IeMRC Abstract

Flagship Project

Integrated Optical and Electronic Interconnect PCB Manufacturing (OPCB)
University College London (UCL) (Technical Lead), Heriot-Watt University, Loughborough University, Collaborating Companies: Xyratex Technology (Project Manager), BAE Systems, Renishaw, Stevenage Circuits Ltd, Cadence, Dow Corning, Exxelis, NPL.

Digital information, encoded onto light signals, is regularly sent along optical fibres over distances varying from a few metres to thousands of kilometres. Fibres have largely replaced traditional copper cables for high performance broadband communication over distances exceeding a metre, as they offer advantages such as lower cost, immunity to electrical interference and weight savings. Printed Circuit Board (PCB) backplanes are widely used in the electronic cabinets or racks that form the heart of a variety of IT systems and incorporate connectors to allow other PCBs to be attached at right angles (Fig. 1). In the highest speed computers for communication between the central processor arrays and the hard disc storage arrays, through data routing switches, there is now considerable interest in incorporating high speed "optical wiring", by means of plastic light-guides, within large, metre-scale, electrical PCBs combining optical and electrical interconnections (OPCBs).

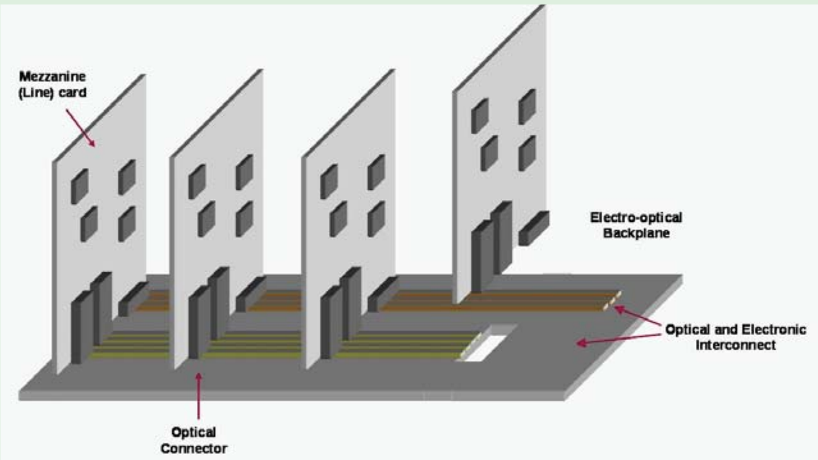


Fig. 1: Schematic view of backplane architecture.

Optical interconnections are being investigated in this IeMRC "Integrated Optical and Electronic Interconnect PCB Manufacturing" flagship project for short distance, high speed, data communication applications on printed circuit boards to replace high data rate copper tracks which suffer severe cross-talk and increased loss and increased cost at data rates above 10 Gb/s. This three-year research project has been exploring novel methods, compatible with traditional multilayer PCB manufacturing processes, for the manufacture of optical waveguides capable of operating at very high data rates within an optical layer laminated into the board. Several waveguide manufacture processes have been investigated, each with different levels of risk and cost. The large team of university and industrial collaborators have explored preparation, evaluation and exploitation of these techniques. Studies have included the future requirements of these techniques in the context of computer aided design through the modification of commercial software packages. The three universities are conducting research in the following areas:

Modelling and Characterisation of Waveguide Structures
University College London (UCL) has been technical leader of the whole project and their research includes:

Establishing waveguide design rules for photolithographically fabricated waveguides and incorporating them into commercial design rule checker and constraint manager layout software for printed circuit boards so that PCB designers can easily incorporate optical connection layers without detailed knowledge of the optics involved.

Measuring insertion loss of each of the four waveguide manufacturing techniques: photolithography, laser direct writing, laser ablation and inkjet printing.

Investigating and understanding the effect of waveguide wall roughness and cross sectional shape on the behaviour of light and the effect on waveguide loss.

Characterising the behaviour of optical waveguide backplane systems in real world conditions, including aging tests at high temperature and humidity.

Developing novel connector designs suited for interfacing flip chip lasers and photodiodes to OPCBs.

Developing low cost novel manufacturing techniques compatible with commercial PCB manufacturing processes.

Sourcing suitable waveguide manufacturing techniques and material and transferring the technology to Stevenage Circuits Ltd.

