

# Limits to the Exponential Advances in DWDM Filter Technology?

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DARPA/MTO WDM for Military Platforms

April 18-19, 2000

McLean, VA

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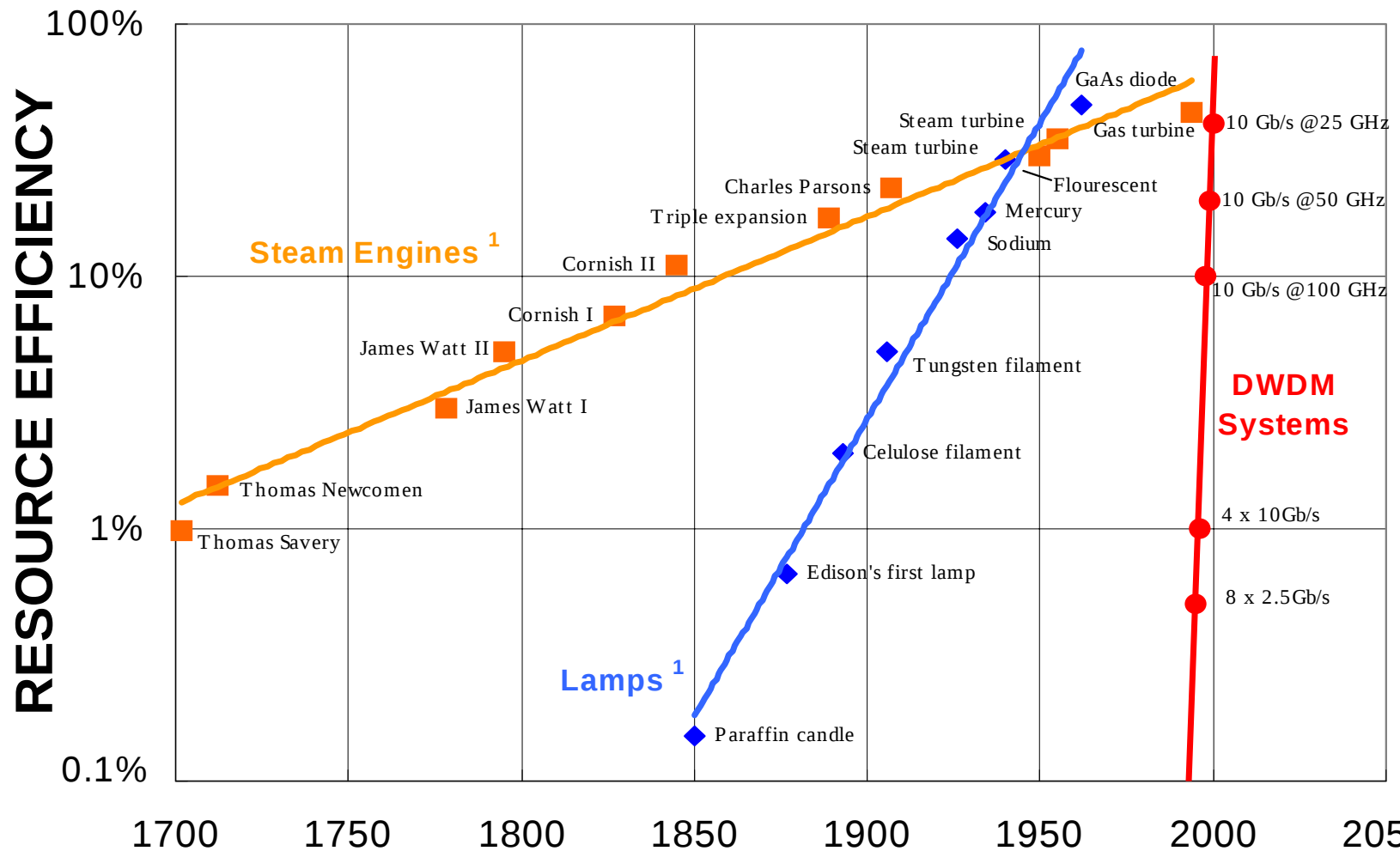
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# Limits to the Exponential Advances in DWDM Filter Technology?

