Active alignment of massively parallel free-space board-to-board optical interconnections using an adjustable liquid prism

Tsuyoshi Yamamoto

NTT Network Service Systems Laboratories

Outline

Free-space optical board-to-board interconnections for large-scale switching systems

- Overcome pin bottlenecks in conventional bookshelf-assembled circuit boards

Active alignment system using an adjustable liquid prism

Experimental results

- Positioning error of beams between circuits boards
- Coupling loss between circuit boards

Pin bottlenecks in board-to-board data transmission

Required data throughput between circuit boards in future connection-intensive switching systems:

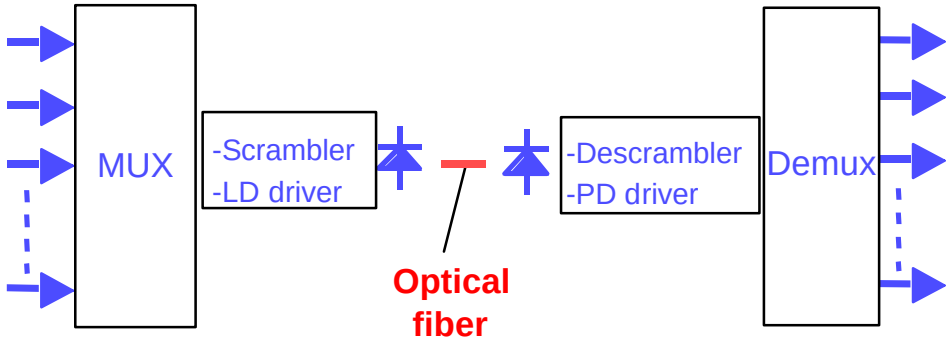
: 540 Gbit/s [MCM(8x4), each chip fabricated by 0.25- m process]

Data throughput between circuits boards in conventional plug-in units
(Hi-PAS standard developed by NTT)

Case1	Number of connectors: 6 (26-pin electrical) Throughput: 156 Mbit/s x 26 x 6= 24.3 Gbit/s
Case2	Number of connectors: 18 (16-pin electrical) Throughput: 156 Mbit/s x 16 x 18= 44.9 Gbit/s
Case3	Number of connectors: 6 (8-pin MU-type optical) Throughput: 2.4 Gbit/s x 8 x 6= 115.2 Gbit/s

Large-scale optical interconnections

Serial-data transmission



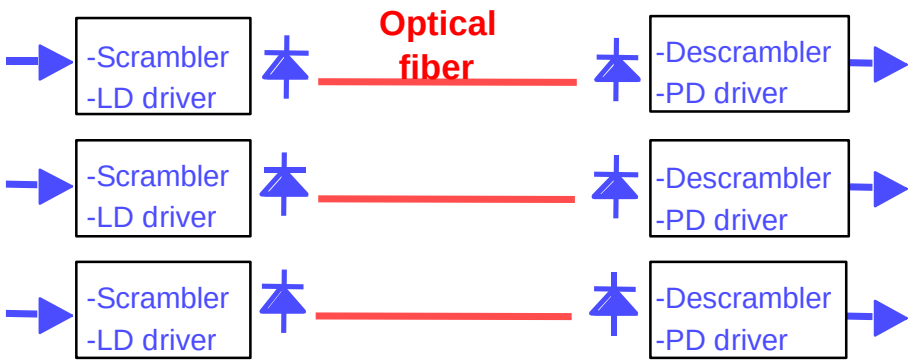
Advantages:

- Pin bottlenecks can be avoided
- Low skew in channels

Disadvantages

- LSIs used for multiplexer are costly
- High power consumption

Parallel-data transmission



Advantages:

