Embedded optical interconnect for use in data-storage systems

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A new, active optical-connection technique allows peripheral devices to plug into electro-optical printed-circuit boards at data rates of over 10Gb/s.

Emerging trends in data storage are set to severely impact the design of future storage systems. In the last decade, we have seen a dramatic increase in the volume of data that is captured, processed, stored, and manipulated as digital content. Information is generated from many sources, including critical business applications, email communications, the Internet, and multimedia applications that have collectively fueled an increasing demand for storage capacity. However, the increasing system bandwidth and density required to satisfy this demand would impose unmanageable cost and performance burdens on future data-storage technologies. In particular, the reduction in size of peripheral storage devices—such as hard-disk drives—and the increase in data-communication speeds will expose the system to some of the fundamental constraints encountered when higher-frequency data is transported along electronic channels. Many of these constraints—including crosstalk, dielectric loss, skin effect (leading to limited penetration of a signal into a conductor), and electromagnetic interference—can be mitigated to some degree, but at a mounting cost to the overall system design.

One promising approach is to convey the high-speed data optically instead of electronically, which requires incorporation of optical channels into the system at the printed-circuit-board (PCB) level. While significant advances have been made in embedding conventional optical fibers onto PCBs in Japan,1 focus across Europe over the past decade has been on fabrication of transparent plastic channels (waveguides) directly onto PCB substrates. Various authors2–5 have successfully demonstrated a wide range of waveguide-fabrication techniques. However, a number of challenges remain to be solved before this technology can reach its full commercial potential. One crucial requirement, for instance, is the need for a reliable method of connecting peripheral devices to an optical PCB (OPCB). Recent advances6 have shown how fiber-optic cables can be connected orthogonally to optical channels embedded in the PCB. However, this approach requires the use of right-angled mirrors, which can be expensive and difficult to implement on a commercial scale. To overcome this, we developed a new method of connecting to an OPCB, which precludes the need for both embedded mirrors and intermediary fiber-optic cables.

In a typical data-storage array (see Figure 1), multiple hard drives are connected to controller boards and power supplies across a passive motherboard (known as a midplane). We aim to embed optical channels into the data-storage midplane to overcome a critical communications bottleneck there and develop technologies to plug and unplug the peripheral devices optically to and from the midplane. One of our main achievements has been the invention and first real-world demonstration of a pluggable electro-optical midplane connector.

Since the midplane and its peripherals are connected in a mutually orthogonal way, we developed an in-plane connection method where optical devices on the peripherals’ mating

Figure 1. Typical data-storage array with hard-disk drives connected to one side of the midplane, and controller boards and power supplies to the other.

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Figure 2. Electro-optical midplane and curved waveguide illuminated with 635nm light exiting one of the connector slots. PCB: Printed-circuit board. PCI: Peripheral-component interconnect.

edge can be butt-coupled to optical channels on the midplane. The optical axis of the peripheral device is collinear with the embedded channels, thus eliminating the need for right-angled mirrors and minimizing the number of boundaries incurring optical loss. Our prototype connector incorporates a parallel optical-transceiver circuit that contains four vertical-cavity surface-emitting laser transmitters and four PIN photodiode receiver elements, each capable of data transport at a rate of 10.3Gb/s at an operating wavelength of 850nm. (PIN diodes are characterized by a wide, lightly doped intrinsic semiconductor layer between p- and n-type regions.)

We designed a passive electro-optical midplane, which includes copper layers for power and low-speed bus communication, as well as one polymeric optical-interconnect layer to transport high-speed serial data between peripheral connectors (see Figure 2). The embedded step-index waveguides are made of a polymer that exhibits low optical loss at 850nm. We chose a core size of 70×70μm² to define a multimode waveguide that can meet the alignment tolerances of both the transmit and receive elements. The optical interconnect is framed by a complex routing pattern, which includes crossovers with a range of acceptable intersect angles and cascading bends with radii of 17mm.

To evaluate the viability of these new technologies, we constructed a demonstration platform accommodating four peripheral test cards, each supporting an optical connector. The platform relays high-speed data optically from one peripheral connector to another across the electro-optical midplane (see Figure 3). We successfully operated parallel optical data streams at 10.3Gb/s between all four active connectors with an acceptable level of signal recovery, and fully characterized the loss profiles of the complex optical-waveguide structures. Although the relatively large minimum bend radii required would place significant routing constraints on future OPCB layouts, these can be effectively mitigated in future by refinement of manufacturing techniques, flexibility in crossing angles, and adoption of in-plane mirrored bends.

In summary, the rapidly developing demand for faster and more compact data-storage systems is fueling a need for embedded optical-interconnect solutions. We have therefore developed and successfully demonstrated an active approach that will allow peripheral devices to plug into and unplug from an electro-optical midplane. Our results have thus far been promising. They show that a complex optical-interconnect pattern of polymer waveguides could be used to effectively transport high-speed optical data across a densely populated board. Our next step will be to adapt these prototypes to conventional data-storage peripherals and embed an optical architecture into a future data-storage system.

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References