

Integrated Optic and Fiber Optic Devices for Communication and Sensor Networks

Henry F. Taylor

Electrical Engineering Department

Texas A&M University

College Station, Texas 77843

taylor@ee.tamu.edu

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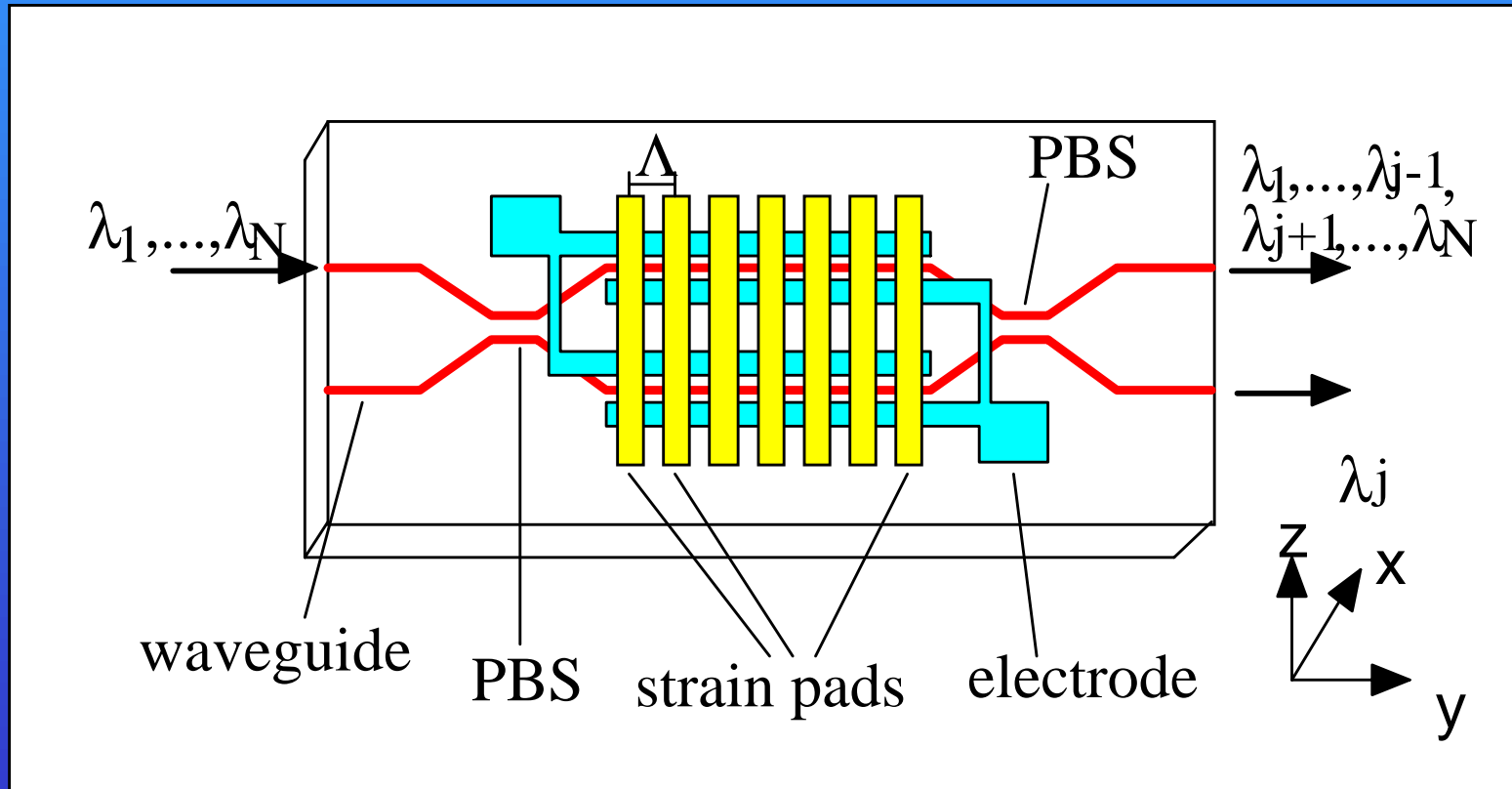
WDM-Related Research at Texas A&M University

