1296-port MEMS Transparent Optical Crossconnect with 2.07Petabit/s Switch Capacity

R. Ryf, J. Kim, J. P. Hickey, A. Gnauck, D. Carr, F. Pardo, C. Bolle, R. Frahm , N. Basavanhally , C. Yoh, D. Ramsey, R. Boie , R. George, J. Kraus, C. Lichtenwalner, R. Papazian, J. Gates, H. R. Shea, A. Gasparyan, V. Muratov, J.E. Griffith, J.A. Prybyla, S. Goyal, C.D. White, M.T. Lin , R. Ruel, C. Nijander, S. Arney, D. T. Neilson, D. J. Bishop, P. Kolodner, S. Pau, C. Nuzman, A. Weis, B. Kumar, D. Lieuwen, V. Aksyuk, D. S. Greywall, T.C. Lee, H.T. Soh, W.M. Mansfield, S. Jin, W.Y. Lai, H.A. Huggins, D.L.Barr, R.A. Cirelli, G. R. Bogart, K. Teffeau, R. Vella, H. Mavoori, A. Ramirez, N.A.Ciampa, F.P. Klemens, M.D. Morris, T. Boone, J.Q. Liu, J.M.Rosamilia, C. R. Giles

Lucent Technologies
791 Holmdel-Keyport Rd
Holmdel, NJ 07733
Email: ryf@lucent.com

Agere Systems
600 Mountain Ave.
Murray Hill, NJ07974-0636

Abstract
A 1296-port MEMS transparent optical crossconnect with 5.1dB+/-1.1dB insertion loss at 1550nm is reported. Measured worst-case optical crosstalk in a fabric was ñ38dB and nominal switching rise/fall times were 5msec. A **2.07Petabit/s** switch capacity was verified upon cross-connecting a forty-channel by 40Gb/s DWDM data stream through a prototype fabric.

Summary
Major data communications optical networks are growing in capacity and sophistication to accommodate the demand for reconfigurable and reliable Internet data transport. Traditional SONET rings can no longer economically manage the data traffic and more flexible mesh architectures are looking attractive. Optical crossconnects would then manage WDM traffic at major network intersections, redirecting optical channels as dictated by provisioning, protection and restoration needs. Hundreds of optical fibers with potentially one hundred or more WDM channels may reach a central office, necessitating large, scalable optical crossconnects[1-3]. Here we report a 1296-port transparent, strictly nonblocking, Micro-ElectroMechanical Systems (MEMS) optical crossconnect. The fabric had a mean insertion loss of 5.1dB (1530-1560nm), worst-case optical crosstalk of ñ38dBand nominal connection rise/fall times of 5msec. Single-port data capacity of 1.6 Tb/s using forty 40Gb/s DWDM channels was demonstrated in a prototype subsystem, which when fully implemented to populate all ports of a 1296-port fabric, corresponds to 1296x1.6Tb/s=**2.07Petabit/s** switch capacity.

This new optical crossconnect was assembled using two integrated 1296-MEMS single-crystal silicon mirror arrays and matching lens-fiber arrays [1]. The MEMS-mirrors were built as electrostatically actuated gimbal structures capable of 2-axis tilt motion and the mirror arrays were sealed behind glass windows in ceramic packages. The MEMS mirrors were designed for sustained operation with a maximum electrode voltage of 200V. Single-mode optical fiber input and output ports were arranged in lens-fiber assemblies, comprised of 36x36=1296 square-pitch fiber bundles, having matching collimating lenslet arrays. Both diffractive and refractive lenslet arrays were tested, the diffractive lenses were designed for restricted wavelength operation, the refractive-element design extended the fabricís operating wavelength range to ~1300nm-1600nm.

Figure 1 shows a schematic of switch fabricís opto-mechanical layout. The figure also shows the placement of a retroreflector, enabling the use of one MEMS mirror array and lens/fiber array with half of the MEMS mirrors committed to input-ports and the remaining committed to output-ports. This folded configuration was used in the DWDM signal switching experiments. In operation, prescribed voltages are applied to the input- and output-mirror electrodes, steering input optical beams to impinge on the output-destination mirrors that are tilted to minimize coupling loss to the output-ports. The photographs in figure 2 show front-views of a 1296-port optical switch module and of a prototype crossconnect tested in the folded configuration. The prototype shows that the majority of the bay area is occupied by optical port connectors, and highlights the density of the drive and control electronics.