## DARPA/MTO WDM for Military Platforms

- Progress in DWDM Filtering Technology
  - Thin Film Filters
  - Arrayed Waveguide Gratings
  - Holographic Gratings
- Interleaver Status
- Roadmap for the Near Future

# TECHNOLOGY PROGRESS



1) Jesse H. Ausubel, "Where is Energy Going?", The Industrial Physicist, Vol. 6 (1), p. 17 (Feb. 2000).

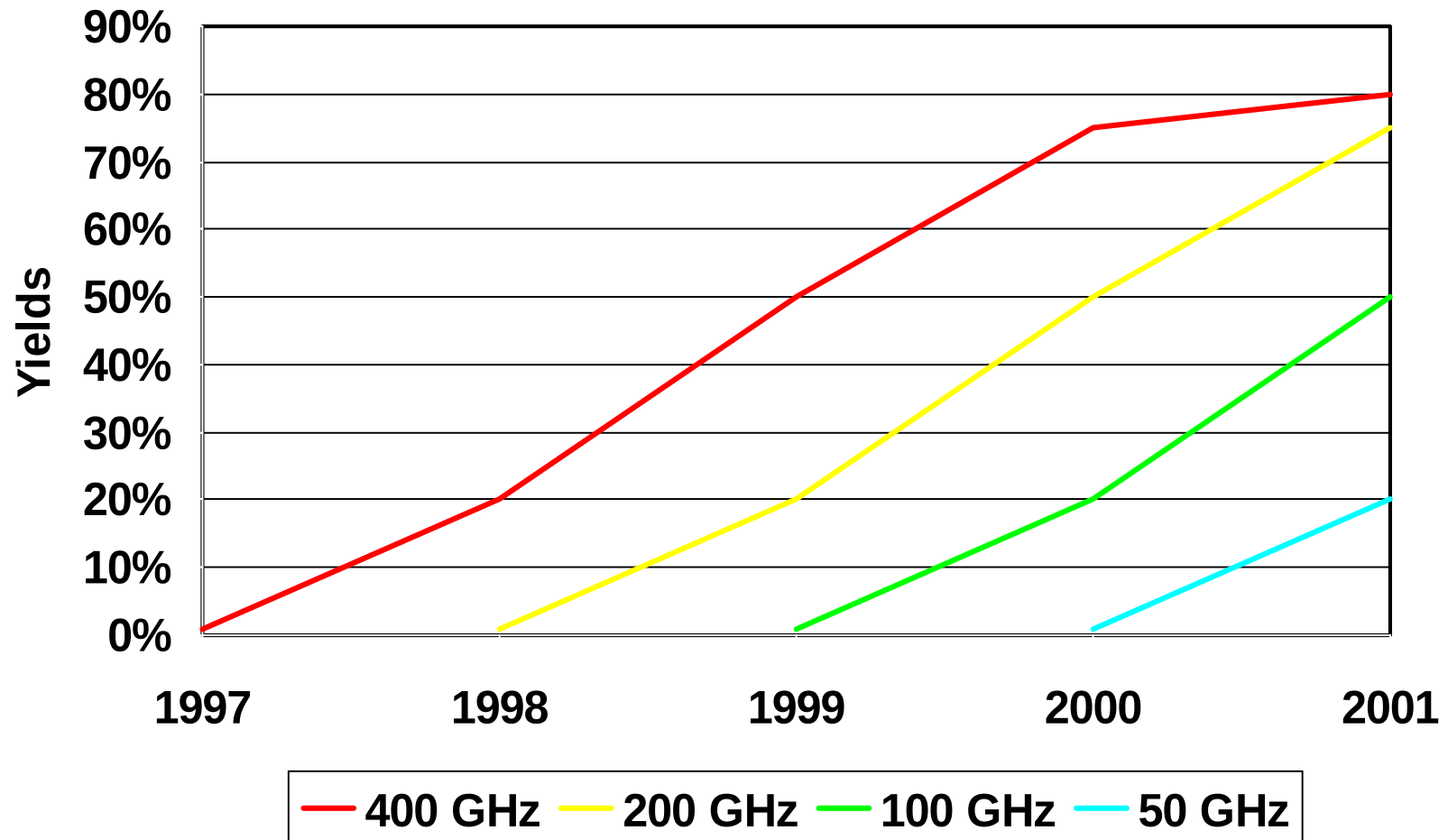
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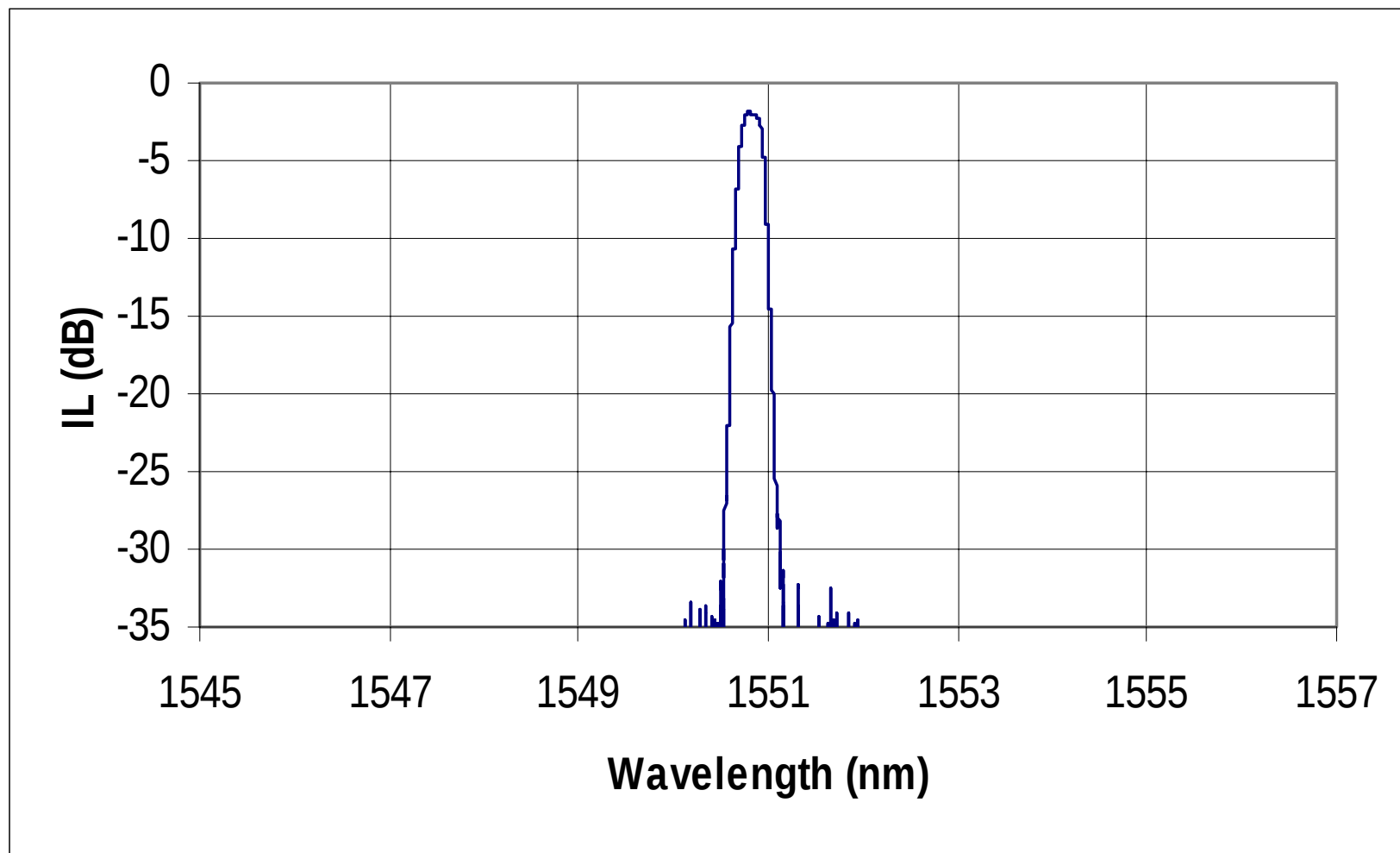
# Industry Filter Yield Improvements