- 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

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Electrooptic Tunable Filter (EOTF)



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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

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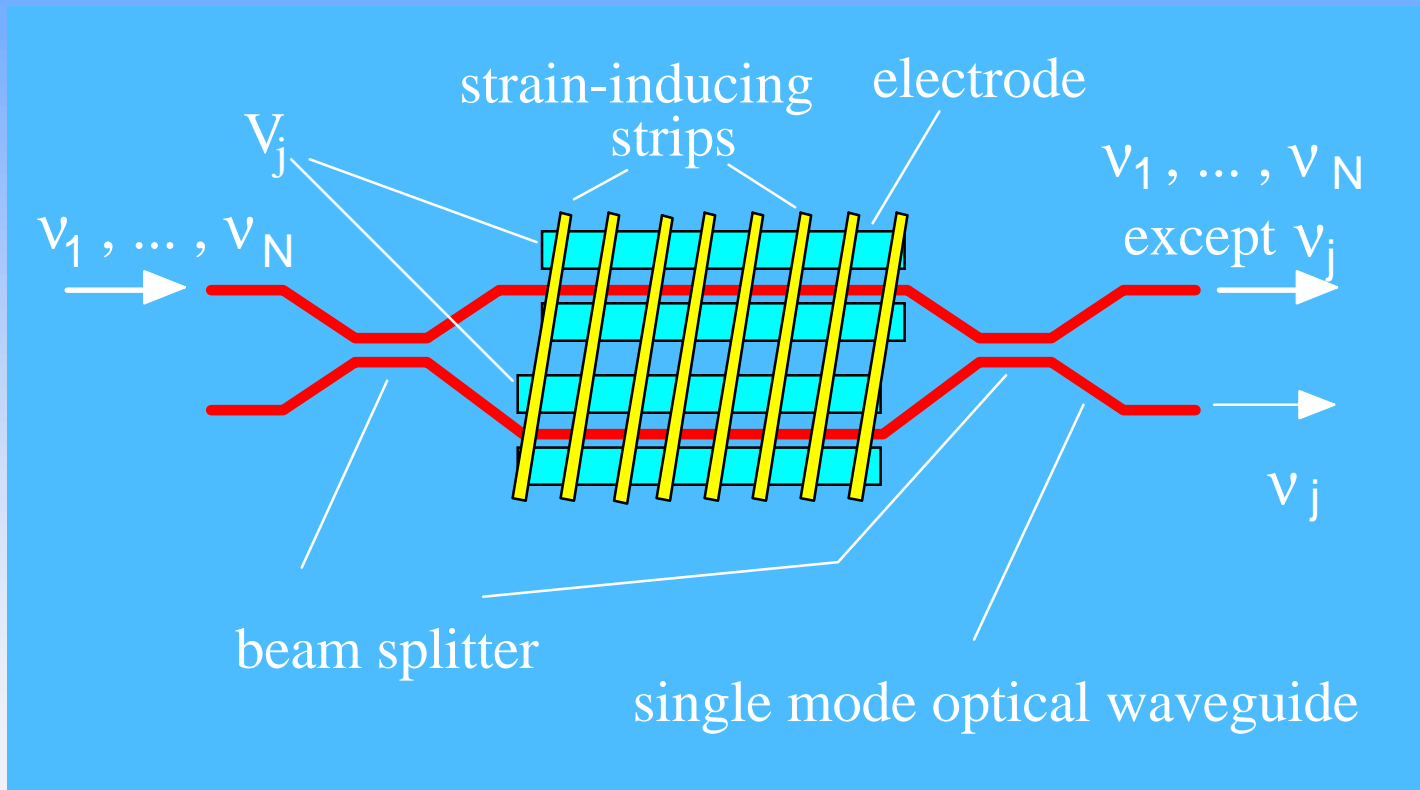
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Electrooptic Tunable Filter Development

