Integrated Optic and Fiber Optic Devices for Communication and Sensor Networks

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DARPA/MTO, WDM for Military Platforms Workshop held in McLean, VA on April 18-19, 2000, The original document contains color images.
WDM-Related Research at Texas A&M University

• Electrooptic Tunable Filters for Fiber Optic Networks
• Slow Wave Electrooptic Modulators for Reduced Microwave Drive Power and Improved Response Linearity
• Fiber Fabry-Perot Interferometer Sensors for Measuring Pressure, Temperature, and Strain
Electrooptic Tunable Filter (EOTF)
Electrooptic Tunable Filter Development

Objective

Develop filter to meet requirements of dense wavelength multiplexing:

- Polarization independence
- 50 or 100 GHz channel spacing
- Submicrosecond tuning
- < 3 dB insertion loss
- < -25 dB interchannel crosstalk
Electrooptic Tunable Filter Development
Technical Approach

- Substrate: lithium niobate
- Waveguide structure: Mach-Zehnder interferometer; polarizing beam splitters not required
- Polarization coupling: periodic, strain-inducing silicon dioxide film
New 4-Port EOTF Design

\[ \nu_j, \ldots, \nu_{1N} \]

except \( \nu_j \)

strain-inducing strips

electrode

\( \nu_1, \ldots, \nu_N \)

beam splitter

single mode optical waveguide

\( V_{j} \)
TE/TM Mode Conversion

Channel Waveguides with Grating

Conversion Efficiency
\[ \eta_{TE(TM)} = \frac{P_{TM(TE)}}{P_{TM} + P_{TE}} \]

Conversion Bandwidth
\[ FWHM = 0.8 \frac{\lambda}{N} \]
N: number of grating periods

PA: Polarization Analyzer
Mode Conversion Efficiency and Thermal Tuning

![Graph showing mode conversion efficiency and thermal tuning]
FWHM of Filter

TM to TE, FWHM=2.32nm

TE to TM, FWHM=2.28nm
Polarization Splitter (TE/TM splitter) (Ti: LiNbO$_3$)

Principle: Two Mode Interference (TMI)

Angle $= 0.55^0, 0.62^0$

**TM Mode:**

$$ER = -10 \log \left( \frac{P_1^{TM}}{P_1^{TM} + P_2^{TM}} \right)$$

**TE Mode:**

$$ER = -10 \log \left( \frac{P_1^{TE}}{P_1^{TE} + P_2^{TE}} \right)$$

ER: Extinction Ratio

TM Mode: 57$\mu$m

TE Mode: 7$\mu$m
Experimental Results of Splitter

\[ ER[dB] = 10 \log \left( \frac{P_{TE(TM)}}{P_{TM(TE)}} \right) \]
EOTF Summary

- High (>99.5%) polarization conversion was achieved in channel waveguides.
- High (> 25 dB) extinction ratio has been obtained in polarizing beam splitters.
- New EOTF design with relaxed beam splitter requirements has been proposed.
- Completion of first four-port EOTFs is planned for Dec. 2000.
Low-Voltage SBN Modulator

substrate material: SBN:60
waveguide loss: < 0.3 dB/cm
voltage-length product: 0.25 V-cm
Summary of SBN Results

- Low-loss (0.3 dB/cm) strain-induced waveguides
- Low optical damage susceptibility (<< lithium niobate, < lithium tantalate)
- GHz modulation demonstrated
- Record low voltage-length product (0.25 V-cm)
Slow Wave Electrooptic Light Modulator

- Slow wave propagation regime
- Microwave in
- Single mode optical waveguide
- Cw light in
- Coplanar electrode
- Electrooptic substrate
- Line termination
- Modulated light out
Slow Wave Electrooptic Modulator
Potential Benefits

- Orders-of-magnitude reduction in electrical drive power
- Improved response linearity and SFDR
Fiber Sensors for WDM Networks

Fiber Fabry Perot Interferometer (FFPI)  FFPI Strain Sensor
Fiber Sensors for WDM Networks

FFPI Pressure Sensor       Engine Instrumented with
                          FFPI Pressure Sensors
Demonstrated FFPI Sensor Measurands

- Pressure (static, acoustic, ultrasonic)
- Temperature
- Strain
- Magnetic field
- Acceleration
- Flow rate
FFPI Sensors for WDM Networks

- FFPI sensors can operate at high temperatures (to 1200 K), high pressures (> 10 kpsi) and high speeds (> 50 kHz)
- Readout using white light interferometry (WLI) provides absolute parameter measurement (dc performance) and multiplexing of many sensors on one fiber
- FFPI sensors are produced by Fiber Dynamics, Bryan, TX
Conclusion

Electrooptic tunable filters, slow wave modulators, and FFPI sensors are emerging technologies with considerable potential for application in military and commercial WDM networks.