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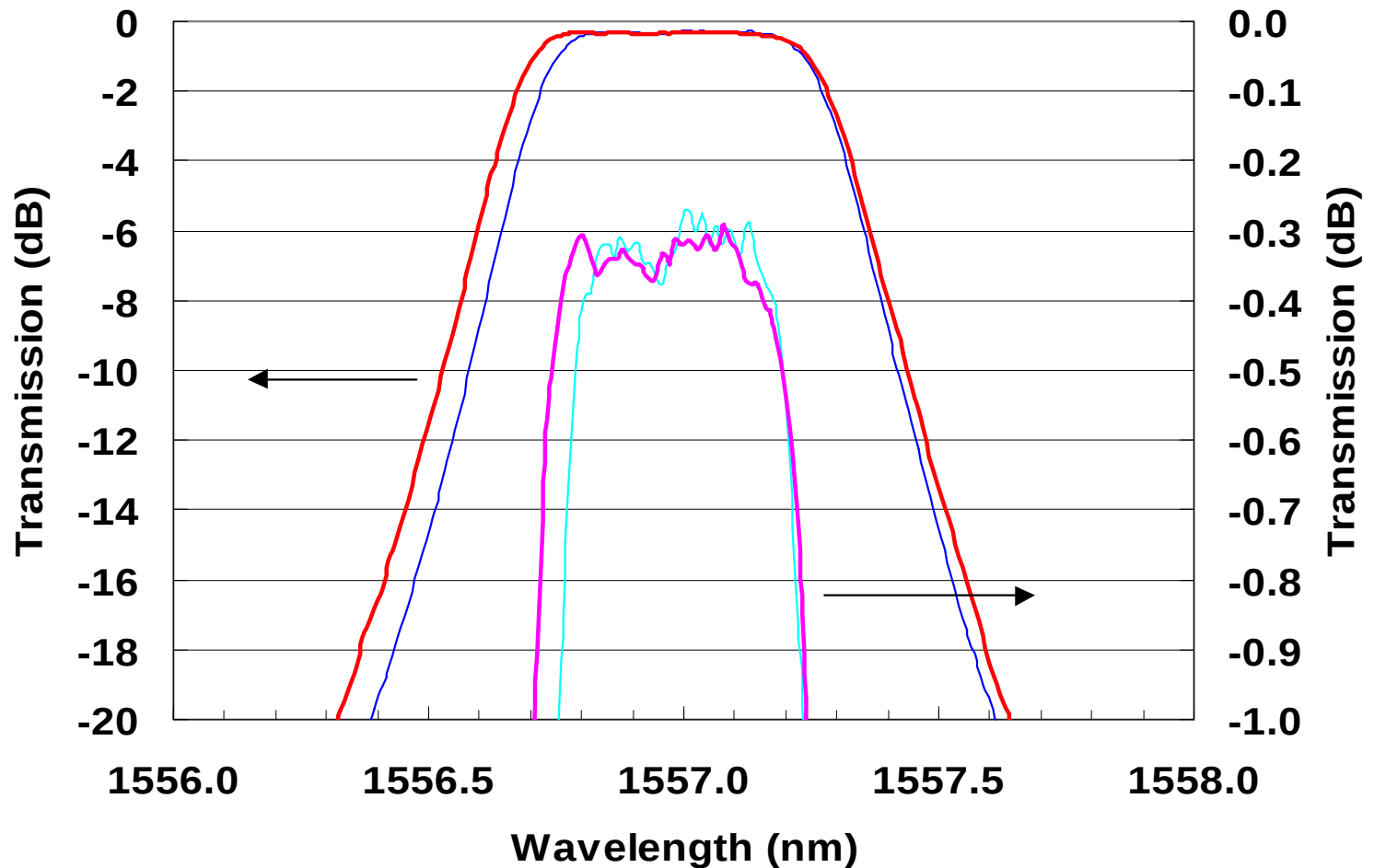
# 50GHz DWDM Spectrum-Transmission



