Tuneable All-Fiber® Delay-Line Interferometer for DPSK Demodulation

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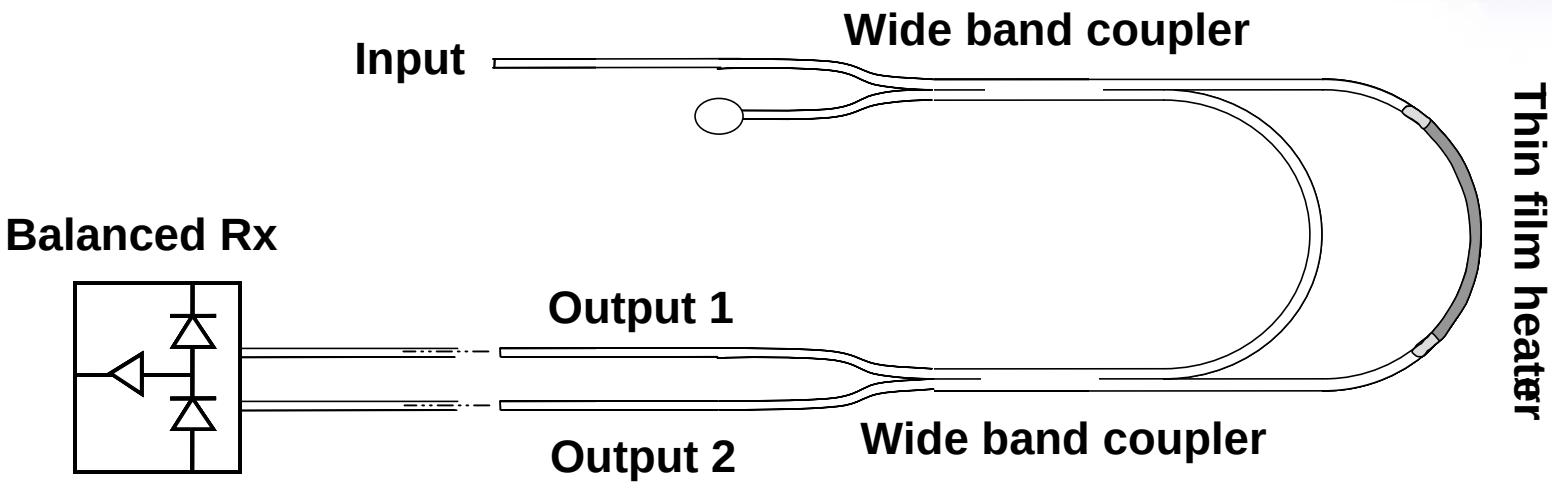
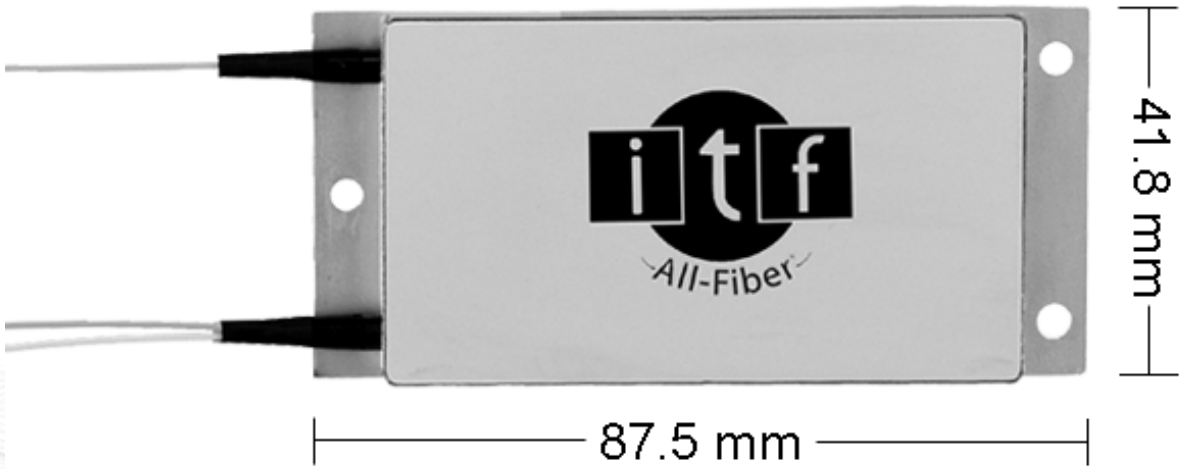
Introduction