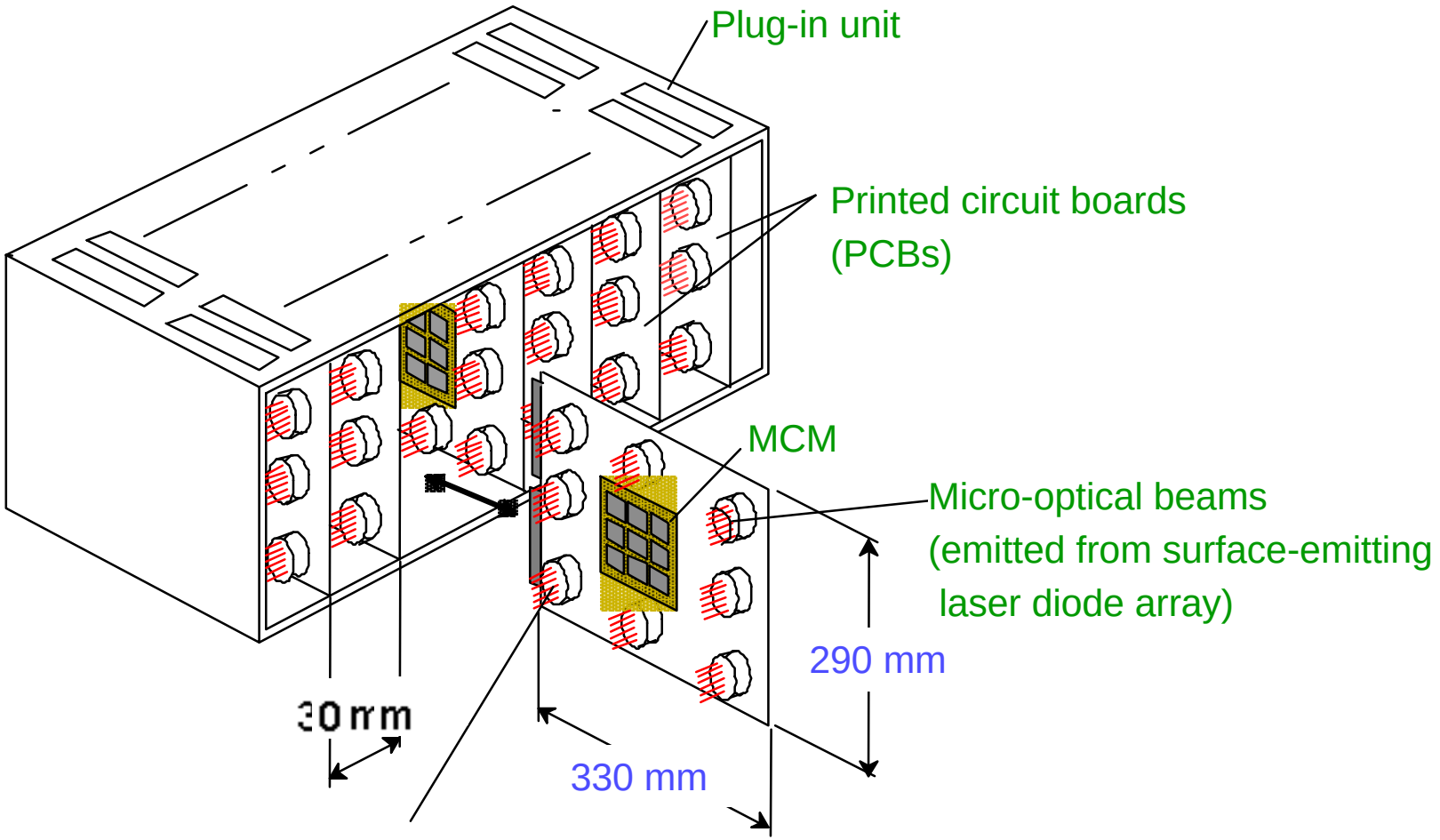
- Special LSIs not needed
- Simple structure

Disadvantages:

