Optoelectronic Multi-Chip Modules Based on Imaging Fiber Bundle Structures

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Hybrid optoelectronic (OE) chips that include large scale CMOS circuitry with area pads bonded to VCSEL and detector arrays can now be fabricated. Using these devices, it is possible to consider system designs based multiple OE chips connected optically in an optoelectronic multi-chip module (OE-MCM). Successful OE-MCM's must support highly parallel, low latency, and high-bandwidth interconnections with a goal of achieving bandwidth and latency between chips that is comparable to the bandwidth and latency of an electronic channel in a "long metal trace" running from side to side of a single chip. If optoelectronics can meet this performance goal, it will break the limits of feature size and chip area that currently constrain silicon electronic designers.

For an OE device, using flip-chip-bonded VCELS and detectors, it is relatively easy to meet the goal of OE-MCM bandwidth comparable to on-chip bandwidth. Latency is significantly more difficult and can only be achieved if the OE-chips are packaged in close proximity. An OE-MCM package must therefore be a 3D device with dimensions comparable in size to a single chip

In this talk, I will present a number of OE-MCM designs based on rigid segments of imaging fiber bundles. These bundles have been traditionally used in medical imaging systems and remote inspection devices such as flexible endoscopes. They consist of a dense array of small core fibers arranged in a lattice. Fiber diameters typically range from 5 to 20 microns yielding core densities of two to fifteen thousand cores per square millimeter. The relative spatial position of each fiber within the lattice is maintained throughout the length of the bundle. Segments of fiber bundles are uniquely suited to OE-MCM applications since they are simultaneously the package and the interconnection channels of the OC-MEM. The waveguides within the fiber bundle provide both the structural elements and the communication channels.

In our designs, optoelectronic chips are directly bonded to the end surface of the fiber bundle either with an adhesive or be soldering to metal contact plated on the surface. This approach has several advantages over other types of OE interconnection structures. Since all parts of the systems are directly bonded to one another, the package is far more tolerant to thermal and mechanical stress. Minimum size systems can be designed, with time of flight latency based on three dimensional optical paths. Each device needs only to be aligned to the package. There are no global alignment constraints.

I will present designs of OE-MCM structures with high connectively, and low latency designs for small, (three to seven) ensembles of chips. I will demonstrate multiple approaches for scaling these systems to large numbers of devices. I will also present several prototype systems that we have developed in our laboratory.

[1] Donald M. Chiarulli, Steven P. Levitan, Paige Derr, Robert Hofmann, Bryan Greiner and Matt Robinson. "Demonstration of Multi-channel Optical Interconnection using Imaging Fiber Bundles Butt Coupled to Optoelectronic Circuits, *Applied Optics,* Vol. 39, #5, pp 698-703.