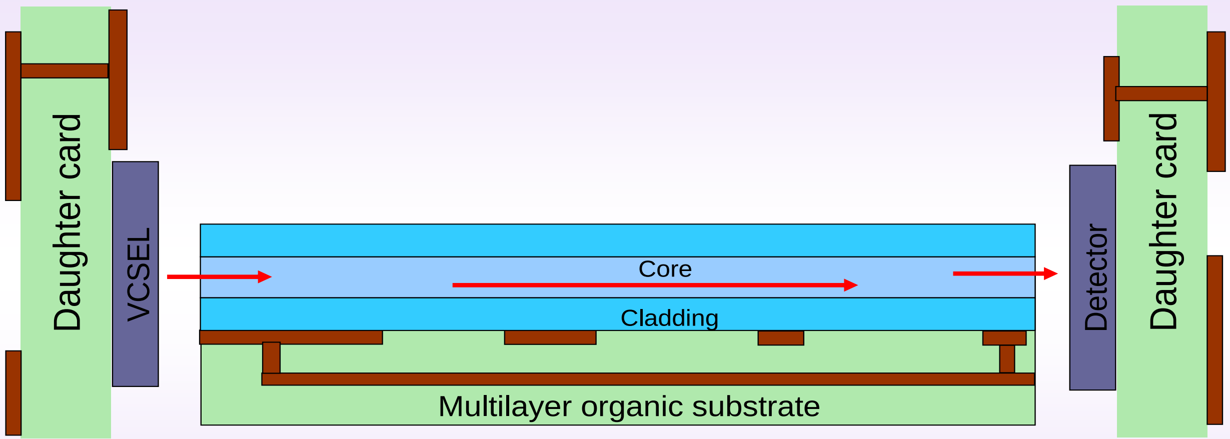
Optical Polymer Dielectric Waveguides on Printed Circuit Boards – Aims

- The research includes
  - Development of accurate measurement techniques. Dr David R. Selviah incorporates these into international standards as the UK academic expert on the international standards committee for fibre optics, interconnecting devices and passive components, optical functionality for electronic assemblies.
  - Development of design rules for waveguide components and their incorporation into PCB layout software. The most recent releases of the Cadence Allegro software suite include features resulting from the UCL research.
  - Development of modelling software for waveguide components in which the speed of light varies across the waveguide and which take into account the nanoscale sidewall roughness of real fabricated waveguides.
  - Invention of precision, low cost technique of alignment of laser and photodiode to waveguide – patented and licensed with revenue stream

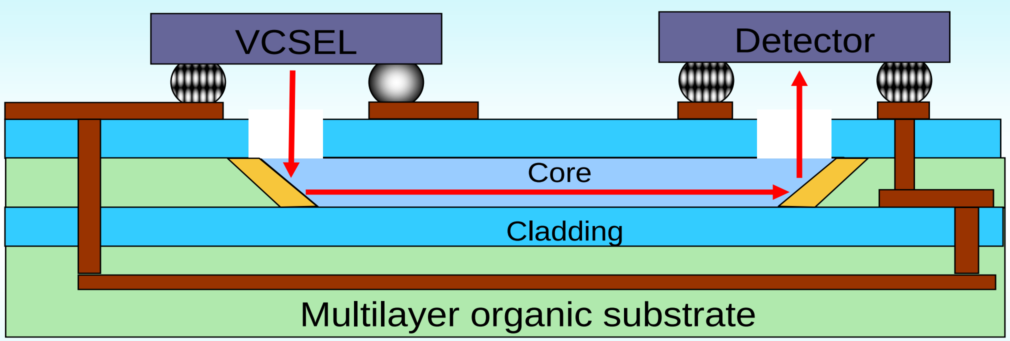
- Dr David R. Selviah led the Integrated Optical and Electronic Interconnect PCB Manufacturing (OPCB) consortium of 8 companies and 3 universities in the £1.6 million EPSRC IeMRC project.
- The consortium included Xyratex Technology, BAE Systems, Renishaw, Stevenage Circuits, Dow Corning, Exxelis, Cadence Design Systems, National Physical Laboratory, Heriot Watt University, Loughborough University, UCL.