-Pin bottlenecks can t be avoided

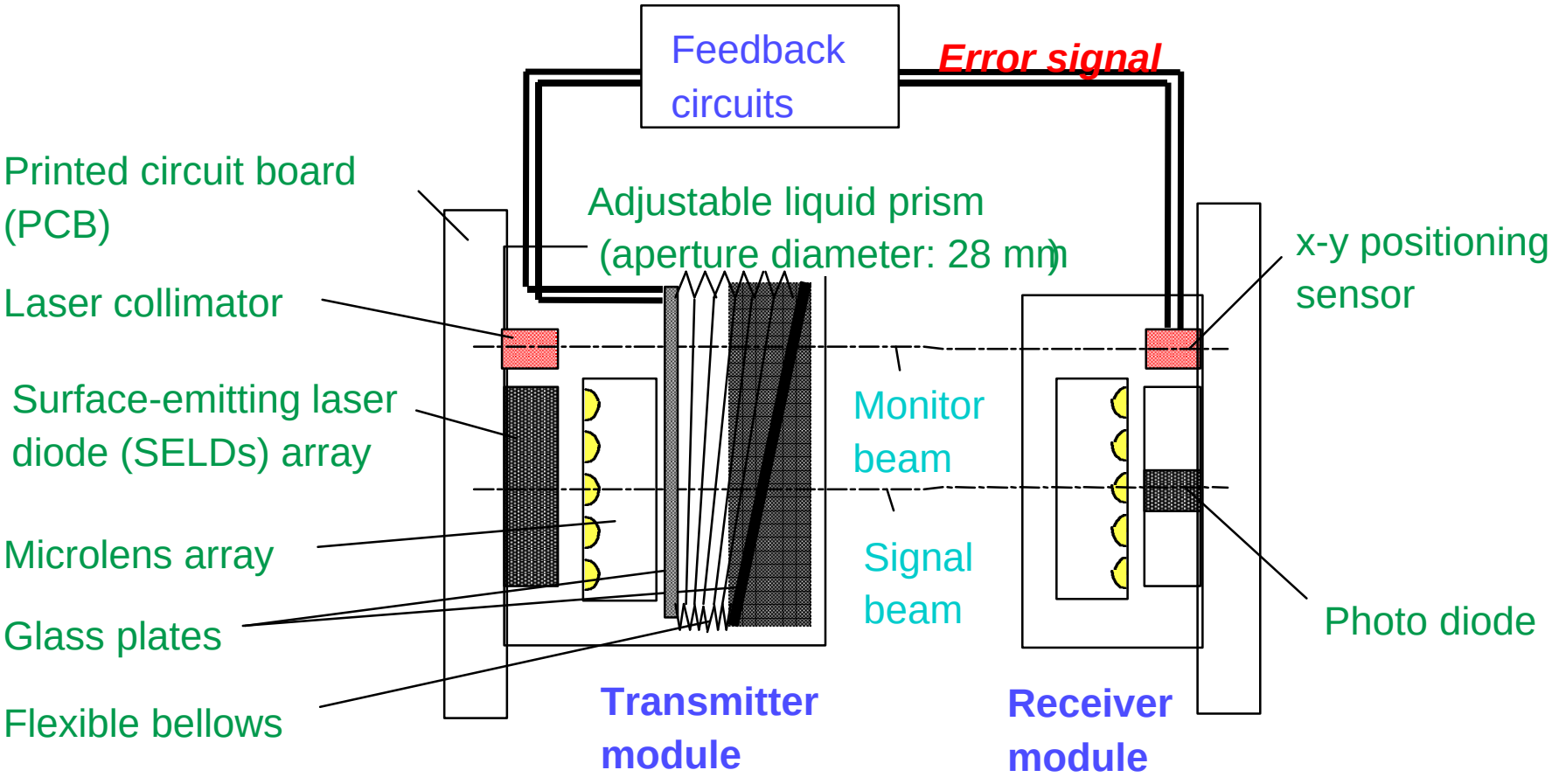
-Optical-fiber packaging is costly

Free-space board-to-board optical interconnections



Transmitter module

Basic setup of active-alignment system



Prototype components

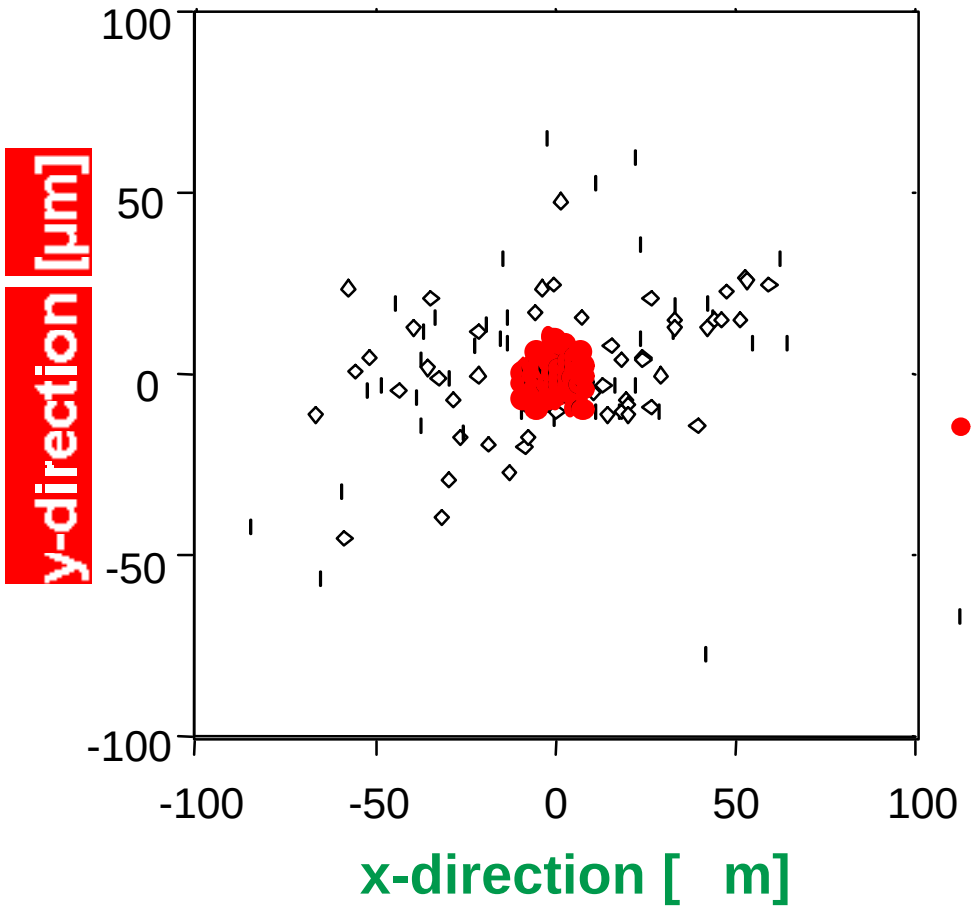
Transmitter module

SELD array (GaAs/AlGaAs)	Dimensions: 8 x 8 or 1 x 8; Cell spacing: 250 m Wavelength: 850-853 nm Output power: 1.0-2.0 mW
Collimating lens array	Planar microlens array Focal length: 650 um; Cell spacing: 250 um
Adjustable liquid prism	Aperture diameter: 28 mm Deflection angle (max.): +/-1.5 deg [Applied voltage: +/-1.0 V]
Fiber collimator	Beam diameter: 200 m