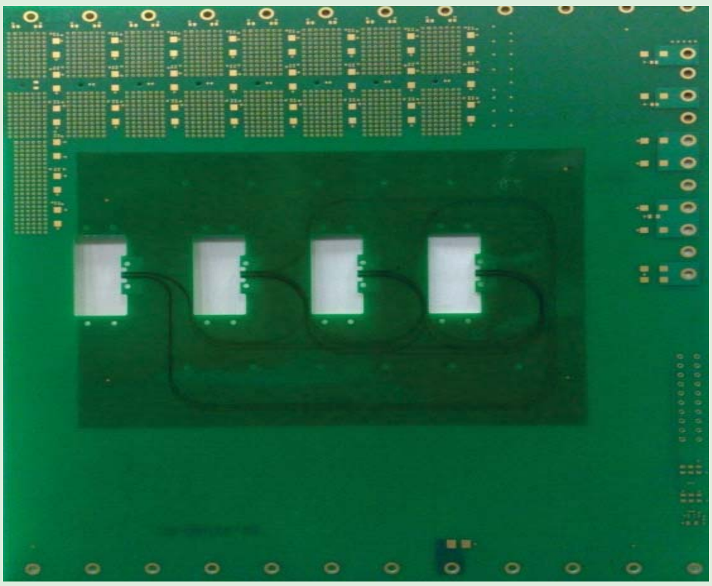


Fig. 2: Demonstrator board showing the layout of the waveguides

Design rules derived from measurements of waveguide components were used to design a novel backplane layout (Fig. 2). There were two requirements. First, the line-cards had to be interchangeable: all optical interfaces were designed to face in the same direction and to be identical to each other. Secondly, the line-cards were required to be closely spaced. 9 waveguides fully connect the 4 optical connectors on the backplane to allow every daughter card to directly communicate with each of the others. UCL sent 10 Gb/s Ethernet traffic through each of the waveguides, obtaining open eye-diagrams. UCL and Xyratex constructed a demonstrator (Fig. 3) inter-linking four daughter cards via pluggable active connectors using the patented UCL self alignment technique, containing 4 VCSELs and 4 Photodiodes. This is the most integrated demonstrator to date incorporating connectors to allow other daughter cards to be attached at right angles and to be interchanged.

Fig. 3: 10 Gb/s Ethernet demonstrator with an optical waveguide backplane and novel 80 Gb/s aggregate self aligning optical connectors.

Laser Direct Writing of Waveguides:

Heriot-Watt University has been studying the viability of direct UV-laser writing as a manufacturing technology capable of forming multimode polymer waveguides over large metre-scale backplanes. An optimum intensity profile for the writing beam has been identified, compatible with producing both straight and curved guides. Following up earlier work with acrylate-based polymers, excellent results are now being obtained using polysiloxane, supplied by recently added consortium partner – Dow Corning. Studies focused on the optimisation of optical power and writing speed have led to the production of well-defined, low-loss waveguides written at speeds in excess of 20 mm/s – approximately two orders of magnitude greater than writing speeds achieved in our previous work. The waveguide writing rig has been upgraded so as to permit production of guides over boards as large as 300 mm x 600 mm, at potential speeds of up to 2 m/s, with sub micron resolution. Current work is targeting production of an optical-interconnect insert board, compatible with a Xyratex demonstrator system.

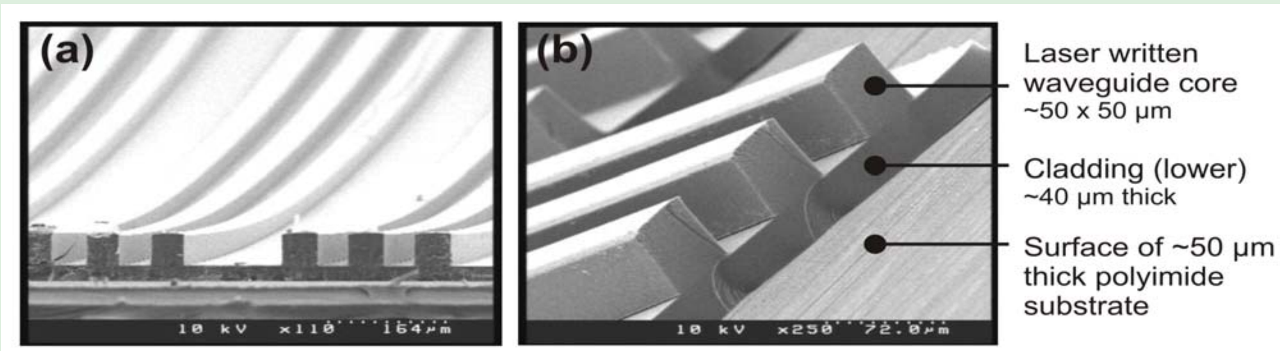
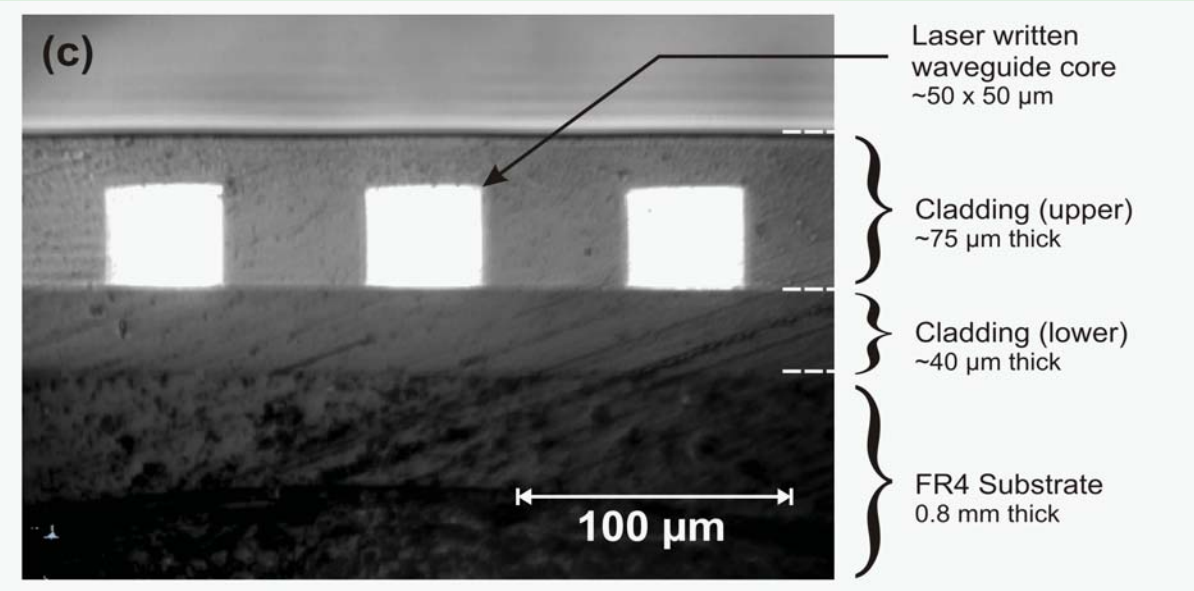