Optical dielectric waveguide research of Charles K. Kao

- Kao was aware that flexible, **dielectric plastic waveguides**, could guide microwaves which are one frequency of electromagnetic radiation
- Elias Snitzer of the American Optical Company showed in 1961 that the theory of **dielectric waveguides** could also be applied to guide light through optical fibres for communication, however, at that time optical fibres had too high a loss to be of practical use.
- Antoni E. Karbowiak of the Standard Telecommunication Laboratories, UK suggests in 1963 the use of flexible thin-film **waveguides**.
- Charles K. Kao and George Hockham succeeded Antoni E. Karbowiak at Standard Telecommunications in 1964 and redirect the research from thin film **waveguides** to optical fibre **waveguides**
- K.C. Kao and G.A. Hockham paper, "**Dielectric-Fibre Surface Waveguides** for optical frequencies" *Proc. IEEE*, 113, 1151 (1966).
- In their paper they wrote that "A fibre of glassy material in a cladded structure represents a practical optical waveguide worth important potential as a new form of communication medium."
- Kao and Hockham discovered that impurities in the glass were scattering and absorbing the light and suggested that optical fibre **dielectric waveguides** made from high purity glass or fused silica SiO_2 could be easily manufactured and would only have a loss of a few dB/km

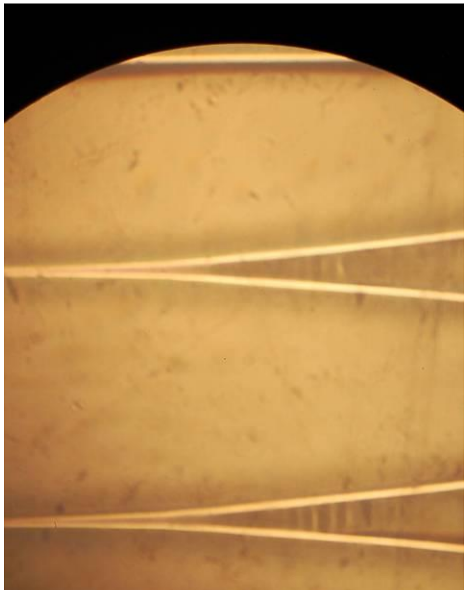


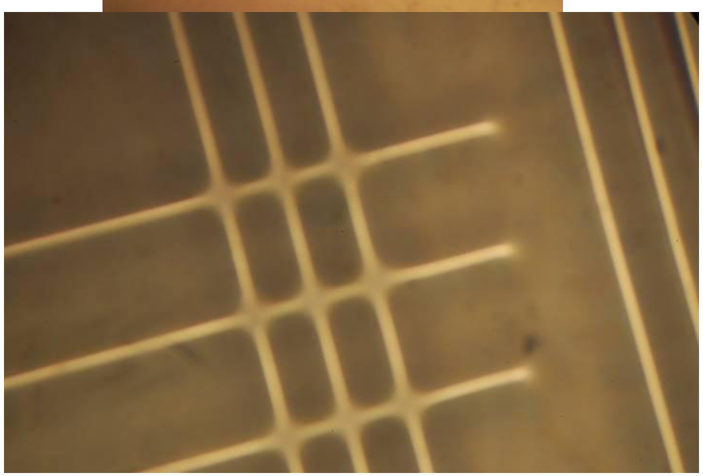
- Backplanes
  - Butt connection of “plug-in” daughter cards
  - In-plane interconnection
- Focus of OPCB project