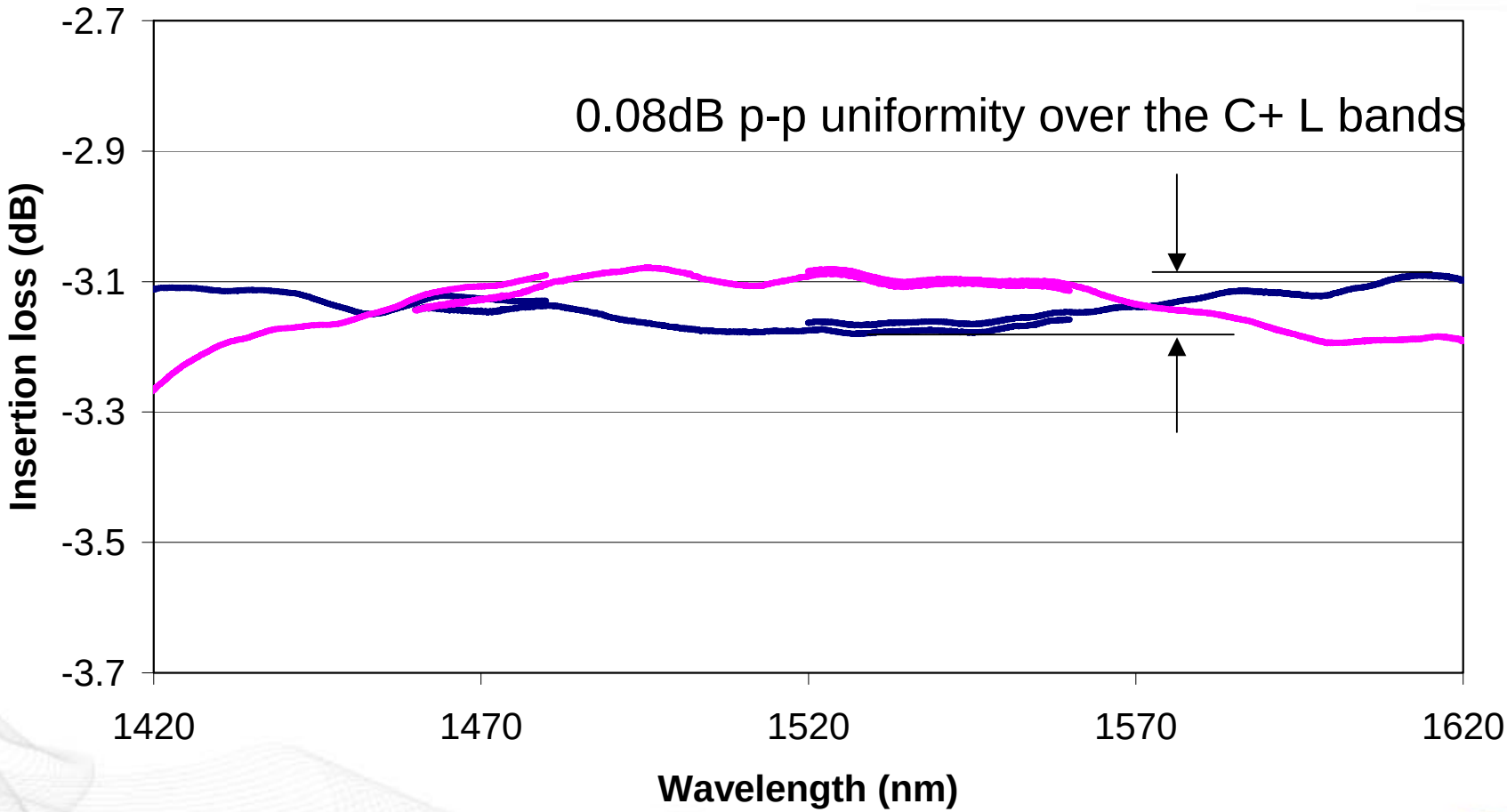
- DPSK will likely be the next generation modulation format
- A novel device is required to extract phase modulation at receiver
  - Phase-Tunable Delay Line Interferometer
- Delay interferometer features must include:
  - Low insertion loss and low PDL
  - Polarization independent isolation, low birefringence
  - Small footprint, board mountable, low electrical consumption
  - Telcordia reliability
  - Low micro phonic sensitivity
  - Stable operation over ambient temperature variations

