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

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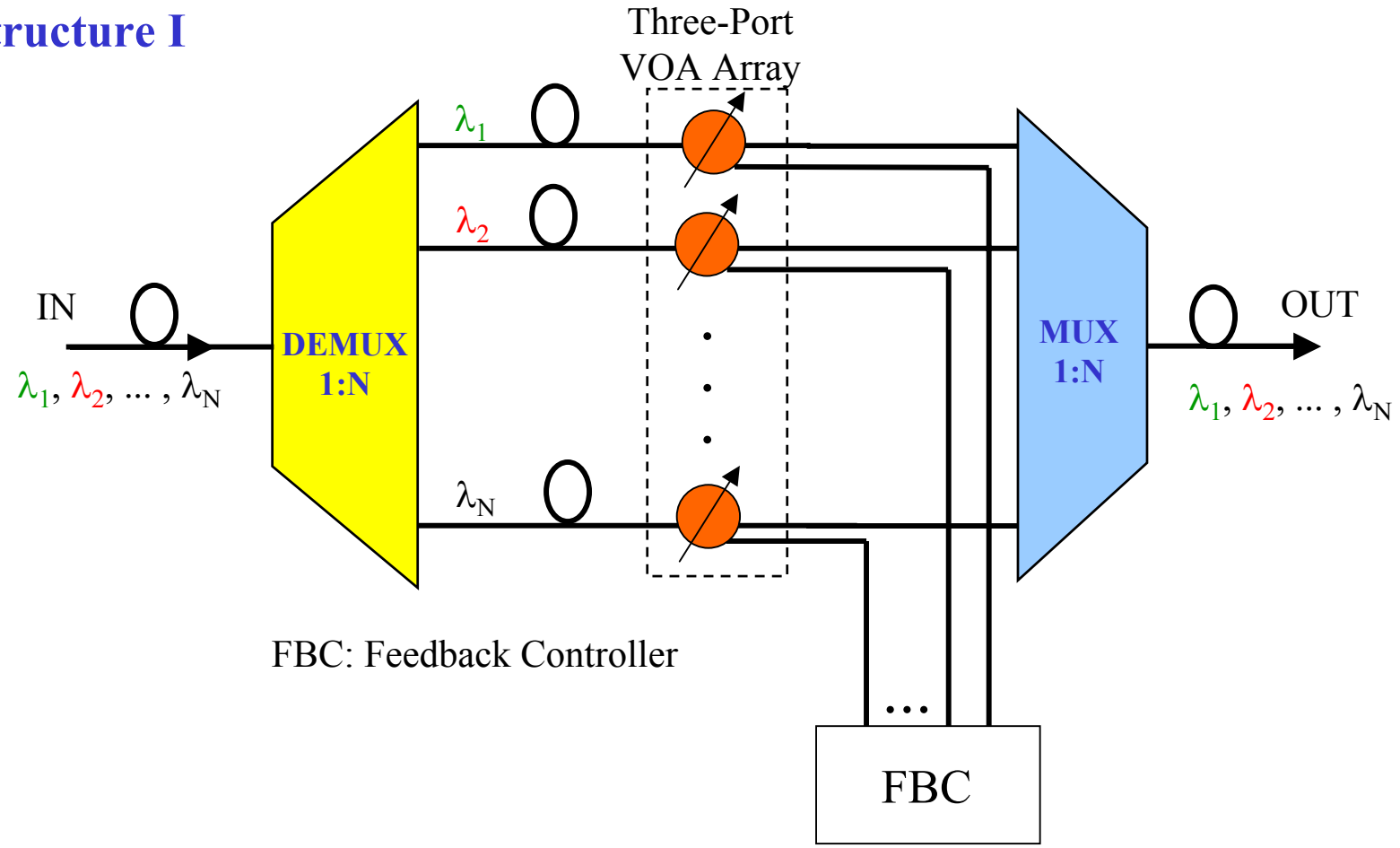
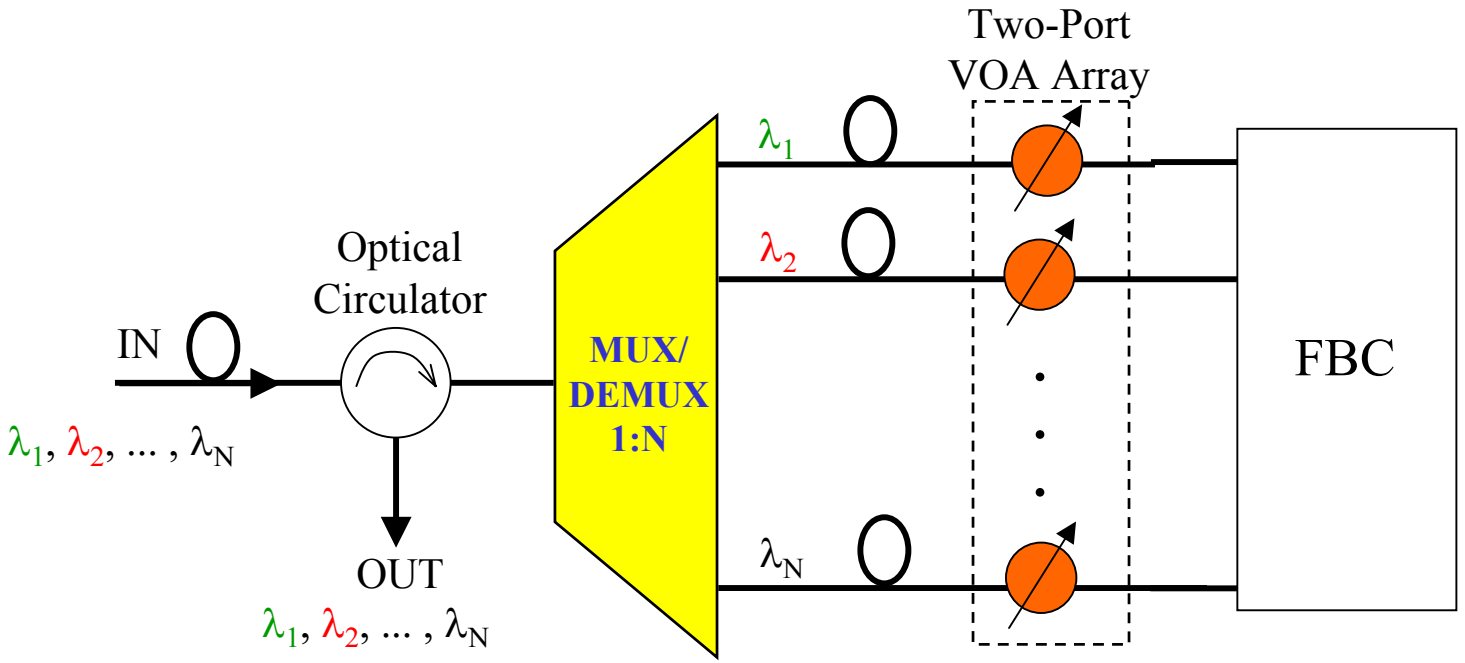
WDM Variable Optical Attenuator Architectures