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

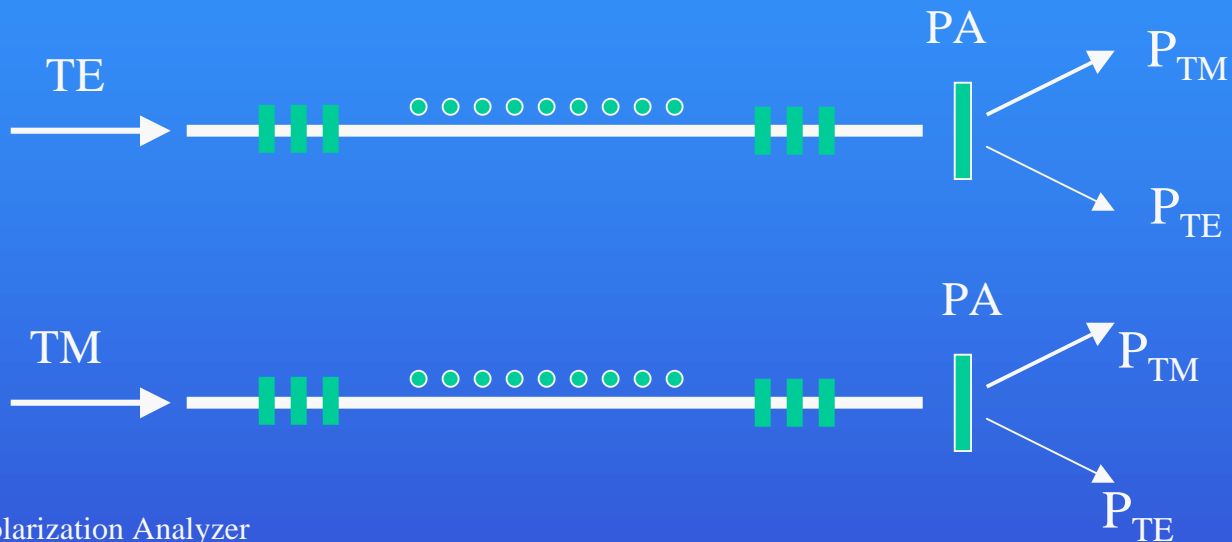


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TE/TM Mode Conversion

Channel Waveguides with Grating



PA: Polarization Analyzer

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

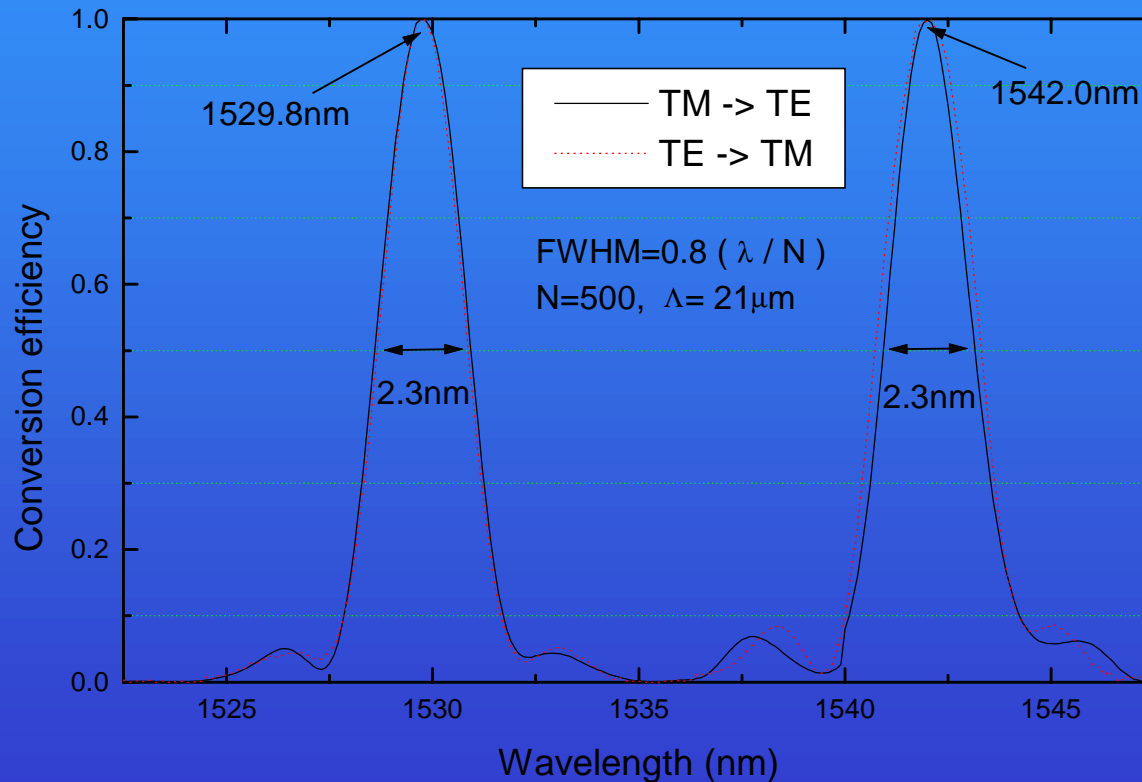
Conversion Bandwidth $FWHM = 0.8 \frac{\lambda}{N}$