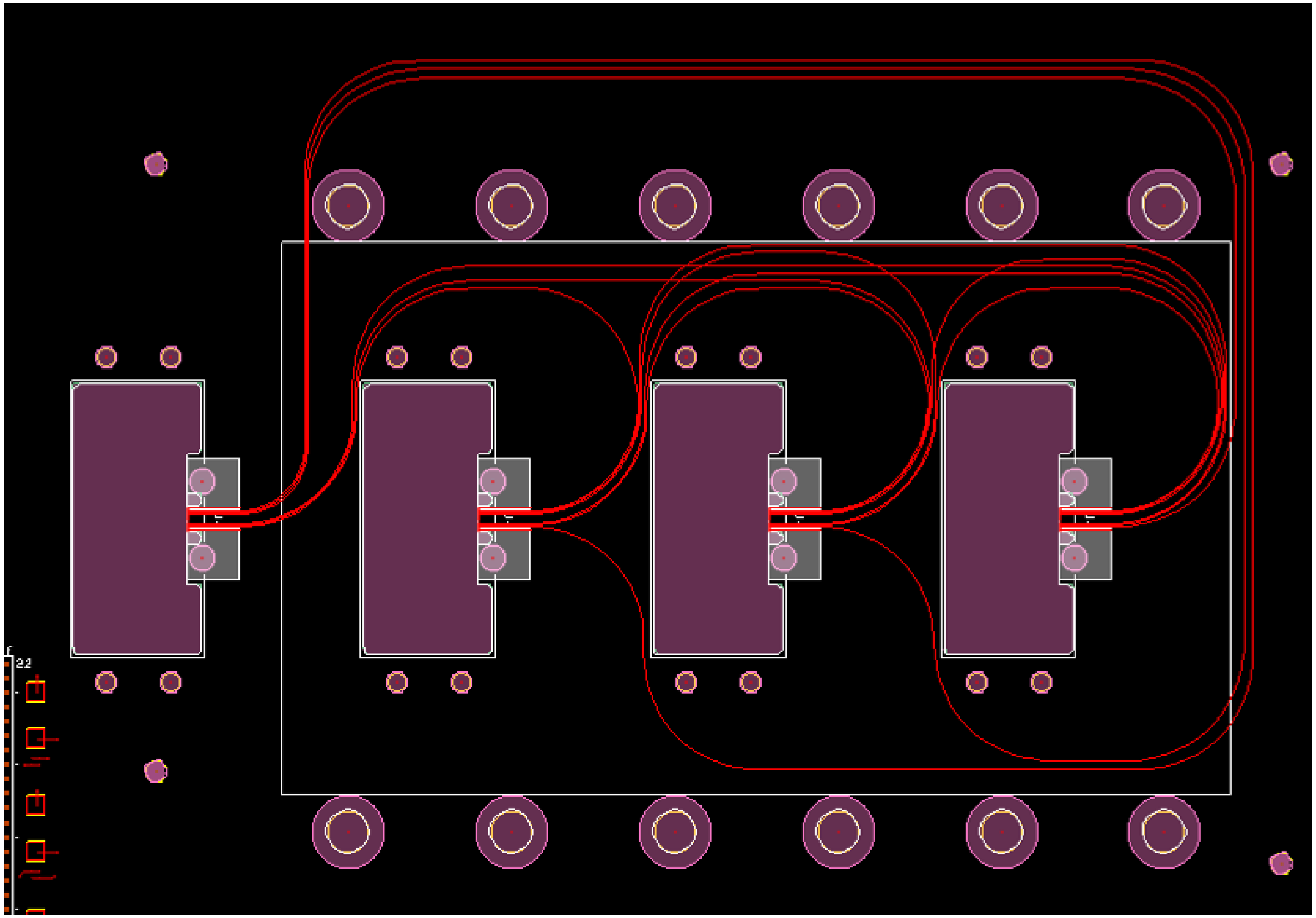
- Out-of-plane connection
  - 45 mirrors
  - Chip to chip connection possible

