Wavelength-Sensitive Thin-Film Filter-based Variable Fiber-Optic Attenuator with an Embedded Monitoring Port

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WDM Variable Optical Attenuator Architectures

• Structure I

- Three-Port VOA Array
- N Three-Port VOAs
- Two MUXs/DeMUXs
- FBC: Feedback Controller

Can be reduced?
• Structure II

- N Two-Port VOAs
- One MUX/DeMUX
- One Optical Circulator *Can be eliminated?*
Our Proposed WDM VOA Architecture

- No Optical Circulator
- No MUX/DeMUX
Motivation of Using Commercially Available Thin Film Filter

- Low Cost Device
- Low Optical Loss
- Low Polarization Dependent Loss
- Low Polarization Mode Dispersion
- Moderate Optical Isolation
- High Durability
Our Proposed Wavelength Sensitive Thin Film Filter-based Three Port Fiber-Optic Variable Attenuator

- Mirror & TF are Simultaneously Moved in the Analog Fashion
- Each Component is Controlled by One Actuator
- Ease of Free-Space Alignment
- Speed \( \sim \) Speed of Typical Mechanical VOA

Theoretical Analysis

Optical Power at OUT:

\[ P_o = 1 - \text{erf}(\sqrt{2}x / w) \]

Optical Power at PD:

\[ P_m = \text{erf}(\sqrt{2}x / w) \]

x: Position of TF \quad w: Optical Beam Radius at the Mirror/TF Plane
Our Experimental Demonstration

- Tunable Laser: Santec, Inc., TSL-210, 1530-1610 nm
- TF: Thin Film Filter Centered at 1546.12 nm
Measured Optical Loss

• At OUT Port:

  Measured Optical Loss = 0.47 dB

• At Monitoring Port:

  Measured Optical Loss = 1.04 dB
Measured Dynamic Range

- Measured Optical Power

Agrees Well with the Theoretical Analysis

Port 1: Monitoring Port
Port 2: OUT Port
• Measured Optical Attenuation in dB

Maximum Dynamic Range

15.9 dB at OUT Port  47 dB at Monitoring Port
Measured Optical Isolation

Unwanted Wavelength Channel at the Desired Output Port

• At OUT Port
  Measured Optical Isolation > 15.9 dB

• At Monitoring Port
  Measured Optical Isolation > 25 dB: TF in the Path
  > 47 dB: Mirror in the Path
Measured Polarization Dependent Loss

- Scrambles the input state of polarization via a mechanical polarization controller
- Observes the maximum and minimum optical power at the desired port

\[
PDL = 10 \log \left( \frac{P_{\text{max}}}{P_{\text{min}}} \right) \text{ dB}
\]

- PDL $< 0.04$ dB: at Monitoring Port
- PDL $< 0.6$ dB: at OUT Port
Key Limiting Factors

• FC/APC Connectors

• Quality of Thin Film Filter

• Quality of Mirror

• Free-Space Optical Alignment
Conclusion

• Proposes Wavelength Sensitive Thin Film Filter-based Variable Fiber-Optic Attenuator with an Embedded Monitoring Port

Our Simple WDM VOA Structure
- No MUX/DeMUX
- No Optical Circulator

• Experimental Demonstration using a Commercially Available Thin Film Filter at 1546.12 nm
  - Measured Average Optical Loss 0.75 dB
  - Measured Dynamic Range > 16 dB
  - Measured Optical Isolation > 16 dB
  - Measured PDL < 0.6 dB

• Future Work Relates to Commercialize Our Proposed Wavelength Sensitive Thin Film Filter-based Fiber-Optic Variable Attenuator