- **Structure I**



- N Three-Port VOAs
- Two MUXs/DeMUXs ➡ *Can be reduced?*

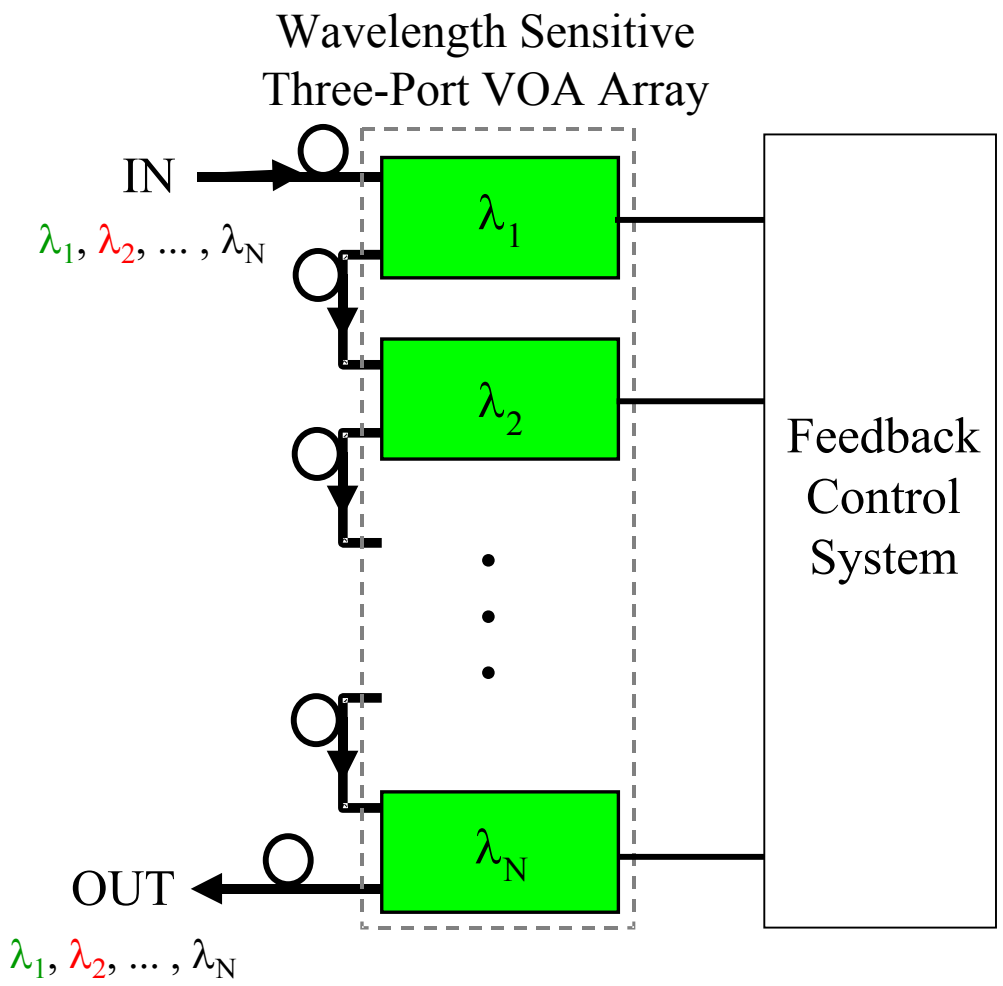
• Structure II



- N Two-Port VOAs
- One MUX/DeMUX
- One Optical Circulator ➡ *Can be eliminated?*