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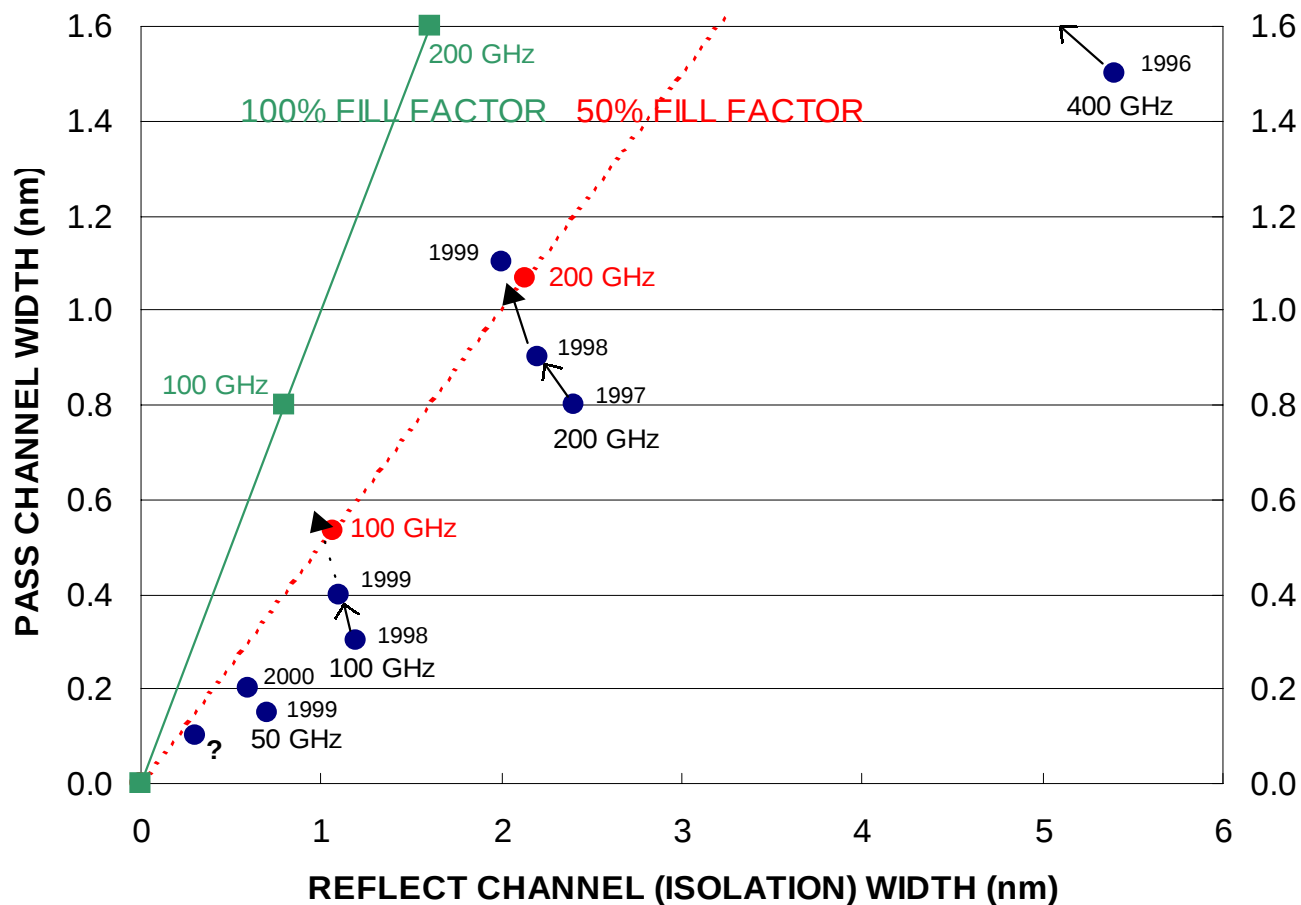
# 100 GHz Filter Shapes