N: number of grating periods

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Mode Conversion Efficiency and Thermal Tuning



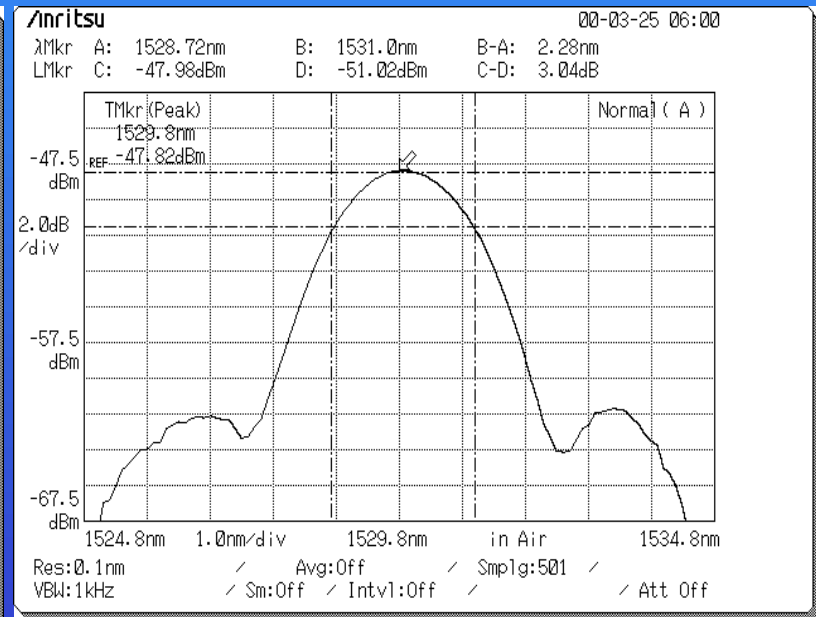
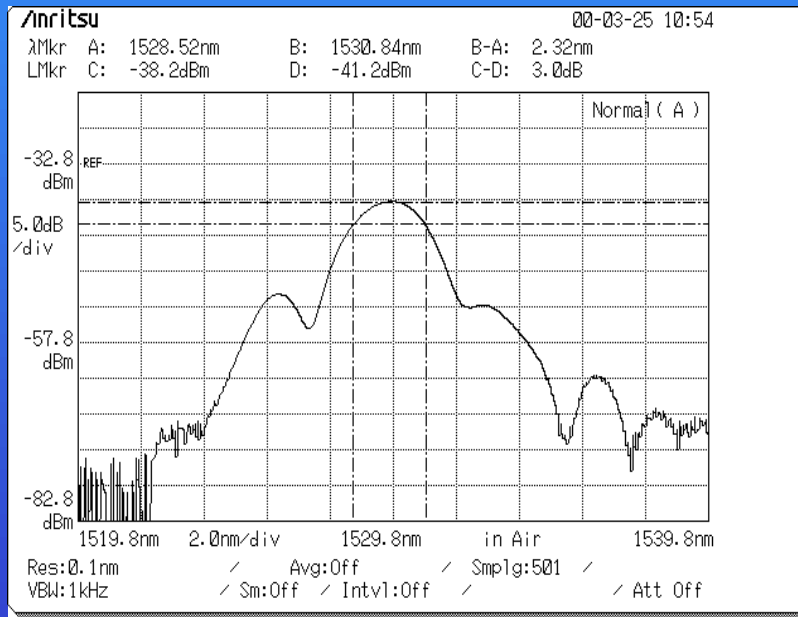
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FWHM of Filter