Delay line interferometer layout and package footprint

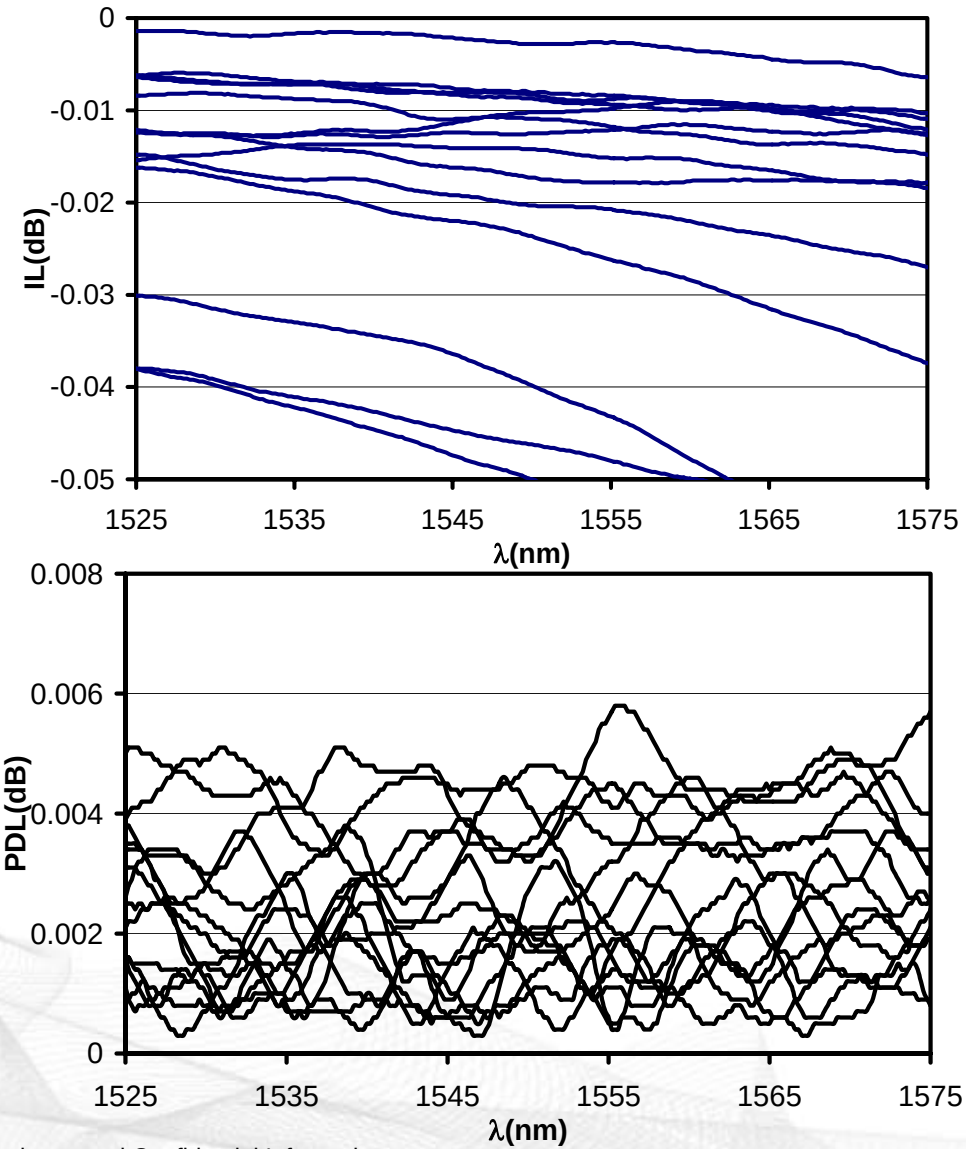


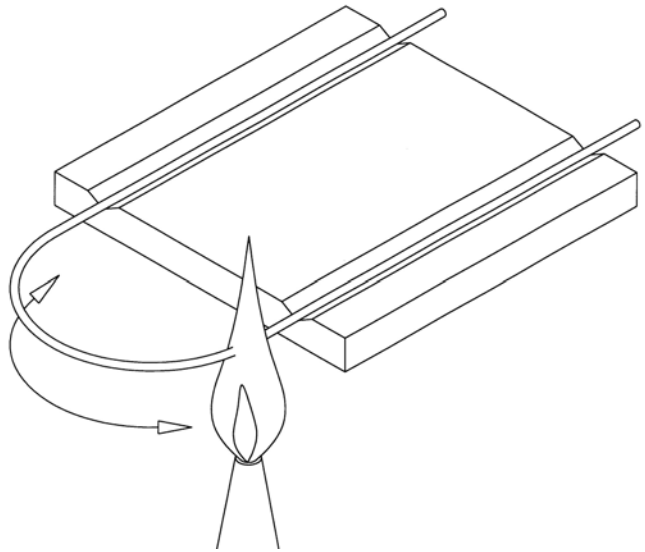


Wavelength insensitive 3dB coupling over 200 nm bandwidth



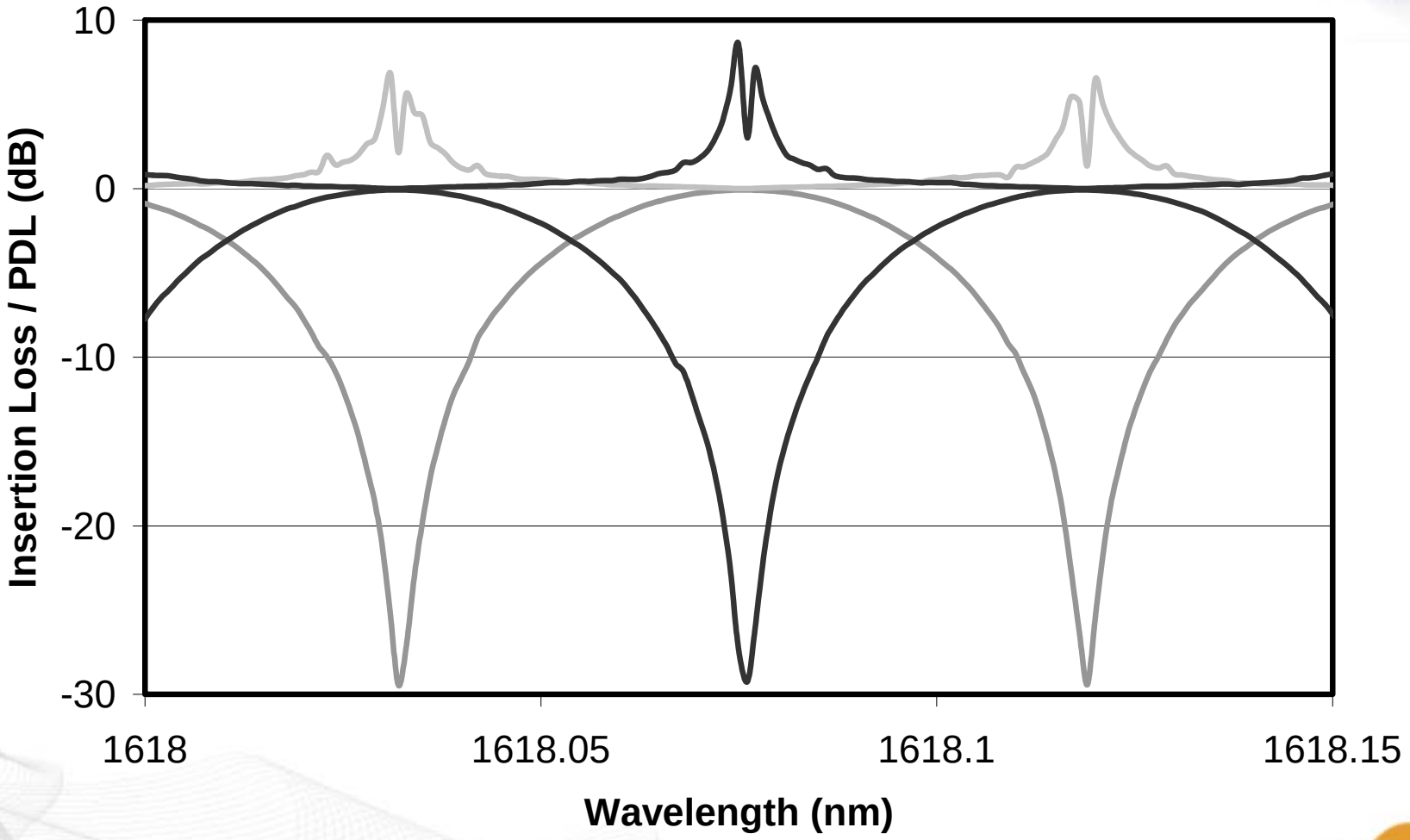
Heat forming eliminates birefringence and maintains good transmission