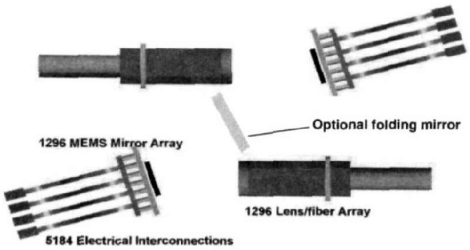

Figure 1. Optical layout of the 1296-port switch fabric. A gold mirror retroreflector placed in the middle of the optical path enables the use of a single MEMS mirror array and lens/fiber array to implement a folded-geometry 648-port fabric.

The loss spectrum of the prototype crossconnect was dictated by the optical properties of the diffractive lenses in the lens/fiber array, which were designed to match the C-band requirements of amplified optical line systems. Connections measured between 60 input ports and 60 output ports yielded a mean insertion loss of 5.1dB+/- 1.1dB. Figure 3(a) shows the loss spectrum of a typical connection through the fabric. Optical crosstalk to output ports adjacent to an established connection was ñ58dB,and worst-case crosstalk originating during beam scanning was less than -38dB. The mechanical response of the MEMS mirror resulted in nominal 5 msec rise/fall times of connections, as shown by the output-port signal response in figure 3(b). In laboratory-environment tests, connection losses were stable to within 1dB over a 1hour period without any active mirror control.

The data capacity and spectral bandwidth of the prototype optical crossconnect was verified by switching a forty channel by 40Gb/s DWDM data stream through the fabric (PRBS length:2^{31} - 1). The experiment used forty multiplexed DFB lasers on a 100GHz channel spacing centered at 1545nm and externally modulated using a single common lithium niobate modulator. This DWDM source was connected to one input port of the prototype crossconnect and switched to the output ports. The total input optical power was 16dBm with 0dBm average channel power. DWDM channels were demultiplexed after the switch fabric and detected by an optically preamplified receiver having -29.5dBm sensitivity at 10E-9 BER. Figure 4 shows the input and output DWDM optical spectra of the fabric together with measured bit-error-rate performance of three connections at four wavelengths. No noticeable signal degradation was observed and error-free transmission through the switch fabric was consistently obtained for all connections and channels. These results confirm the potential aggregate switch capacity for this transparent optical crossconnect of 1296x40x40Gb/s=2.07Petabit/s. This data transparency and the ability to switch DWDM data streams with low optical loss, are suitable for cost-effective management of the vast traffic patterns evolving with the growth of Internet data.

In summary, a 1296-port MEMS-based free-space optical crossconnect with 2.07petabit/s switch capacity has been described. The low insertion loss (5.1dB), low optical crosstalk (-38dB worst-case), and fast switch response (5msec optical rise/fall times) enable the practical implementation of a new generation of scalable switch fabrics capable of managing diverse optical signals found in complex optical networks.

References

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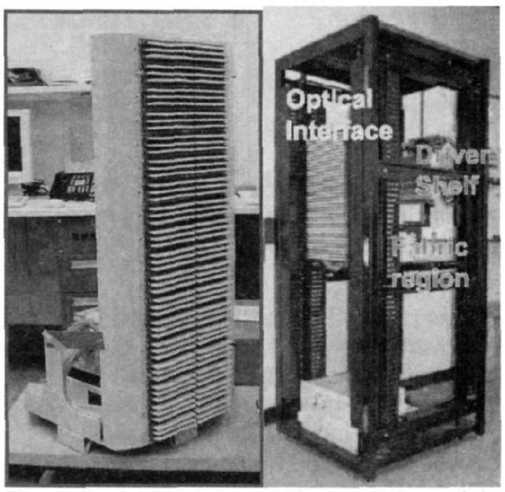

Figure 2. (a)1296-port optical switch module and (b) 648-port folded-geometry optical crossconnect prototype.

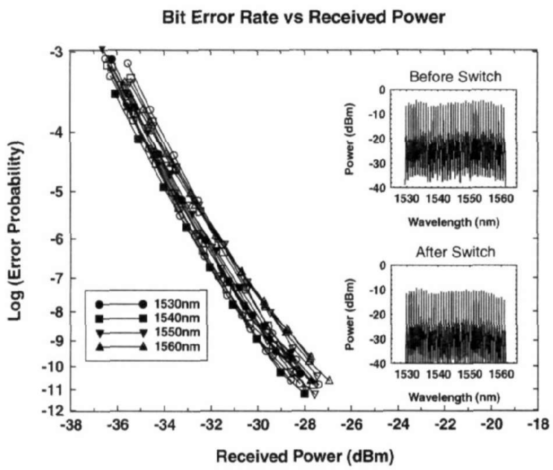

Figure 4. BER of 4 DWDM channels in 3 connections (baselines=solid symbols). Insets show spectra before and after the fabric.

Figure 3. (a) loss spectrum of prototype crossconnect with diffractive lenslet array and (b) output optical signal response upon setting up the connection.