TM to TE, FWHM=2.32nm

TE to TM, FWHM=2.28nm

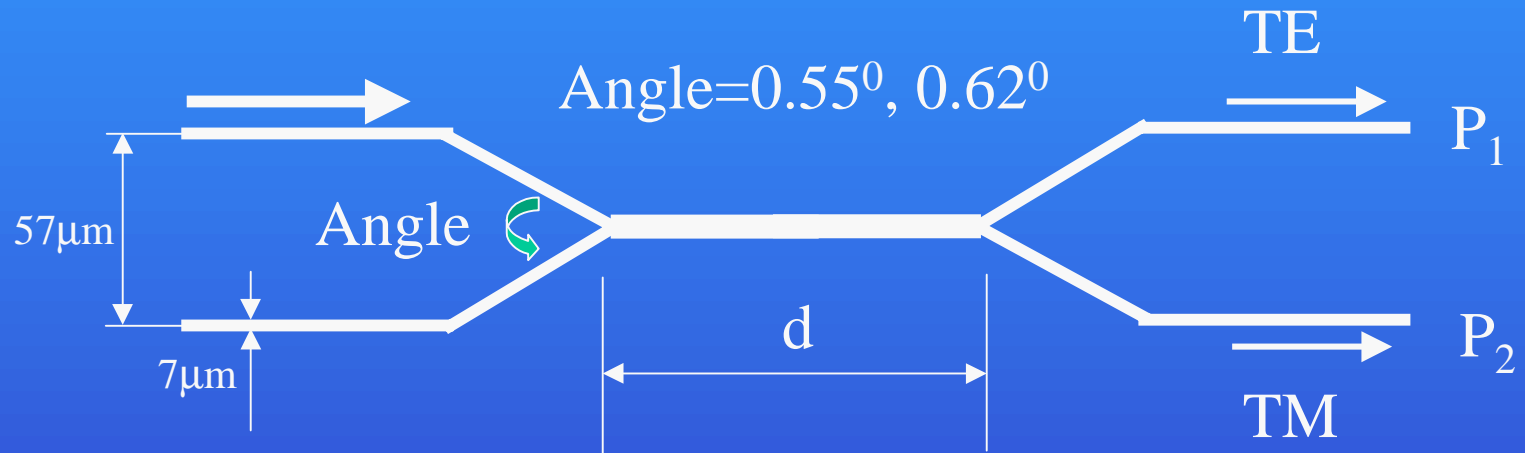


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Polarization Splitter(TE/TM splitter) (Ti: LiNbO₃)

Principle: Two Mode Interference (TMI)