Our Proposed WDM VOA Architecture

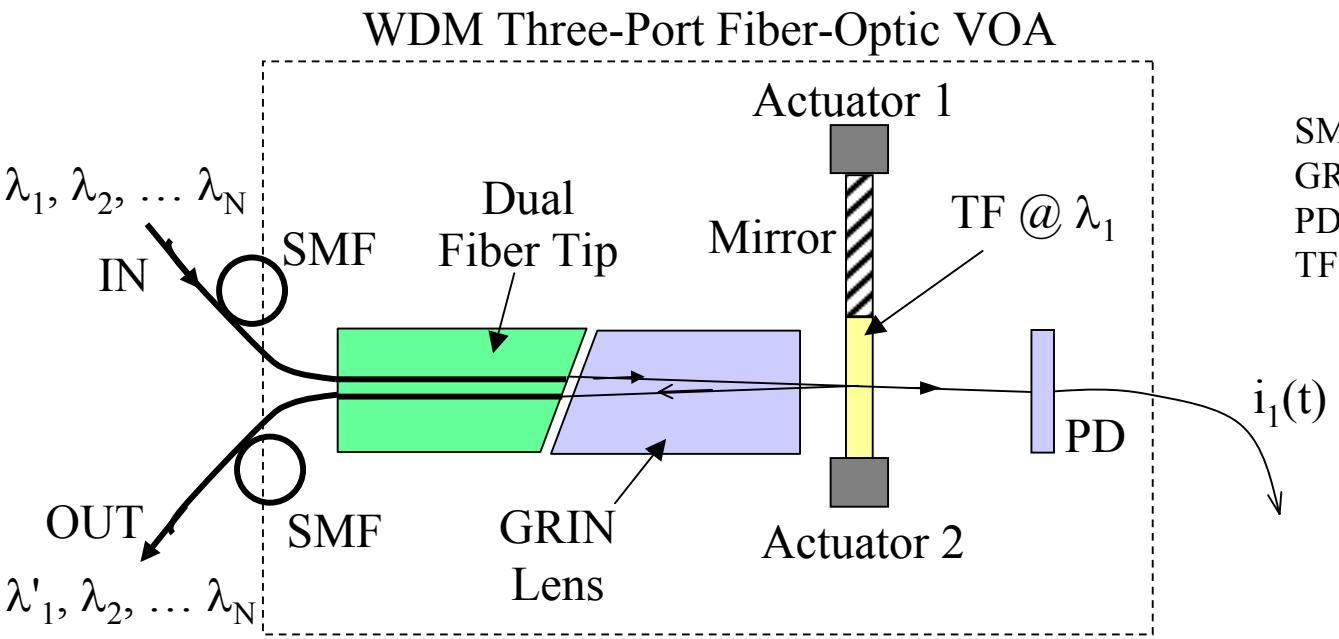
- No Optical Circulator
- No MUX/DeMUX



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



SMF: Single Mode Optical Fiber
GRIN: Graded Index
PD: Photodetector
TF: Thin Film Filter

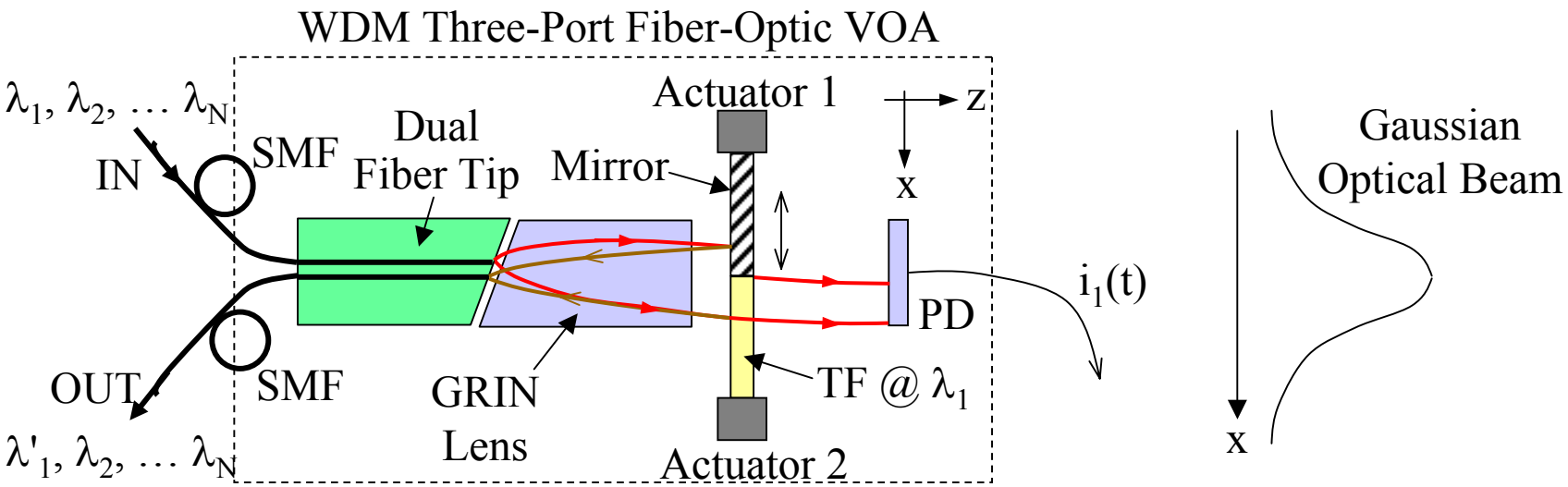
- Mirror & TF are Simultaneously Moved in the Analog Fashion
- Each Component is Controlled by One Actuator

Leads

- Ease of Free-Space Alignment
- Speed ~ Speed of Typical Mechanical VOA

Ref: S. Sumriddetchkajorn and K. Chaitavon, *Patent*, 2003 (Pending).