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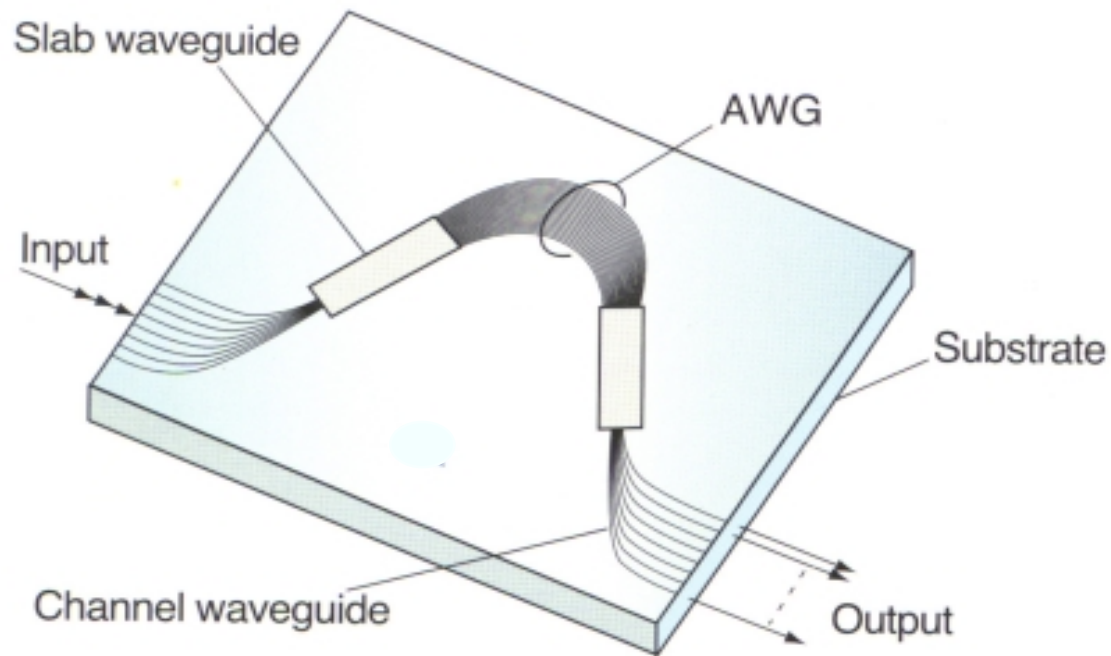
# DWDM THIN FILM FILTER PROGRESS