Optical Polymer Dielectric Waveguide Images



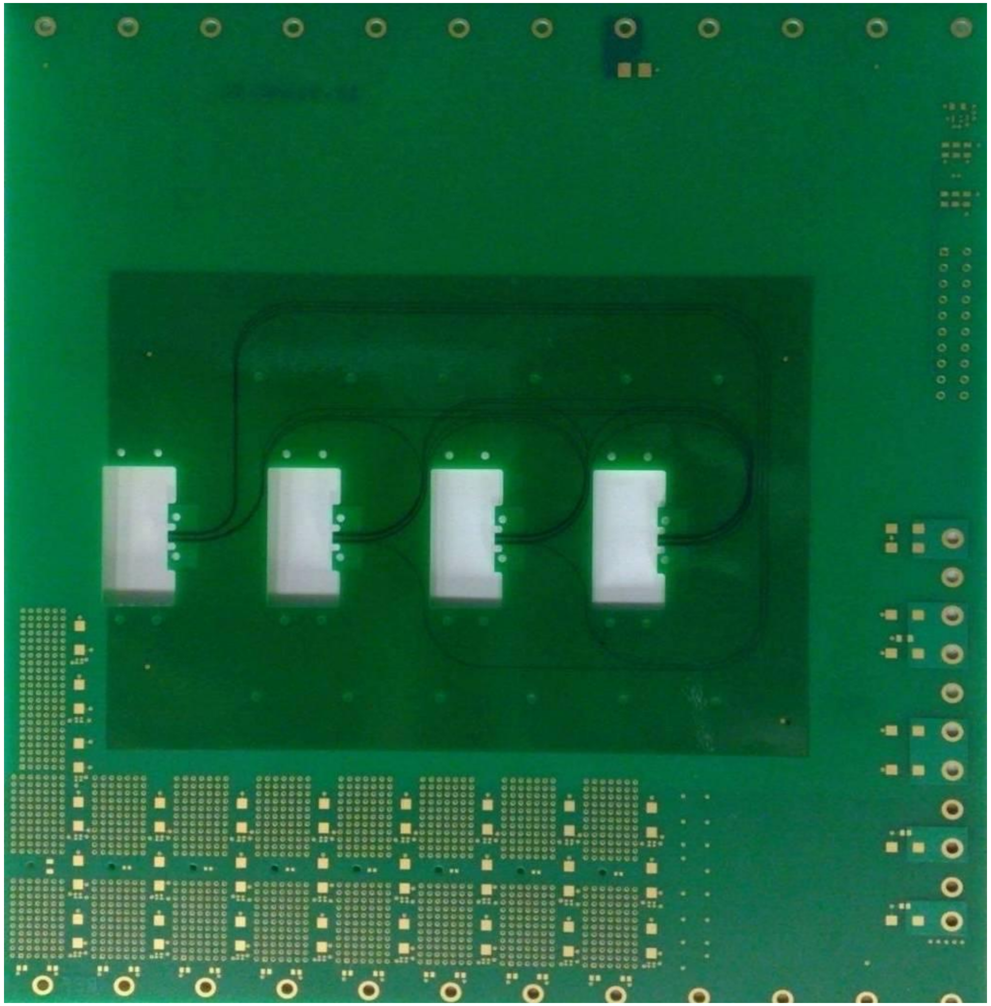


Printed Circuit Board Interconnection