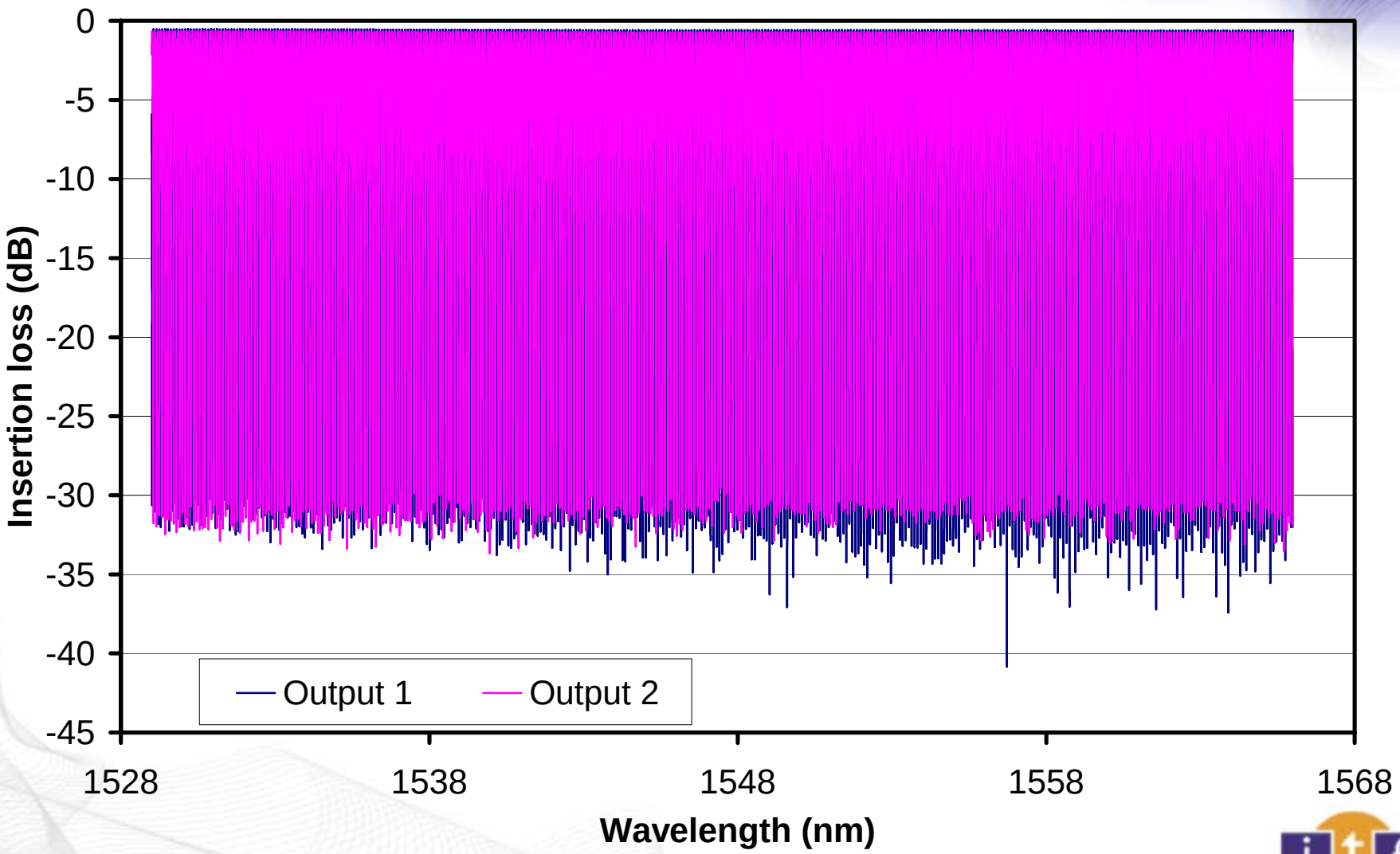


R = 15mm

Insertion loss and PDL of delay line interferometer



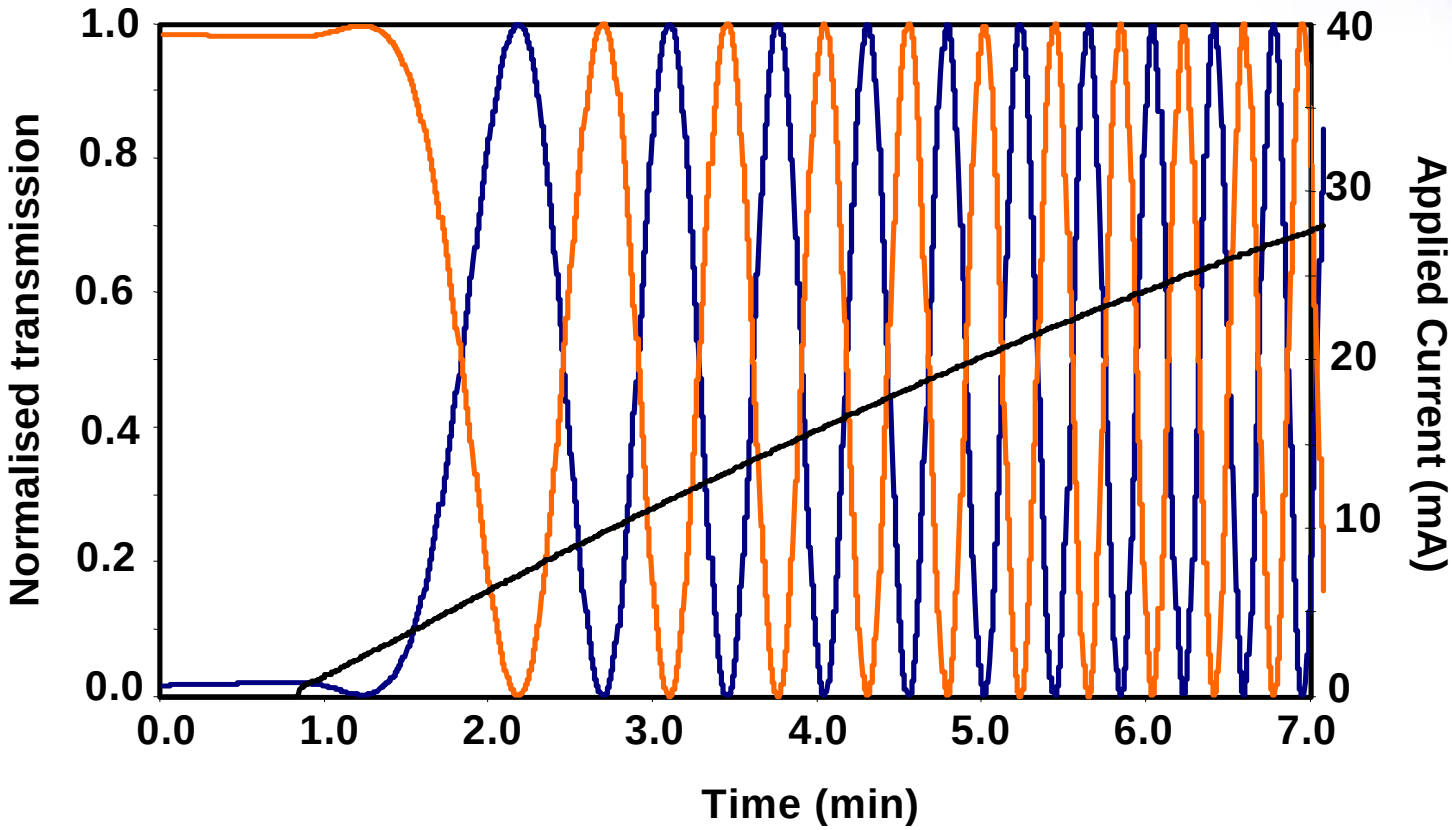
Insertion loss of delay line interferometer over 37nm spectral range