Theoretical Analysis

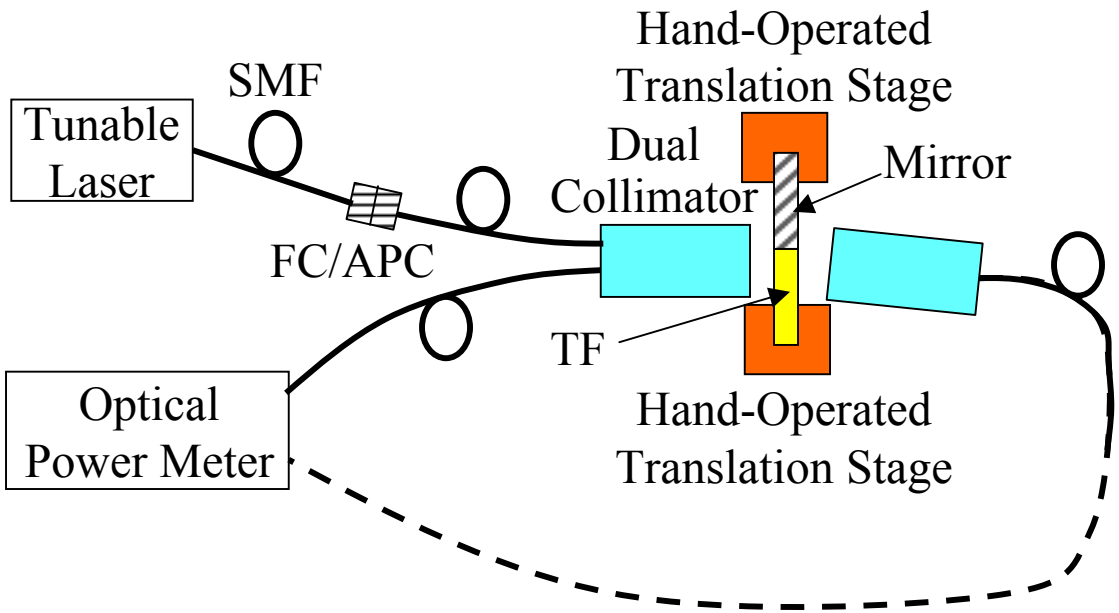


Optical Power at OUT: $$P_o = 1 - erf(\sqrt{2}x/w)$$

Optical Power at PD: $$P_m = erf(\sqrt{2}x/w)$$

x: Position of TF *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:**

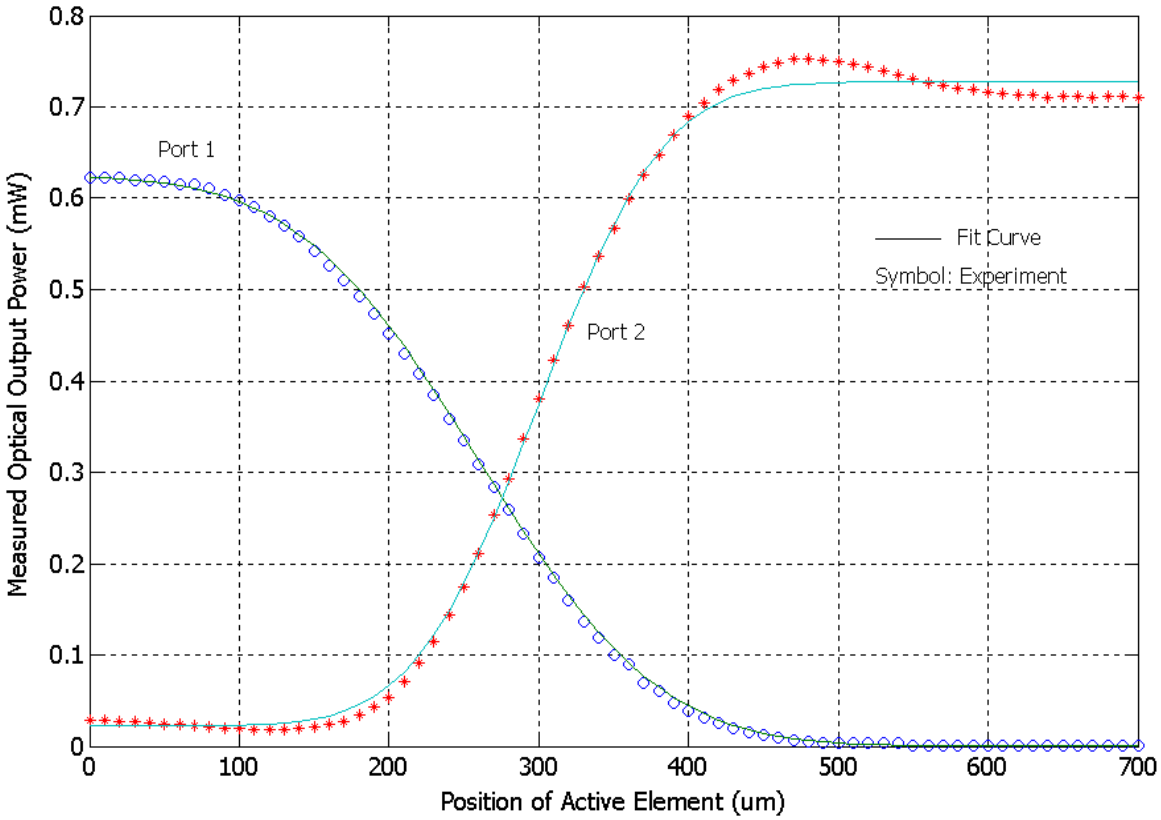
Measured Optical Loss = 0.47 dB

- **At Monitoring Port:**

Measured Optical Loss = 1.04 dB

Measured Dynamic Range