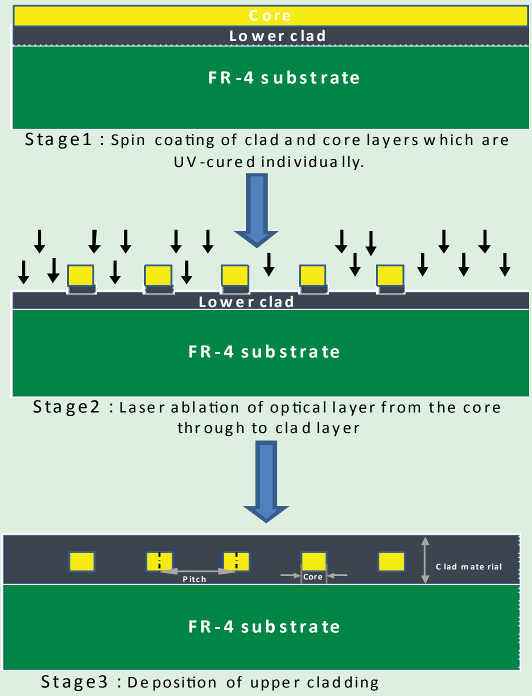
Fig. 4: The SEM images in (a) and (b) show direct laser-written, unclad polysiloxane waveguide cores (~50 x 50 µm) with lower cladding, on a ~50 µm thick polyimide sheet. The guides shown in (b) are on a 100 µm pitch. The optical microscope image in (c) shows an end-on view of back illuminated, clad, laser-written multimode polysiloxane waveguide cores on a 100 µm pitch, on an FR4 substrate. The cores shown in this figure were laser-written using a flat-top intensity profile and an optical power of 3 mW.



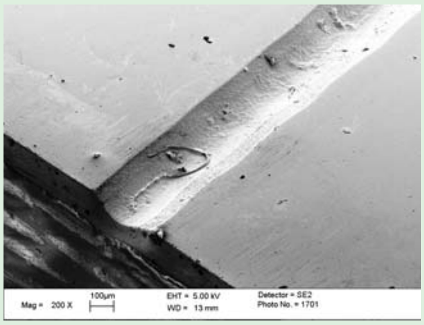
Laser Ablation and Inkjet Printing of Waveguides

Loughborough University have been investigating the laser ablation of optical polymer materials (polysiloxane from Dow Corning and Truemode from Exxelis) to form waveguides (Fig. 5a) and are also examining the preparation of in plane and out of plane mirrors. Excimer, Nd:YAG and CO2 laser systems have been trialled and waveguides fabricated (Fig. 5b,c and d). Measurements of loss from straight waveguides have been carried out at UCL. The aim is to characterise the ablation process and investigate the different process parameters, such that wall roughness can be controlled and accurate mirror profiles generated.