Receiver module

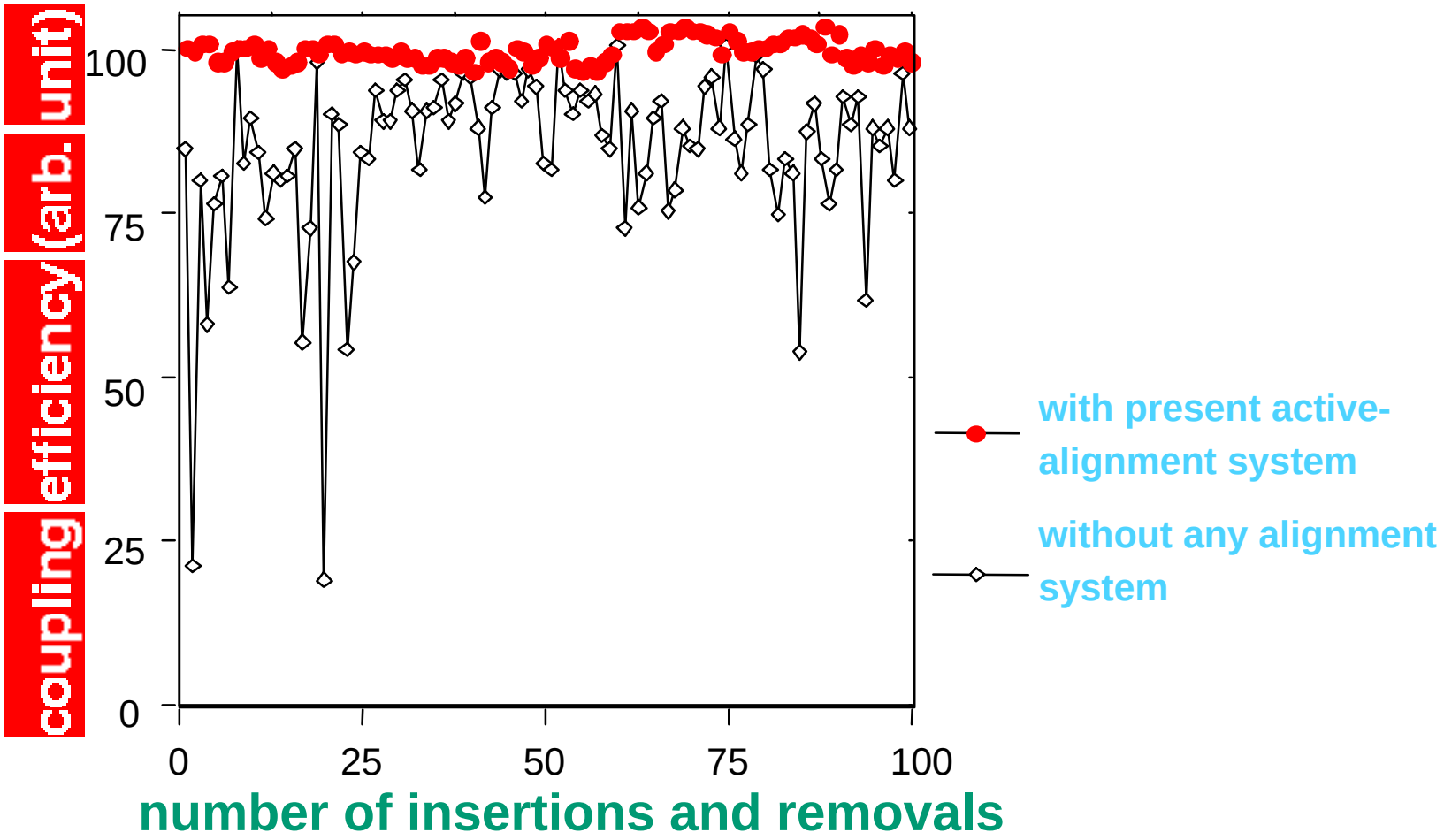
Photo diodes	Si pin Aperture diameter: 20 um
x-y positioning sensor	PSD-S2044 (Hamamatsu Photonics Corp.) Positioning error: < 2.5 um

Positioning-error distribution of beams between prototype boards



- with present active-alignment system
- without any alignment system

Coupling-loss distribution between prototype boards



Summary

Active-alignment system using an adjustable liquid prism for free-space optical interconnections

- **Data throughput: > 250 Gbit/s/cm^2 (640 Mbit/s x 20 x 20)**

Experimental results

- **Positioning error of beams between boards: < 20 m**
- **Coupling-loss distribution: < 5 %**