ER: Extinction Ratio

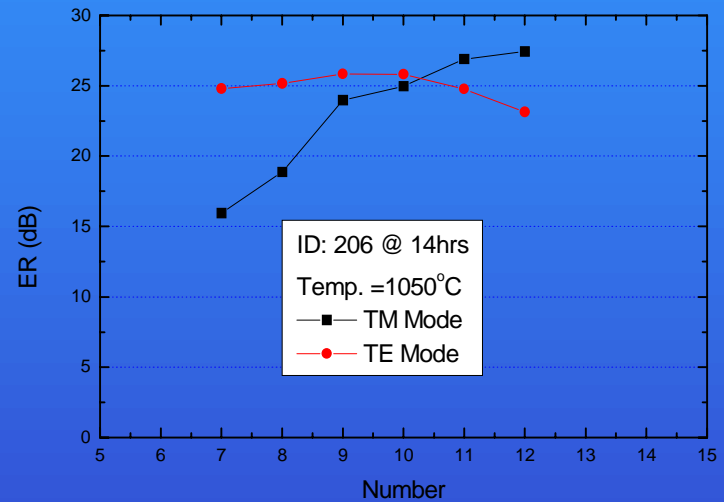
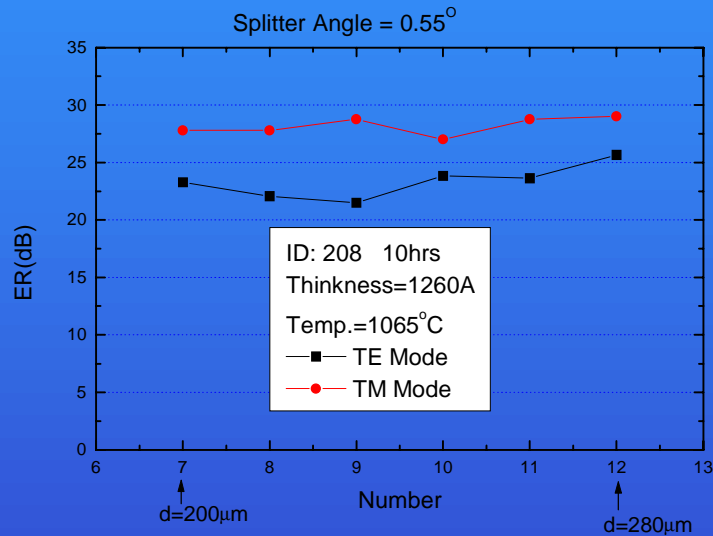
$$\text{TM Mode: } ER = -10 \log \left(\frac{P_1^{TM}}{P_1^{TM} + P_2^{TM}} \right)$$

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

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Experimental Results of Splitter



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

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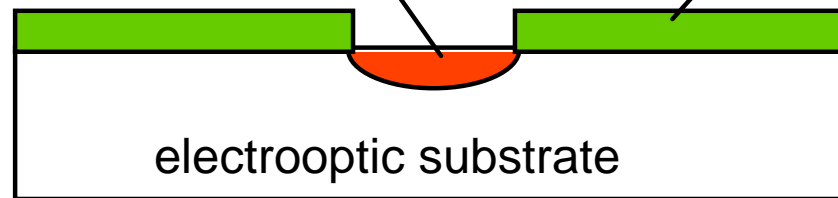
EOTF Summary

