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・Special Feature

Development of 40Gbps Optical Interconnect Technology for Application to Optical Test Systems

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Introduction

In today's world high speed communication is becoming more and more prevalent in the everyday life of many people. This is shown by the huge increase in internet speeds, mobile phones, game consoles and PC users. Not content with these advances further increases in data communication are were seen this year with the introduction of the WiMAX and XGP services in Japan.

Also, the use of optical signals to transfer data has advanced in recent years to hold the promise of even faster and more accurate data transfers in the future. From all of the above it can been seen that, via various methods, high speed data transfer is taking place in various forms and some methods to accurately measure such systems is required.

In this special feature we report on our work on the development of 40Gbps optical interconnect technology for application to optical test systems.

1. Start

In recent years the use of printed circuit boards, PCB's, to carry out high speed data communications has advanced. Most recently to carry on this trend greater and greater communication speeds have been used but the standard technology is reaching a communication bottleneck. Today's MPU's are expected to go multicore and in the future terabit signals are to be expected. To overcome this the use of optical interconnects to boost communication speeds between, on board chips and between boards is being mooted. Considering the above and the use of multicores it is believed that 1ch of the multicore must operate in the range of 20~40Gbps. Interface components between the LSI chips and the optical signals have been steadily developed. In this report we will give details of such a system developed by ourselves.

2. The structure of an optical LSI measurement device and the use of optical interconnects for high speed data transfer

From Fig.1 we can see that present day electrical signals via serial interfaces through the use of pre-interfaces and equalizers can reach speeds of 10Gbps between chips. With chips now going multicore the requirement for higher interconnect speeds has become even more required. To go higher than 10Gbps with present day technology becomes extremely hard and even then a limit at 20Gbps is expected. From this you can see the need for optical interconnections at the board level.

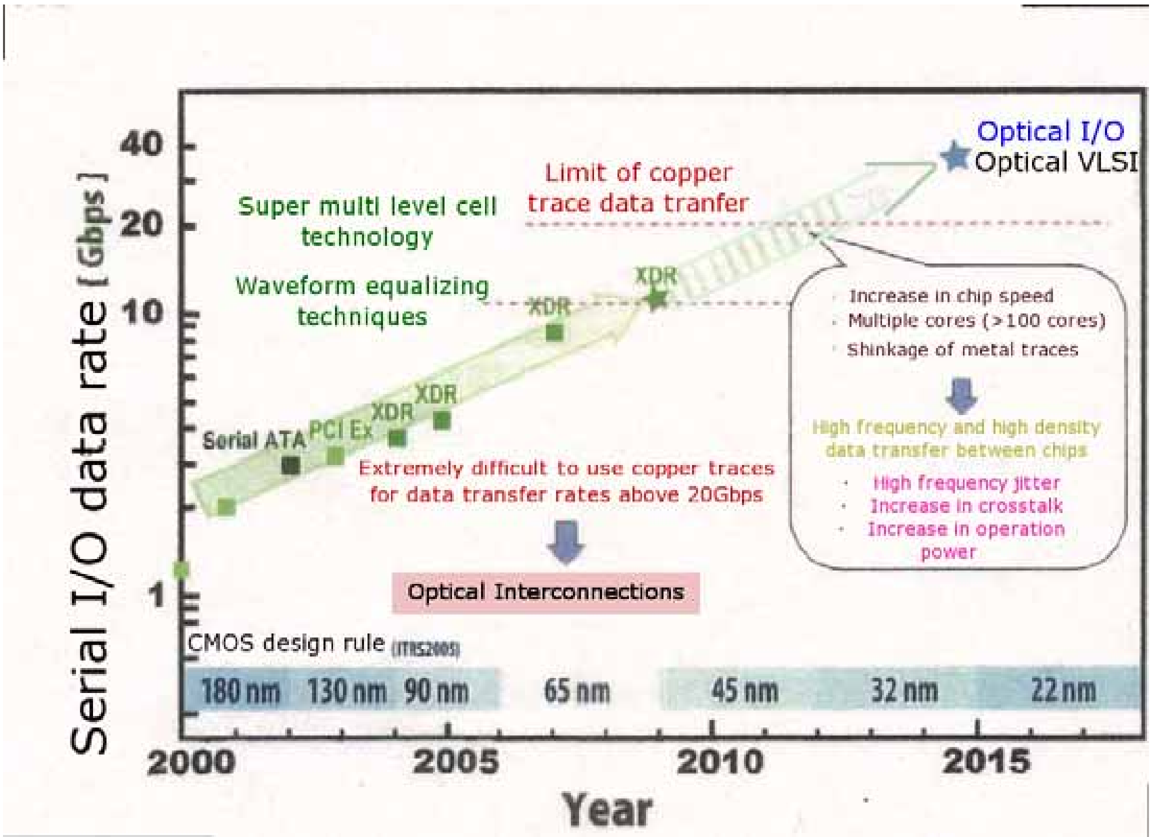


Fig. 1 High speed serial interface trend with the move to optical interconnects shown