Backplane Waveguide Layout Design

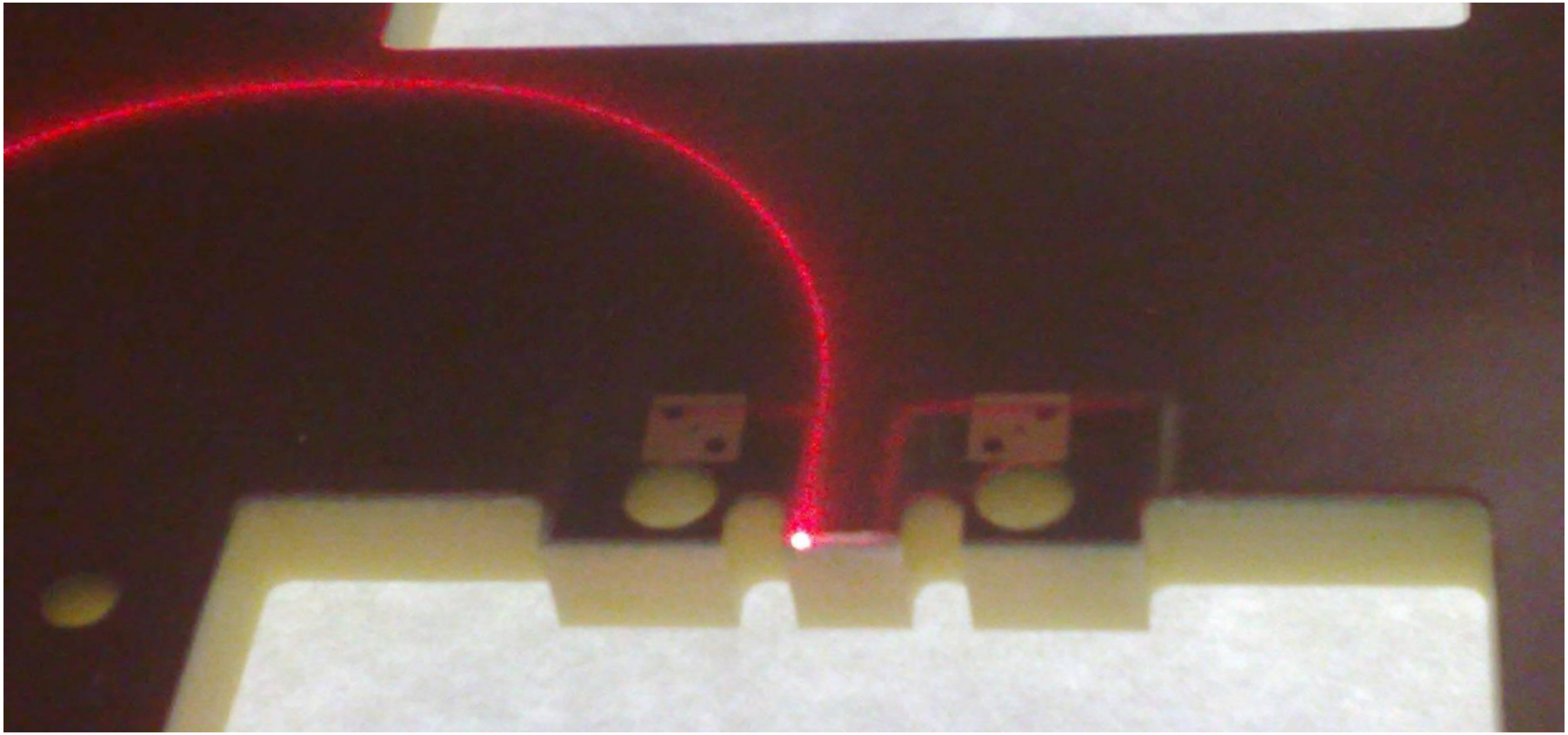


Fully connected waveguide layout using design rules