- 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

strain-induced waveguide

electrode



substrate material: SBN:60

waveguide loss: < 0.3 dB/cm

voltage-length product: 0.25 V-cm

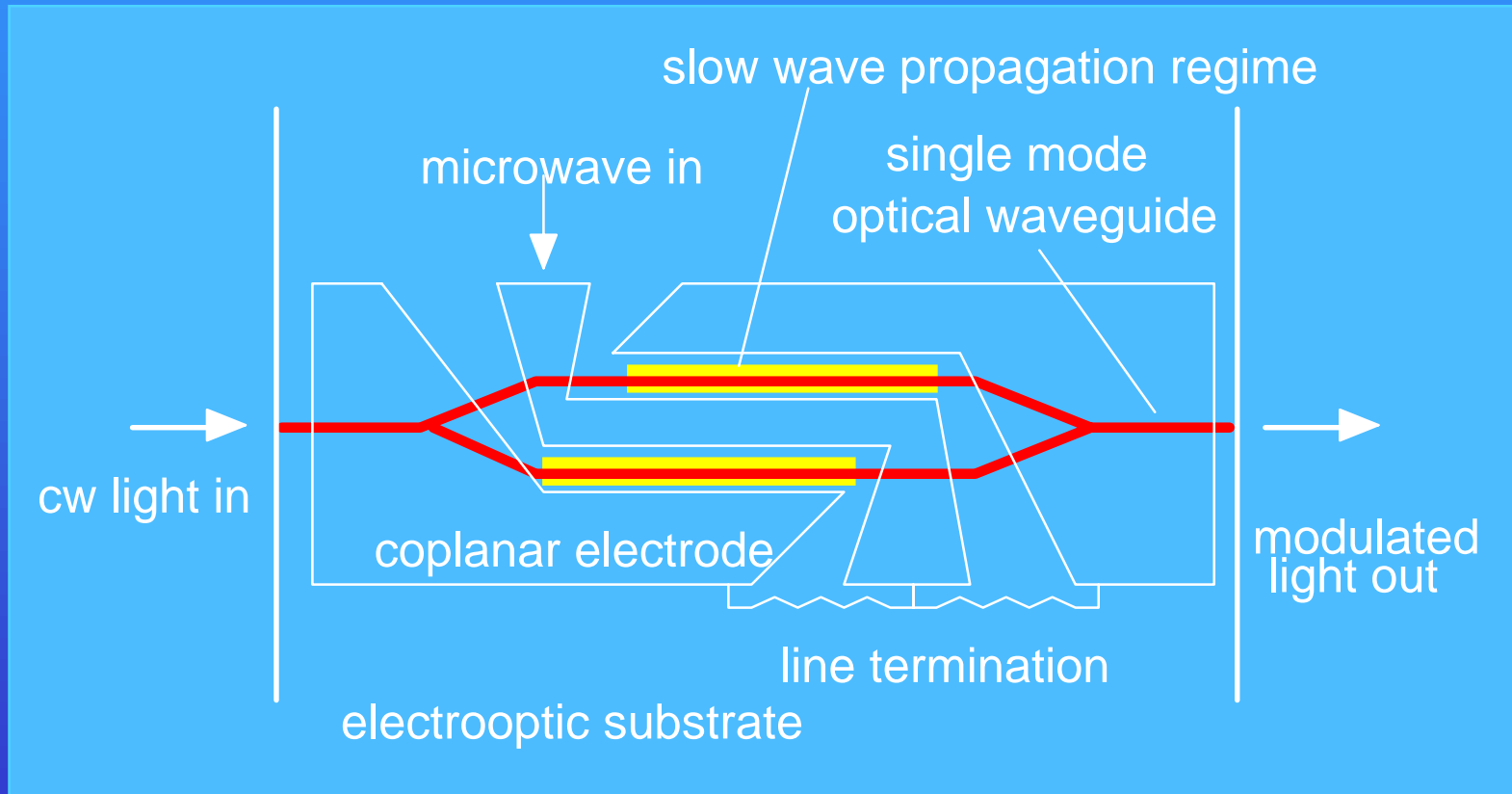
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Summary of SBN Results

- Low-loss (0.3 dB/cm) strain-induced waveguides
- Low optical damage susceptibility (\ll lithium niobate, $<$ lithium tantalate)
- GHz modulation demonstrated
- Record low voltage-length product (0.25 V-cm)