In Fig. 2 is shown our image of a measurement machine for optical LSI having optical interconnects. As you can see the optical interconnects are required not only between component racks and boards but also is required between LSI chips within the same board. The test signal input to the DUT (Device Under Test) comes from the PE (Pin Electronics) board this is first output to the optical signal driver (EO Dr.). This driver then outputs the signal in the 20~40Gbps region. This optical signal travels through the printed circuit board. At the edge of this board is and edge connector that can handle both optical and electrical signals. This edge connector is then connected to a standard optical fiber to facilitate communication with the PB (performance board).

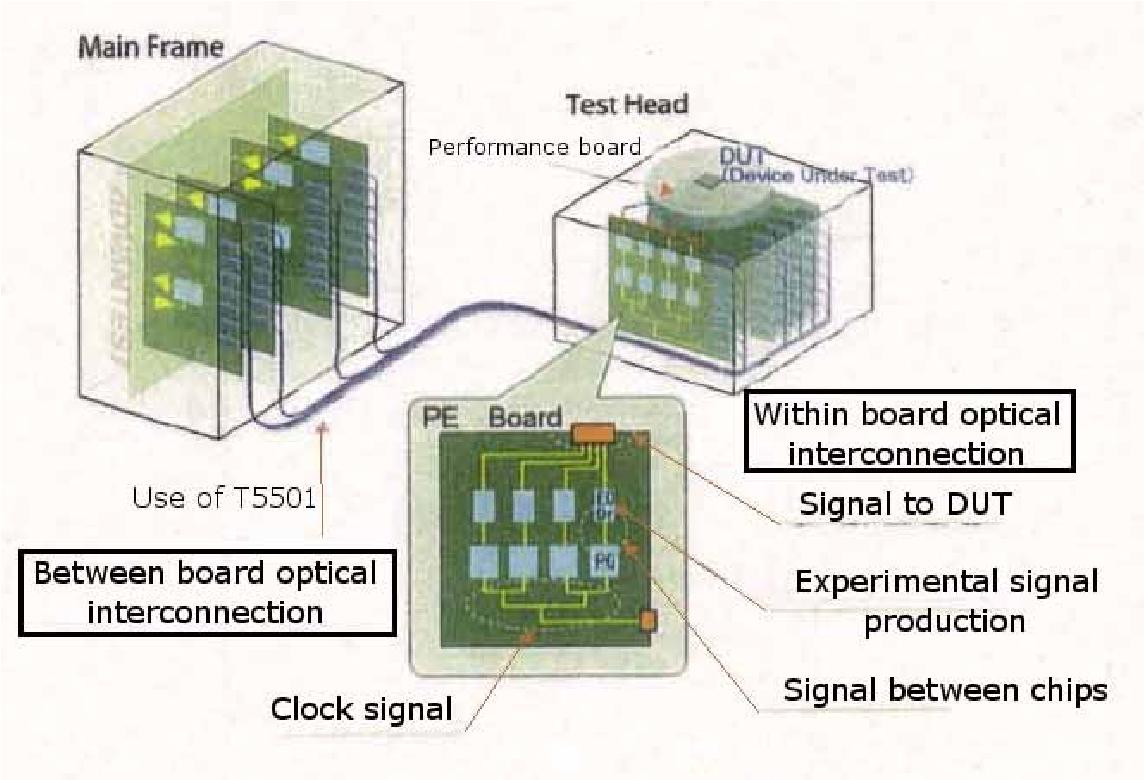


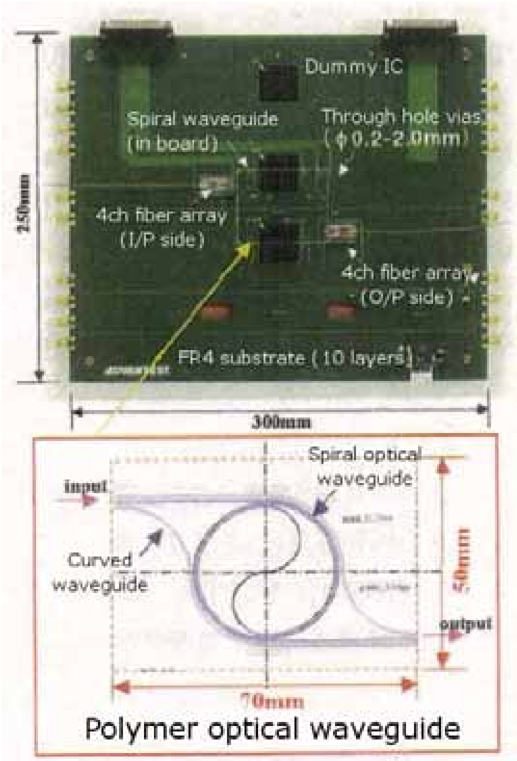
Fig. 2 Schematic of optical test system

3. Development of a wide bandwidth optical waveguide PCB for a high density data measurements

For the system that we envision, that is to say a performance board (PE) that can measure at high speeds and high data density rates, we need to overcome the problem of just how we will incorporate the optical waveguides within the said PCB boards. The data rates we envision are in the range of 20G~40Gbps. A polymer based waveguide was used to construct the required waveguides and these were constructed within multiple level PCB boards after many experiments we have developed a system to meet our demands.

The boards have a combination of electrical and optical components to carry out the high data rate measurements that is the base of our measurement system. To date very little data has been reported on the lifetimes of such systems and this was an area in which we carried out many tests to prove the viability of such a system. A 10 layer PCB board construction was used with the polymer waveguides contained within the boards themselves. Also wide use of through hole vias were used to connect up our hybrid electrical and optical boards.