Performance statistics for ~10GHz free spectral range interferometer

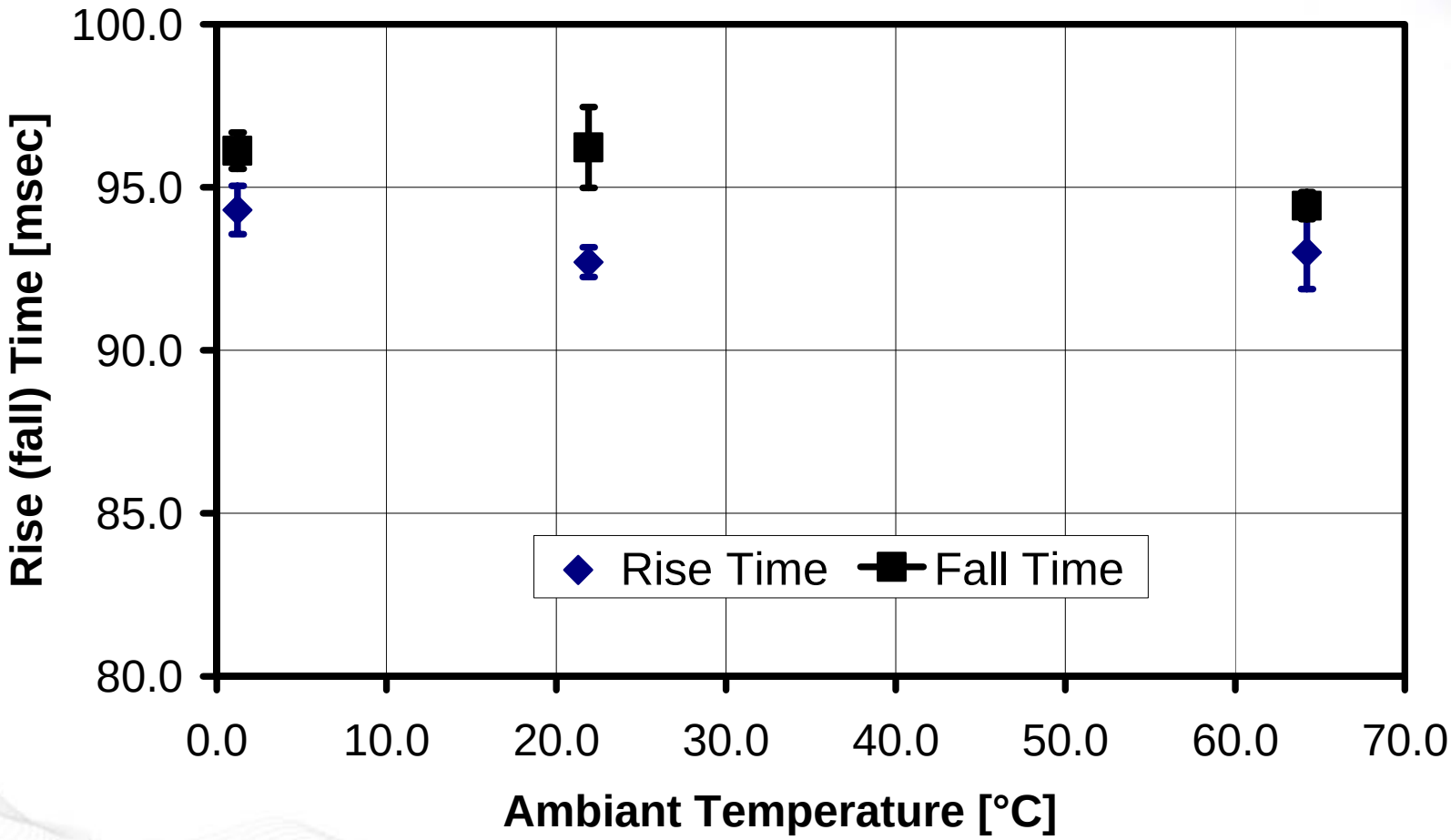
Parameter	target	unit	0°C		22°C		65°C	
			Avg	Std dev	Avg	Std dev	Avg	Std dev
Insertion loss	**0.5**	**dB**	**0.40**	**0.073**	**0.35**	**0.062**	**0.35**	**0.050**
Contrast, depolarised signal	**26**	**dB**	**29.4**	**2.23**	**30.8**	**1.90**	**30.9**	**1.97**
Polarization dependent *f* – split (PDF)	**0.32**	**GHz**	**0.23**	**0.074**	**0.21**	**0.059**	**0.21**	**0.060**
Free spectral range accuracy	**+/- 0.1**	**GHz**	**+0.01**	**0.019**	**+0.01**	**0.019**	**0.01**	**0.019**
Out1/Out2 balance	**0.15**	**dB**	**0.059**	**0.024**	**0.059**	**0.017**	**0.060**	**0.021**

Center frequency tuning using fiber heater



Fiber heater can compensate for 0°C - 65°C ambient drift
Heater requires very low power consumption (no TEC cooler)
Optical performance maintained with heater turned on