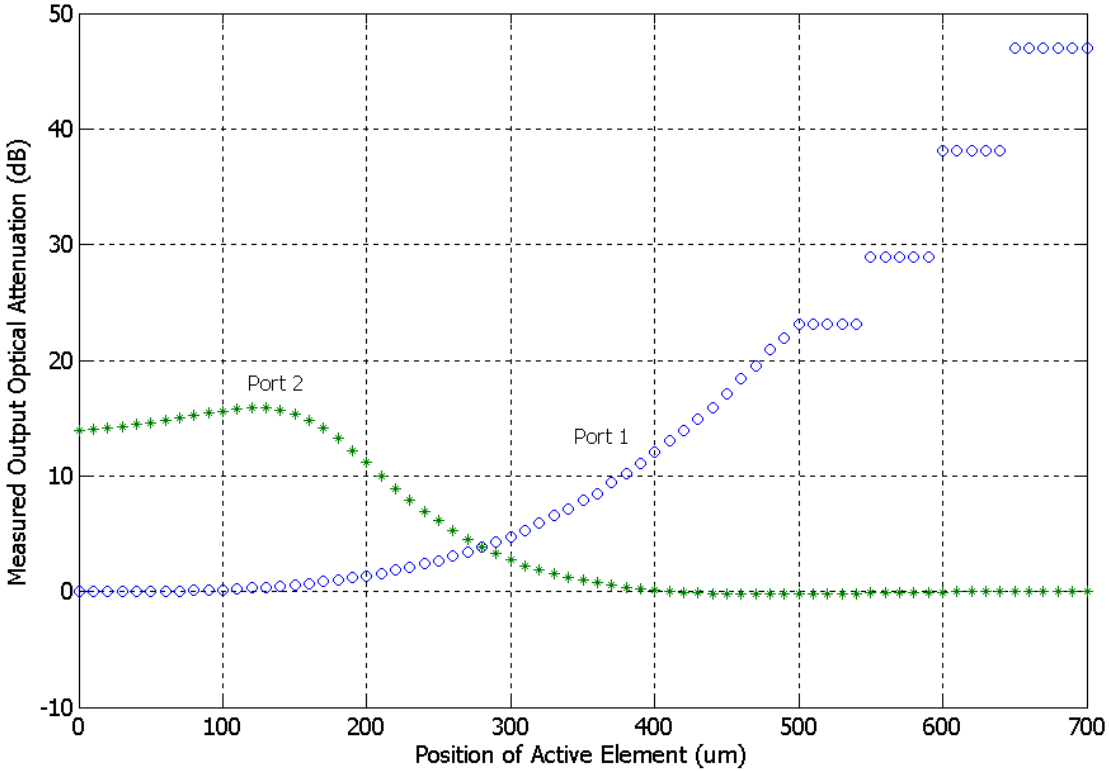
- **Measured Optical Power**



Port1: Monitoring Port
Port2: OUT Port

Agrees Well with the Theoretical Analysis

• Measured Optical Attenuation in dB



Port1: Monitoring Port
Port2: OUT Port

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

$$PDL = 10 log(P_{max}/P_{min}) \quad dB$$

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