In figure 3(a) is shown our PCB board for use in our measurement system. Within this board is our polymer based spiral waveguide. This is exact shape is shown in detail in Fig. 3(b), for ease of understanding this displays an exposed example of the waveguide with light traversing the guide. A cross-section through the board of the waveguides shows the physical construction parameters of our waveguides, this is shown in Fig. 3 (c).



(a) Our PCB layout

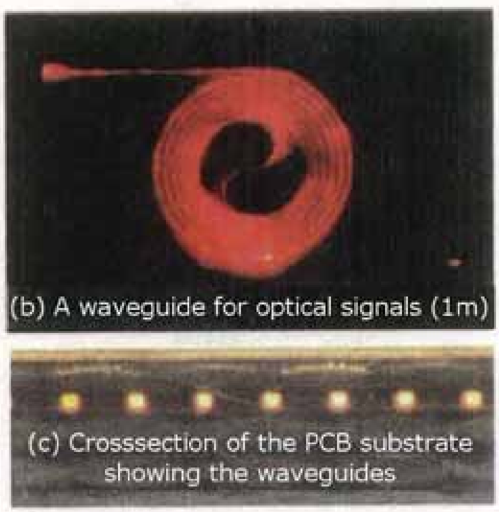


Fig. 3 Showing details of our PCB board for use in high speed high data density measurements

The waveguides are of physical dimensions 50x50um with an overall length of 1m for testing purposes; distance between the waveguides was 250um. Our structure has eight channels running parallel to each other. Since the waveguides are embedded within the board itself there is no problems in connecting the optical signal to optical interfaces and external optical fibers for communication between boards. Also, the construction used standard FR4 boards and as such no extraordinary processing was required in the construction. To test the stability and lifetimes of our boards we used a dummy IC(BGA) which was incorporated into the board after the waveguides were incorporated. This dummy IC was incorporated using standard reflow techniques to see if there were any ill effects on the waveguides due to the heat cycles used. After this we put our boards through a more exacting heat cycle (125/-40C, 500 cycles). After this testing we then tested our system for defects and found none showing the stability of our system.

Normal PCB's with optical lines are manufactured with a polymer that creates a multi mode waveguide. Due to this the optical mode splitting limits the data rate to about 10Gbps. However, our to realize our system a low Δ waveguide structure was used (a low refractive index difference) to lower the mode splitting to allow higher data rates. The same spiral waveguide style as mentioned above was used and the signal loss, for a wavelength of 850nm, was 0.1dB/cm. This figure is very good in comparison to normal polymer waveguide systems. To further test the system we used an impulse test. Figure 4 shows a schematic of the system used.