Slow Wave Electrooptic Light Modulator



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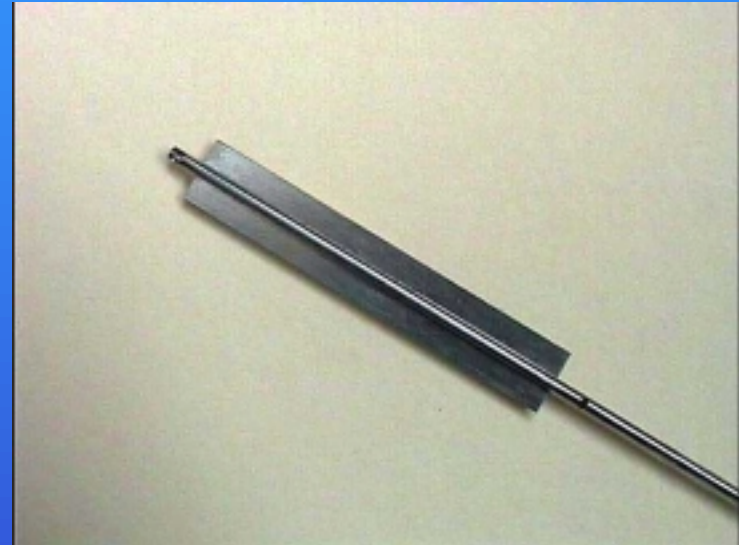
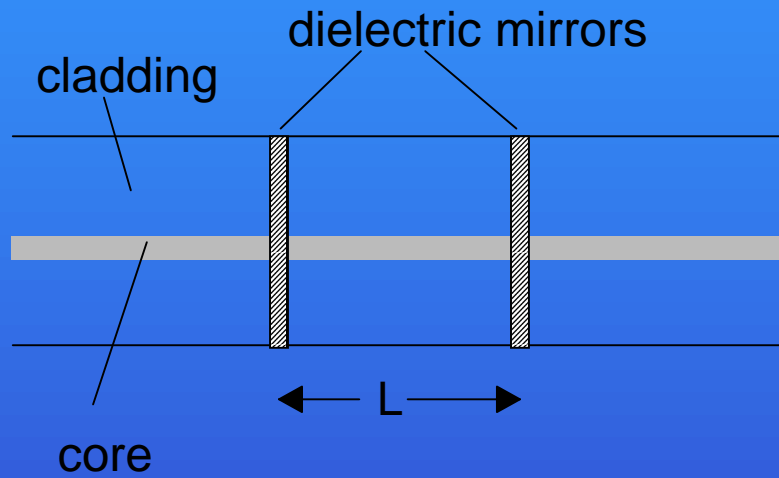
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Slow Wave Electrooptic Modulator

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

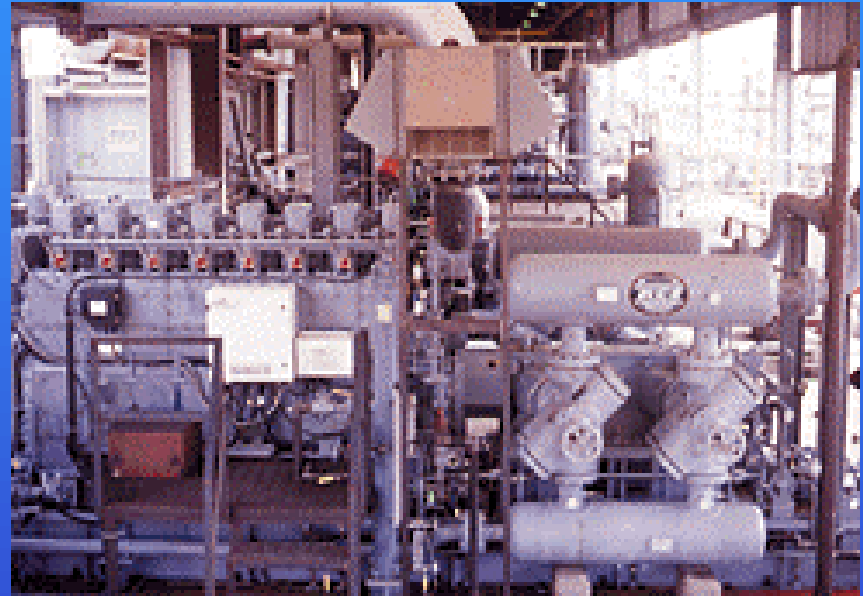
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Fiber Sensors for WDM Networks



FFPI Pressure Sensor



Engine Instrumented with
FFPI Pressure Sensors

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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

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Conclusion

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