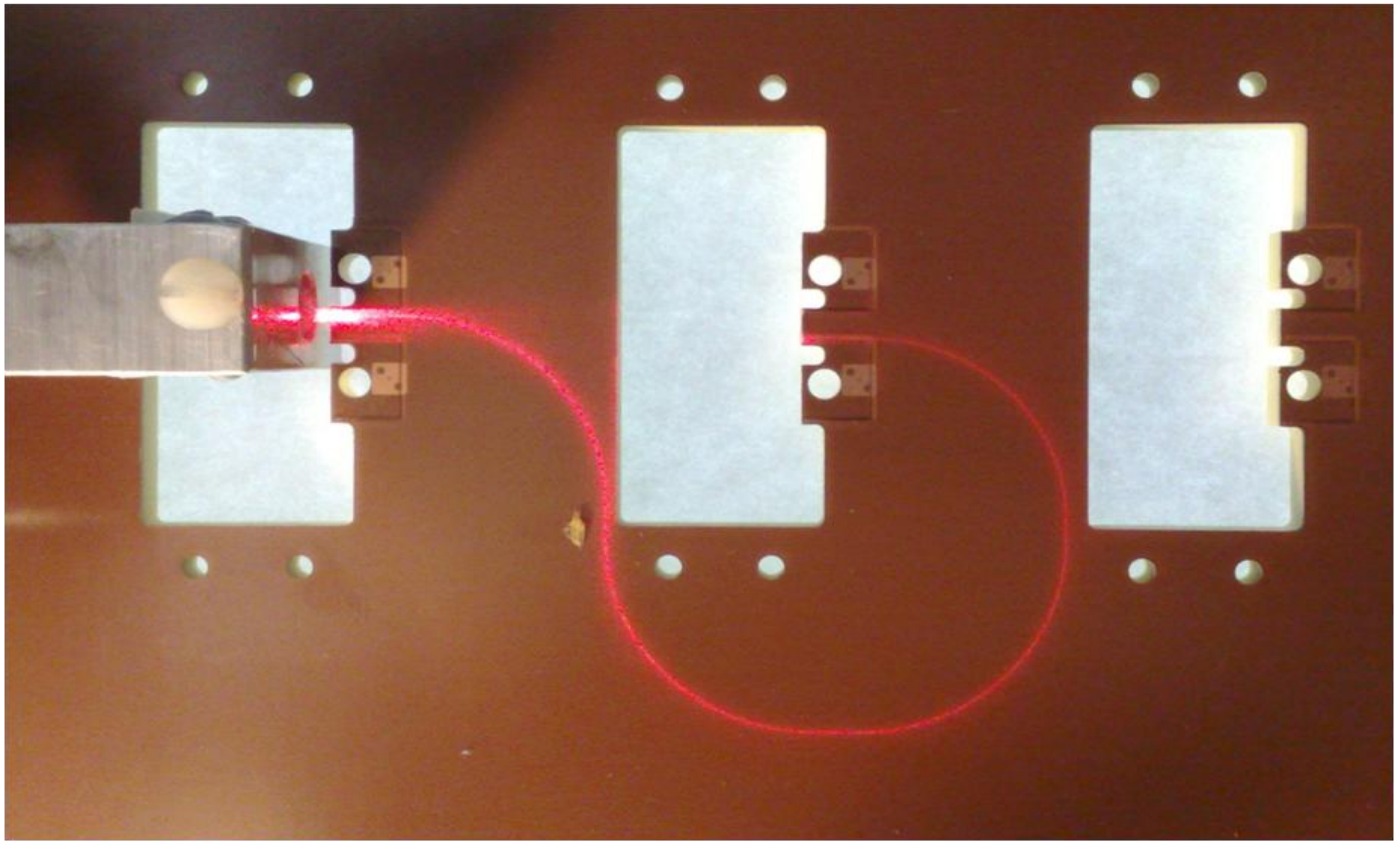
Printed Circuit Board Interconnection Backplane showing the positions of the waveguides