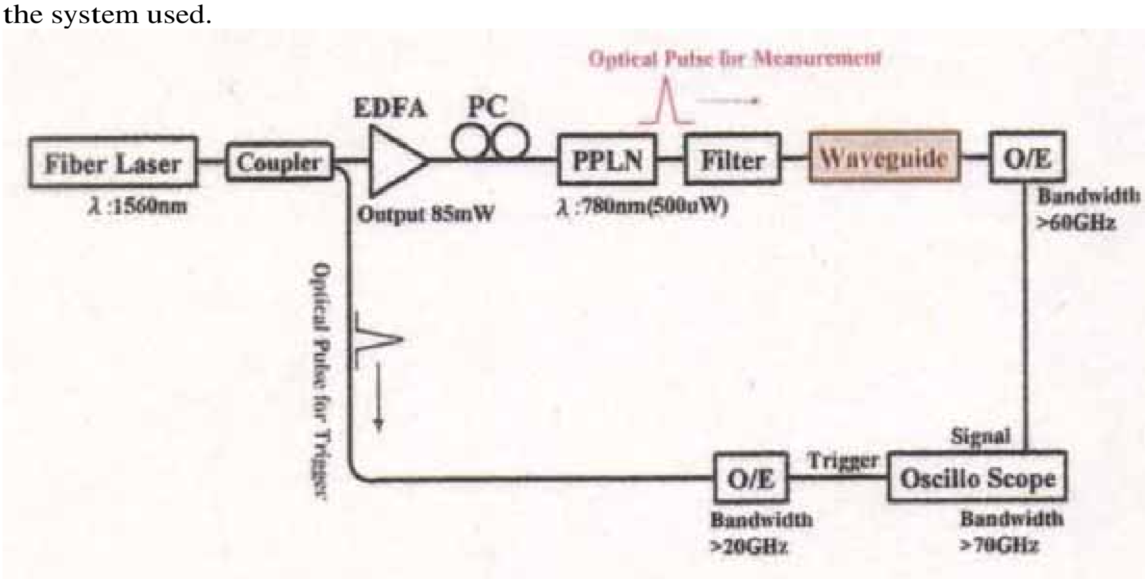


Figure 4. Testing setup for out impulse test

A femto-second fiber laser of wavelength 1560nm was used in conjunction with a high efficiency wavelength converting crystal. This crystal was a periodically-poled lithium niobate (PPLN) crystal resulting in an output of wavelength 780nm with a pulse width of 120fs which was inserted into the waveguide. After traversing the waveguide the output was then analyzed and finally displayed on a sampling oscilliscope. The result was an output of a 10.4ps pulse, which, in comparison to the input, showed an increase of a mere 2.0ps. In figure 5 is shown the comparative input/output fourier spectrum. Here can be seen that a 3dB bandwidth of 75GHz/m was obtained. Also, the simulation result for a NRZ signal (PRBS:2^{31}-1) showed that operation in the 40Gbps range is possible.

Next we input a 40Gbps signal into our system to test it fully. The schematic of the experiment is shown in Fig. 6. A pulse pattern generator was used to output a 10Gbps (NRZ PRBS:2^{7}-1) signal which was split into 4 bands, the output from the split signal ports were delayed by a quarter frequency then output into a multiplexor to result in a 40Gbps signal. This was fed into a DFB laser to create an 40Gbps optical signal of wavelength 1.555nm this was passed through an optical amplifier and then through a wavelength changer to create the signal fed into the DUT. After this the results were shown on a sampling oscilliscope.

