Lecture 23
Optical MEMS (5)

- Agenda:
  - MEMS in Optical Communications

MEMS in Optical Communication Systems

Giles et al., IEEE J. STQE, 1999
MEMS in Optical Communication Systems

- Provisioning Switches
- Protection Switches
- Equalizers
- Cross-connect Switches
- Variable Attenuators
- Filters
- Modulators
- Add/Drop Multiplexers
- VCSELs
Variable Optical Attenuators (VOAs)

- **Tilt Micromirror**

![Tilt Micromirror Image](image1)

- **Variable Optical Attenuators (VOAs)**

- **Tilt Micromirror Array**

![Micromirror Array Image](image2)

For Add/Drop Multiplexer (Lucent)
Variable Optical Attenuators (VOAs)

- Lucent 2D Tilt Micromirror

“Two-Axis” Micromirror

Flag Switch Type

Giles, Aksyuk, Barber, Ruel, Stulz, and Bishop, IEEE JSTQE, 1999
### Closed-loop Control

**Variable Optical Attenuators (VOAs)**

- **Source**: 1550nm ASE
- **Switch**: MEMS
- **Feedback Circuit**:
  - Amplifier: $A = 20$ dB
  - Amplifier: $A = 10$ dB
- **Receiver**: 16mW/μW
- **Optical Power Monitor**

![Graph](image)

Giles et al., IEEE JSTQE, 1999

### Wavelength Add/Drop (WAD) Multiplexer

**Diagram Description**

- **WDM Max**: Wavelength Division Multiplexer
- **Focus Lens**: Used for alignment
- **Cathode**: Part of the device
- **Pass**: Optical mode
- **ADD**: Add mode
- **DROP**: Drop mode

Ford, Aksyuk, Bishop and Walker (Lucent), J. Lightwave Tech., 1999
### MEMS Optical Switches

<table>
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<tr>
<th></th>
<th>Lucent</th>
<th>Cronos (JDS)</th>
<th>Xros (Nortel)</th>
<th>Calient</th>
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#### Trade-offs:

- **Vertical mirrors**: Easy to place other optical components including fibers; but need more complicated process
- **Horizontal mirrors**: Easy to fabricate; but need 3D construction
MEMS Optical Switches

- Lucent 2-axis Scanning Micromirror Array

MEMS Optical Switches

- Lucent 3-D Lamda Router

MEMS 2D Mirror Array
Lucent MEMS OXC

MEMS DEVICE:
- 2-axes, angular range of > ±3°
- continuous, controlled tilt
- directly scalable to 256 mirrors (1024 in the long term)
- simple technology for rapid development/prototyping
- manufacturable

Mirror Array Chip

Prototype
**Calient Networks 3D MEMS OXC**

- 256 x 256
- 1.4 dB insertion loss

Zheng et al., IEEE JSTQE, 2003

**NTT 3D MEMS OXC (100 input and 100 output ports)**

Yamamoto et al., IEEE Photonics Technology Letters, 2003
**NTT 3D MEMS OXC**

Summary of the optical characteristics:
- Insertion loss: 4.0 [dB]
- Return loss: > 30 [dB]
- PDL: < 0.5 [dB]
- Crosstalk: < -60 [dB]

Yamamoto et al., *IEEE Photonics Technology Letters, 2003*

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**MARS – Mechanical Anti-Reflection Switch**

- Unbiased: mλ/4 air gap (m odd - reflection)
- Biased: (m-1)λ/4 air gap (m even - anti-reflection)

Walker, Goossen and Arney (Lucent)
- Electromagnetic Switch

C.H. Ji et al. (LG Electronics Inst. of Tech.), IEEE JSTQE, 2004
MEMS 2x2 Optical Switch

- Electrostatic Sidewall Micromirror

http://www.sercalo.com/

Tunable VCSEL

Chang-Hasnain, UC Berkeley