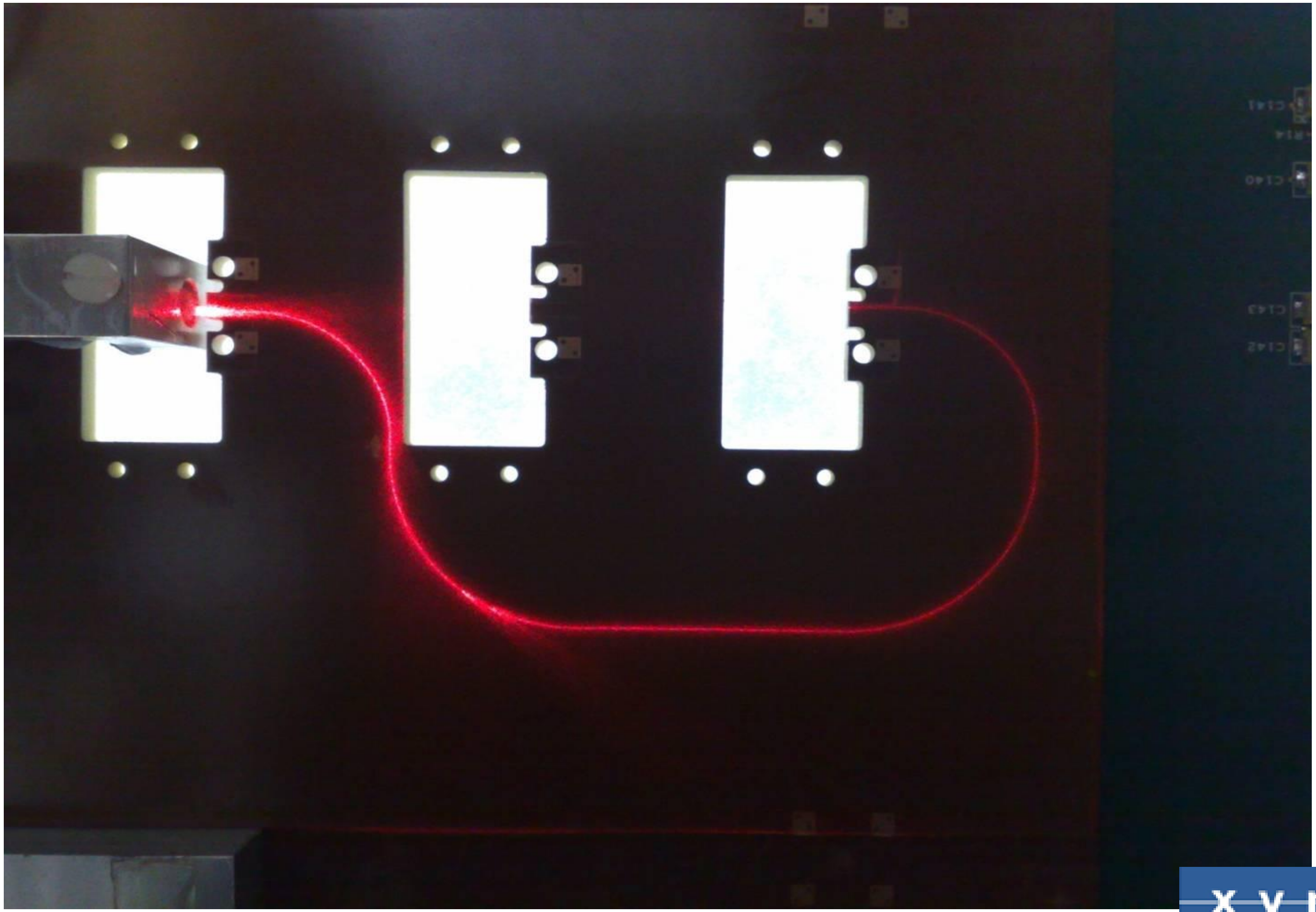
Waveguide bend and output face



Waveguide backplane interconnection illuminated using a red laser



Backplane waveguide interconnect cutting across two other waveguides



UCL Designed Optical Polymer Dielectric Waveguide Interconnection PCB Backplane incorporated into Xyratex Technology demonstrator

- Most highly integrated optical demonstrator to date
- 4 plug in cards optically connected via optical polymer dielectric waveguide PCB.
- Each with 4 input 10 Gb/s channels and 4 output 10 Gb/s channels, 8 x 8 crosspoint switch and FPGA controller