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Reconfigurable optical interconnections using multi-permutation-integrated fiber modules

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Introduction In previous work [1] we explored a way to alleviate wiring congestion in massively interconnected multi-chip architectures using cascaded optoelectronic arrays and **fiber-based, plane-to-plane (2D) optical interconnection modules**. The target application for these modules was packet-switching using a buffered, highly scalable multistage interconnection network. We study here **multi-permutation modules** containing a set of independent addressable permutations. Addressing can be done by minute mechanical displacement of the modules (Fig.1). Cascading these modules without intermediate optoelectronic arrays gives a **transparent** multistage architecture adequate for **circuit switching** in weak-interconnected multiprocessors (small set of permutations required, one at a time).

System The multistage "spanned" version of most direct network topologies (like hypercube, cube-connected-cycles, deBruijn) can be implemented using specially designed interconnection modules. Figure 2 represents a "spanned" version of the 4-dimensional weak-interconnected hypercube (16 nodes, 1 bit wide data-bus). It uses four bi-permutation modules, each providing a cube permutation and the identity, which gives a total of 2^4=16 global permutations for the whole network. (Alternatively, using only two of these modules, one can implement an hypercube of dimension 2, with a four bit wide data-bus).

Experiment Fig. 3 shows the four output patterns obtained by setting the first two modules on each of their two possible positions (125μm displacement pitch) for a fixed input pattern. Efficiency of coupling (without additional optics, index matching oil nor antireflection coating) has been measured between modules (1.7dB), validating the simple cascaded architecture. Alignment tolerance is ±5μm (half peak power).

Conclusion The switching fabric studied here provides a limited number of long-range, all-optical interconnections useful for high throughput massively interconnected multiprocessors. MEMS actuators may be interesting when switching latency in the millisecond range is tolerable. Automatic alignment of modules is a critical issue, now being studied both dynamically [1] and statically (prealigned plug and play exchangeable blocks [2]).

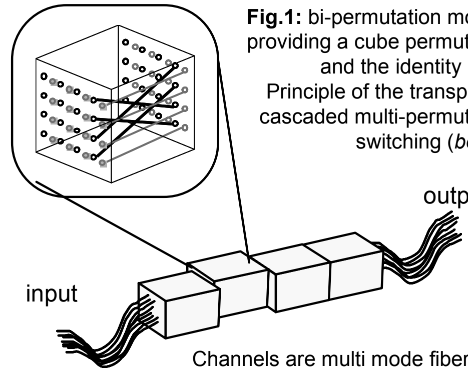


Fig.1: bi-permutation module providing a cube permutation and the identity (*left*). Principle of the transparent cascaded multi-permutation switching (*below*)

Channels are multi mode fibers:
MFD = 9.5 μ m
Grad diameter 125 μm ± 1 μm
NA: 0.1 ± 0.01

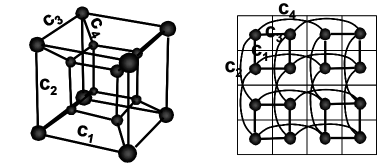
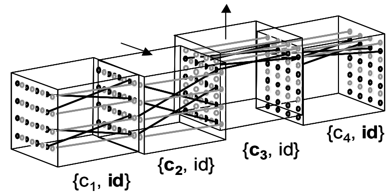


Fig.2 four-dimensional hypercube mapped on a plane (*above*); "spanned" version using bi-permutation modules (*below*).



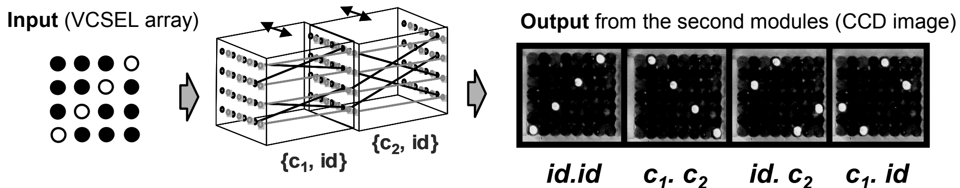


Fig.3: permutation switching in action.

Further research Ongoing research is being carried out at our lab on a similar architecture with additional (electronic) intermediate buffering stages for packet routing purposes using **time-division-multiplexed permutation-routing**. Simulation results are encouraging and besides control simplicity, an additional advantage is that MEMS actuators could be used in AC mode (at their resonant frequencies). However, optical switching (modules with integrated *permutations and directional couplers* for instance) must be used if switching speed needs to be orders of magnitude higher.

[1] Cassinelli et al., JSAP 2002. [2] Naruse et al., JSAP spring meeting 2002. [3] Goulet et al., OJ2000, pp.247-248.