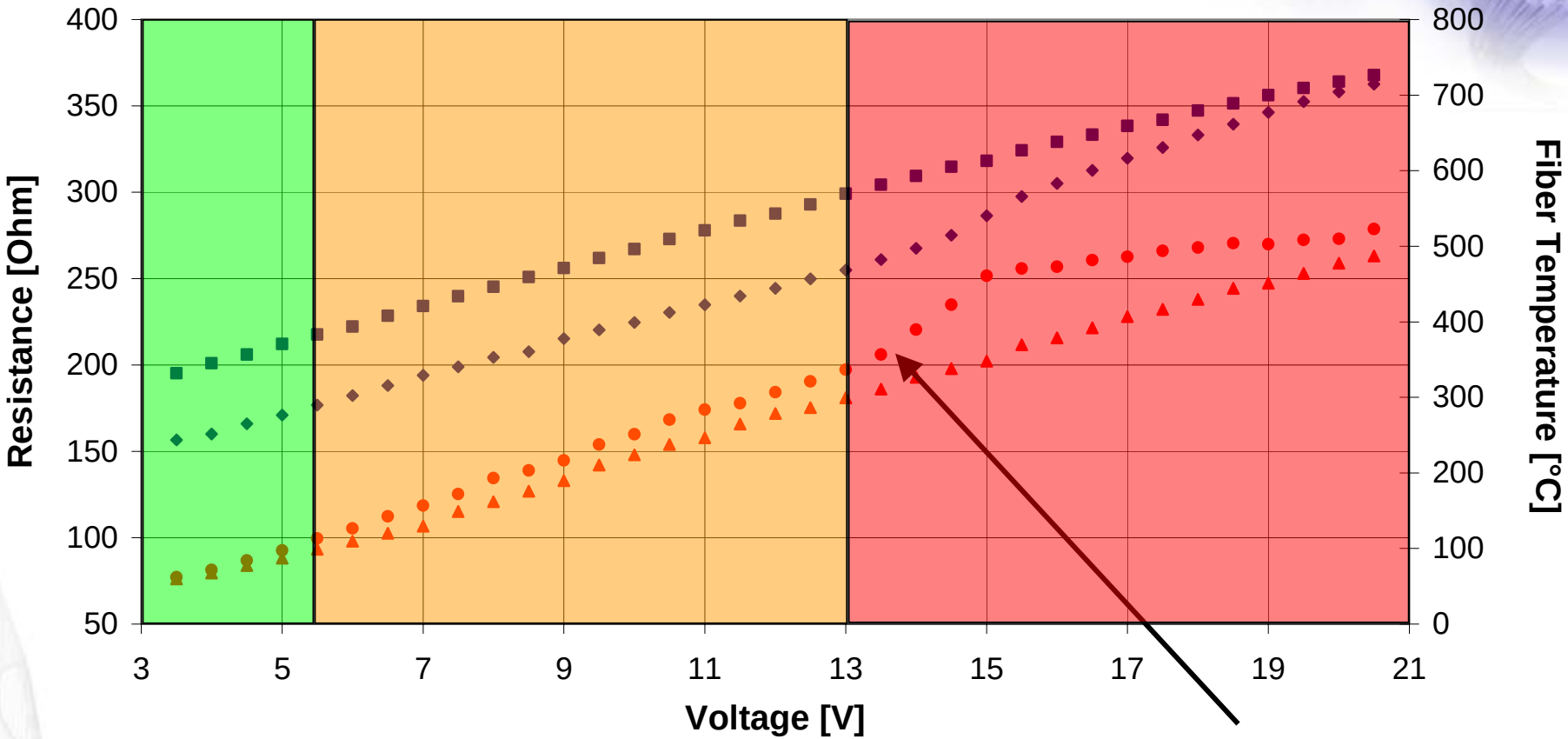
Stability of rise and fall time of thermo-optic tuning with ambient temperature variations



Measured phase shift vs. time after 10V step is applied

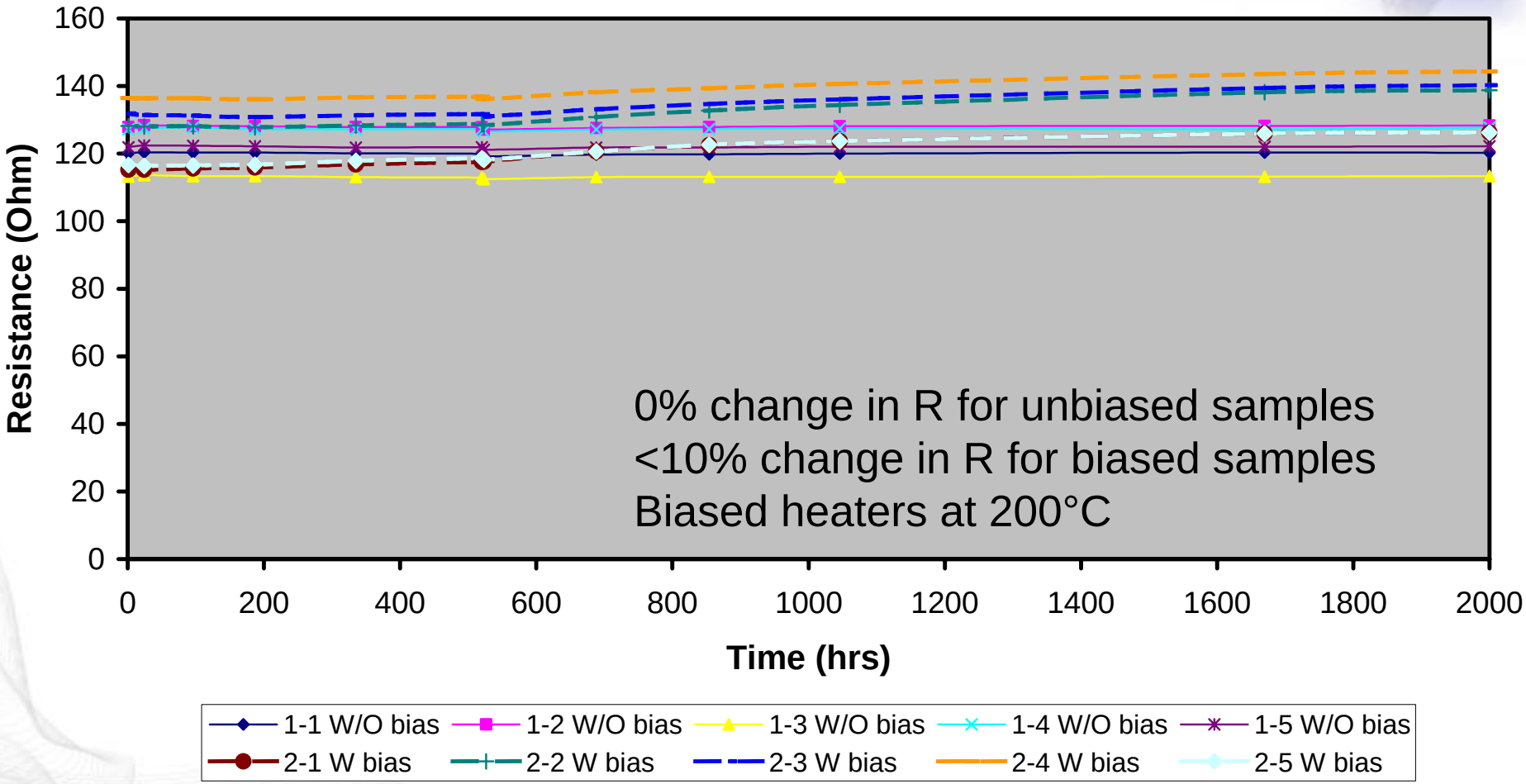
Fitted to $\tau = 1\text{-}\exp(-t/\tau)$