A significant part of the research is considering the inkjet deposition of polymer waveguide structures focussing principally on the structuring of the core layer on top of the lower cladding. Both functional fluids and solution deposition have been examined. It was found that UV cure optical polymer materials such as polysiloxane from Dow Corning and Truemode from Exxelis could be successfully printed by controlling the viscosity and developing correct inkjet printhead waveforms. Using this technique, lines of optical polymer were deposited and then UV cured, however a key issue was preventing the spread of the material such that structures with a good height to width ratio (aspect ratio) were formed. Initial work investigated the control of the substrate wettability (Fig. 6a,b) to increase the contact angle whilst maintaining a stable parallel line structure before UV curing. However, higher aspect ratio structures such as those shown in Fig. 6c,d have been obtained using different methods of UV cure. Further work is underway to reduce the width of these features and measurements of the losses of these structures are being carried out at UCL.



(a)



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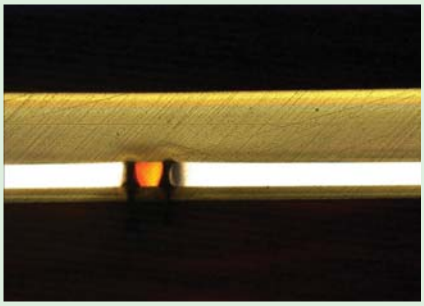

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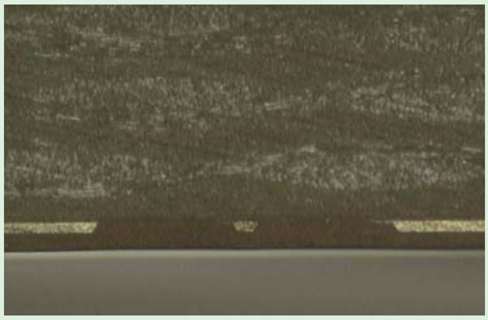
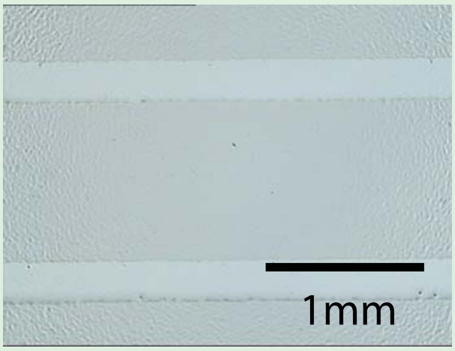
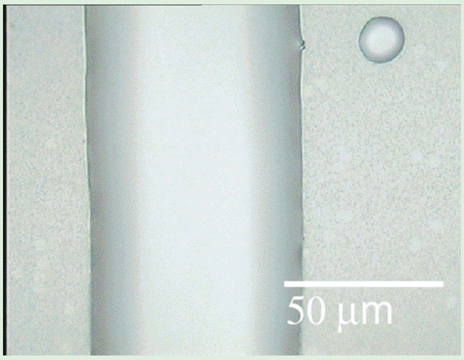


(d)

Fig 5: (a) The laser ablation process to create optical waveguides; (b) a groove machined in Truemode polymer using the CO2 laser showing the influence of the Gaussian beam intensity profile; (c) a cross-section through a waveguide machined in Truemode using an Nd:YAG laser; (d) an optical waveguide prepared using Excimer laser ablation of Truemode polymer.



(a)



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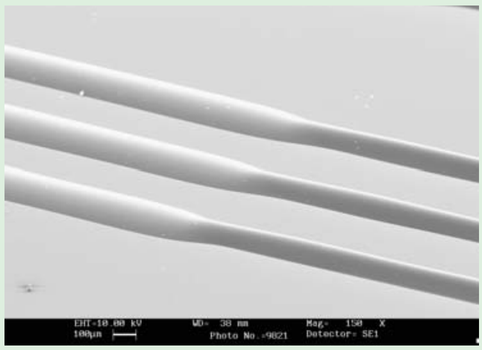

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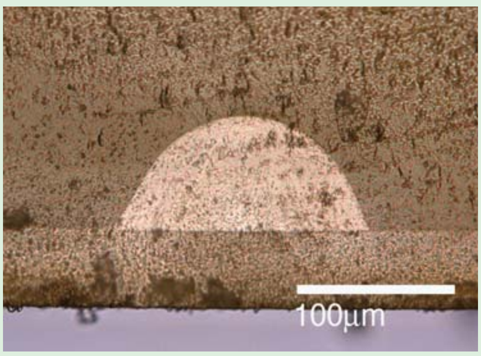

(d)

Fig 6: Ink jet printed lines showing (a) extensive wetting leading to broad features; (b) reduced spreading of ink jet printed line on a modified glass surface. (c) parallel lines of polysiloxane showing the effect of different cure regimes. (d) cross-section through an inkjet printed polysiloxane waveguide.