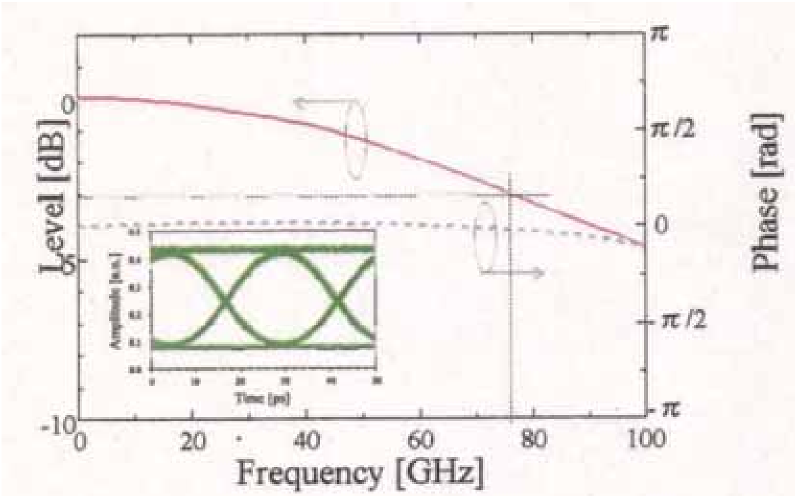


Figure 5. The frequency response of our system

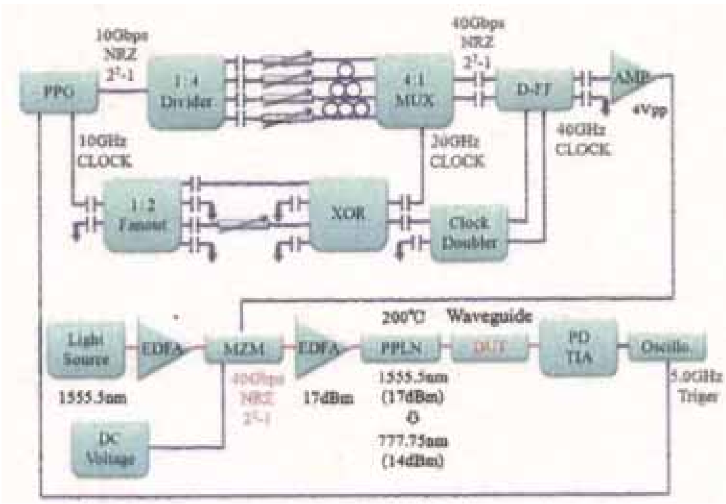
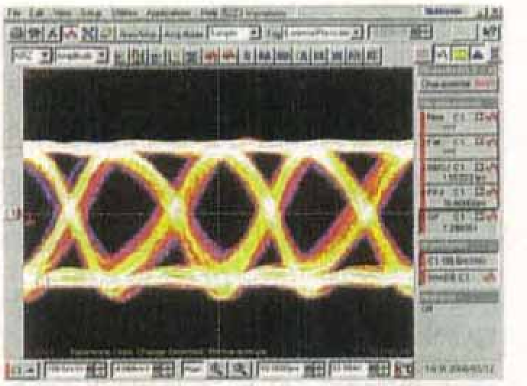


Figure 6. Schematic of the 40Gbps test system

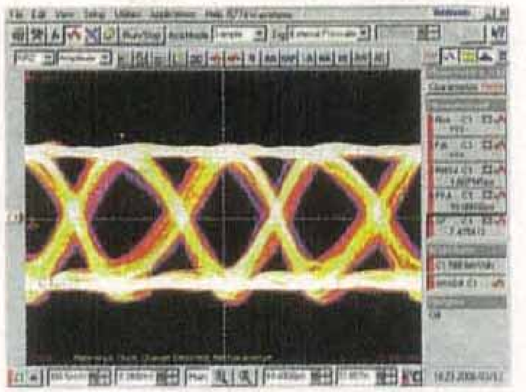
The results are shown in the form of eye pattern diagrams are shown in Fig. 7 below. The patterns are for the signal just before it enters the waveguide and for comparison the signal after it has traversed the waveguide. As can be seen there is little difference between the two eye patterns illustrating that our waveguide system does not degrade the signal. The Q factor was greater than 7 with BER<10^{-12}. All of this shows that our system can operate at 40Gbps.

4. Summary and future work

A PCB board for a measurement system for analysis of high speed high data density communication components was developed. The board was a 10 layer FR4 board with



(a) 40Gbps signal before waveguide



(b) 40Gbps signal after waveguide

Figure 7. The eye patterns for of our system

internal waveguides to facilitate the high speed measurements. Also, a waveguide with a low Δ structure that reduces mode splitting that is very prevalent in standard multimode waveguide systems. Due to this we were able to construct a system, which can operate 40Gbps for a waveguide length of over 1m. Also, it has been demonstrated that our waveguide structure is robust and is not affected by processing such as attachment of IC using reflow techniques. Due to the above we were able to construct an optical waveguide based communication system that can easily operate in excess of 40Gbps. In the future we intend to extend this work by developing a true single mode waveguide system that has completely alignment free devices to further improve the performance of our systems.