Fiber heater resistance and surface temperature vs. applied voltage



Permanent resistance shift when heater T > 350°C (performed in air, IR camera measurement)

Evolution of resistance in damp heat 85°C/85%RH
Directly exposed heaters, biased and unbiased

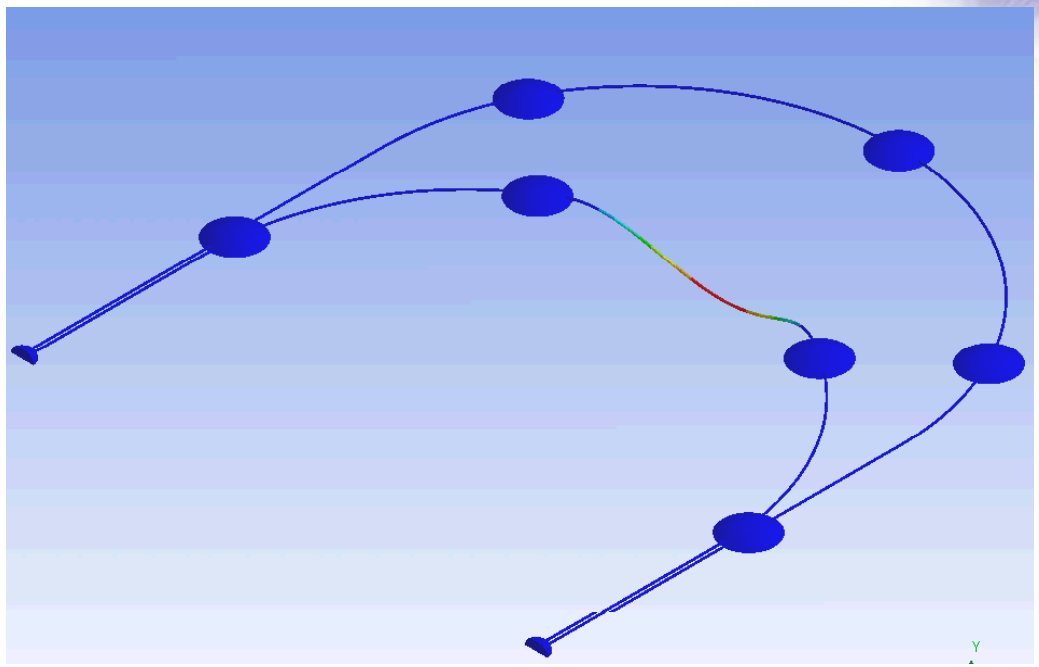


Eigen mode analysis

Anchoring design Optimization:

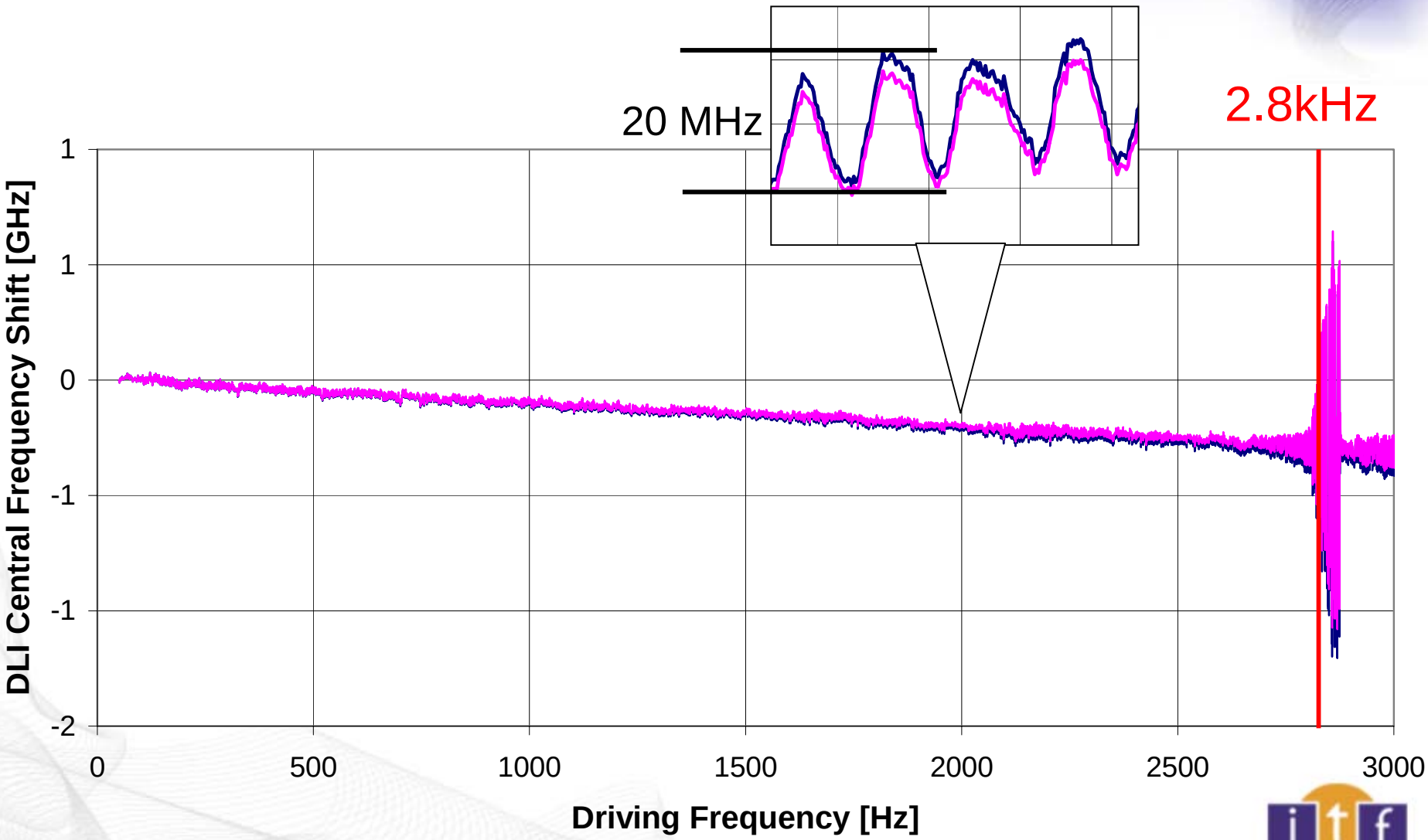
Resonance frequency > 2000Hz

Minimal thermal conduction with substrate

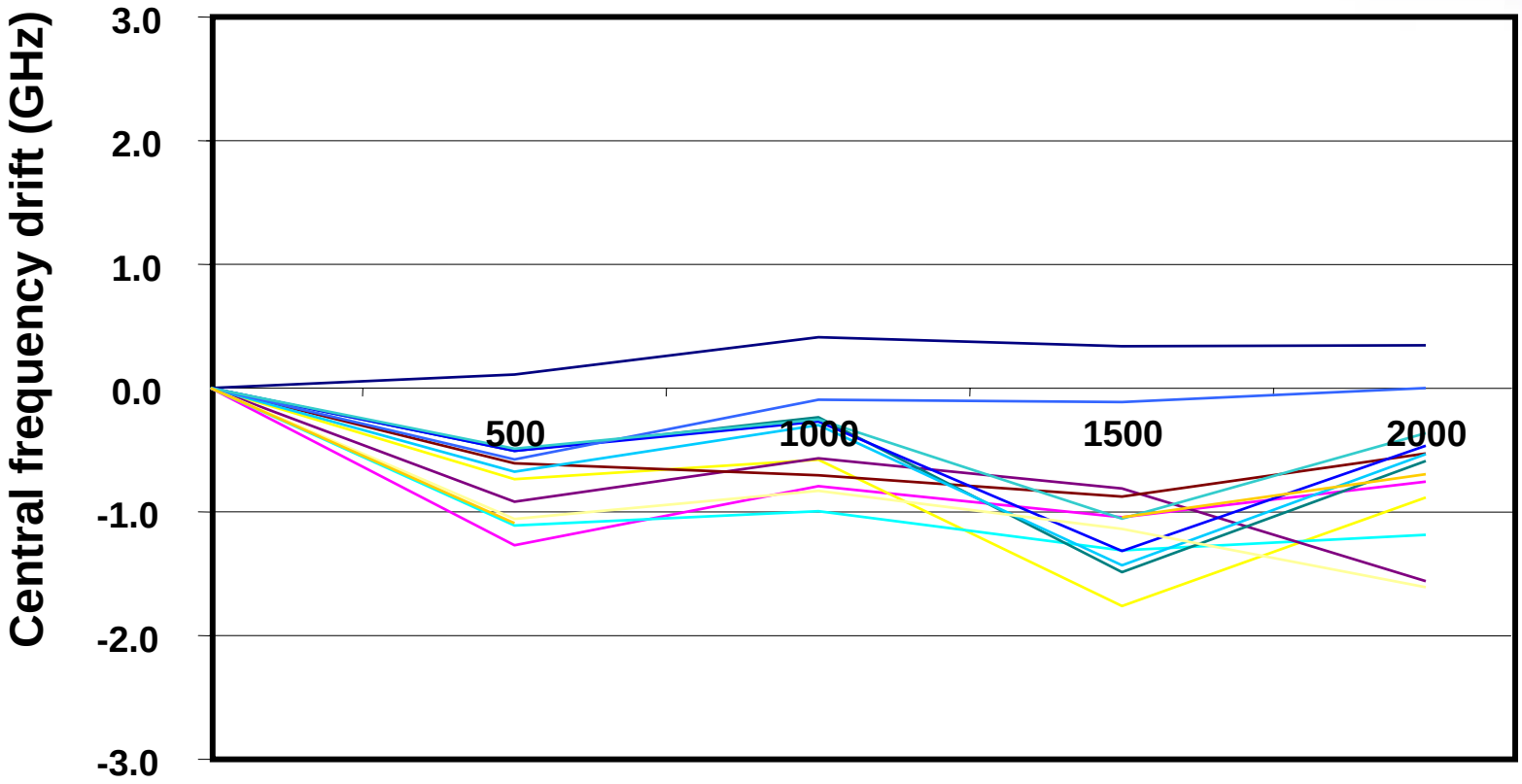


Fiber geometry	Anchoring point distance	Fundamental mode resonance frequency
125μm Heat formed	14.75 mm	2830 Hz

10GB/s delay line interferometer frequency shift under sine vibration 0-3000Hz 3g



Dry heat (85°C) of passive delay interferometer structure



Frequency centering maintained within 1.7 GHz for 2KHrs

Conclusions

- We have developed an All-Fiber® tuneable Mach-Zehnder device for use as a delay-line interferometer for DPSK demodulation
- This technology allows:
  - Precise control of free spectral range
  - Very low insertion loss and PDL
  - Minimal birefringence
  - Polarization-insensitive high isolation over the C+L bands
- Fiber heat forming is used to reduce package size
  - No impact on optical performance or reliability
- Anchoring design provides immunity to ambient vibration up to 2000Hz
- Efficient fiber heater can compensate for environmental T- drift
  - No TEC required
- Optical structure is stable in dry heat
- Product release after completion of Telcordia qualification in Q2 2005