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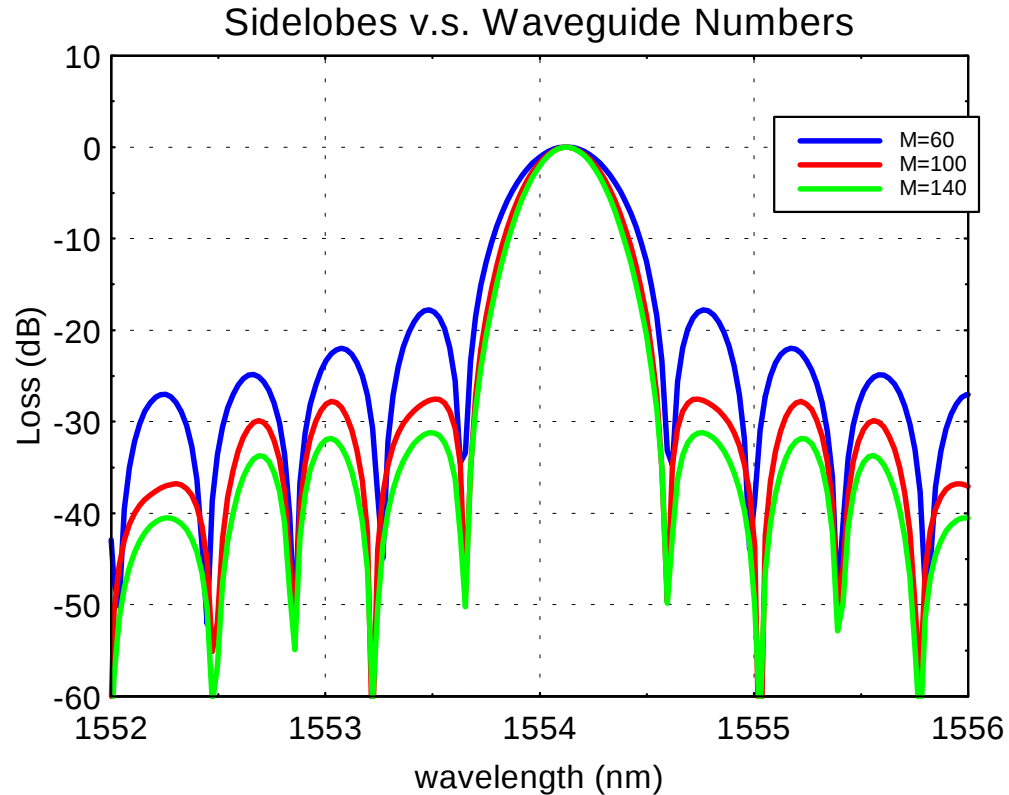


# AWG DWDM MUX & DEMUX



Waveguide pattern of AWG multi/demultiplexer chip

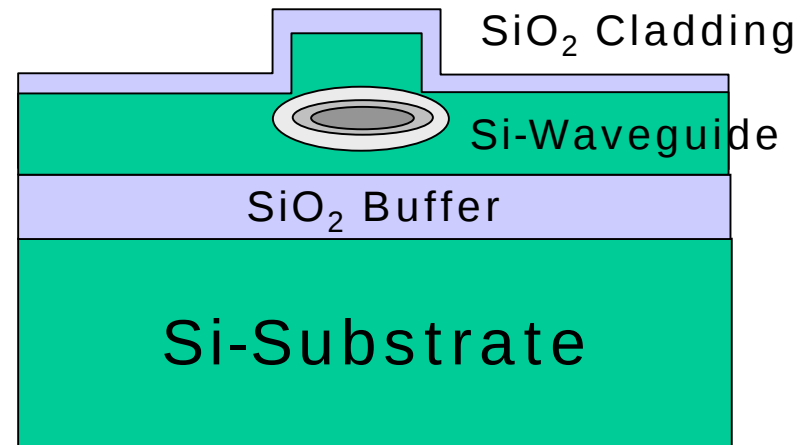
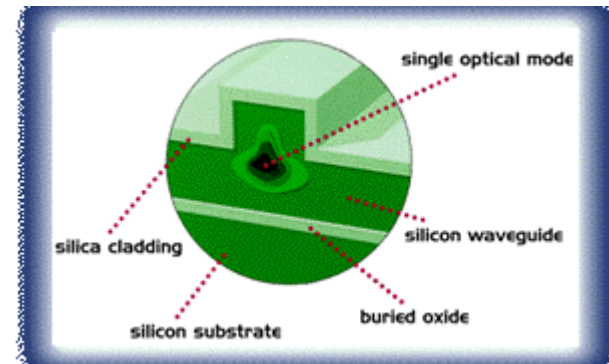
# Basic Performance of an AWG



# Basic Waveguide Structure

## Silicon-on-Silicon (Bookham Technology)

- easier to manufacture, Si-CMOS process
- pure semiconductor waveguide, small bending radius, small chip size
- difficult to package due to mode miss-match
- few vendors, little R&D
- offer lowest X-Talk
- further integration, OEIC

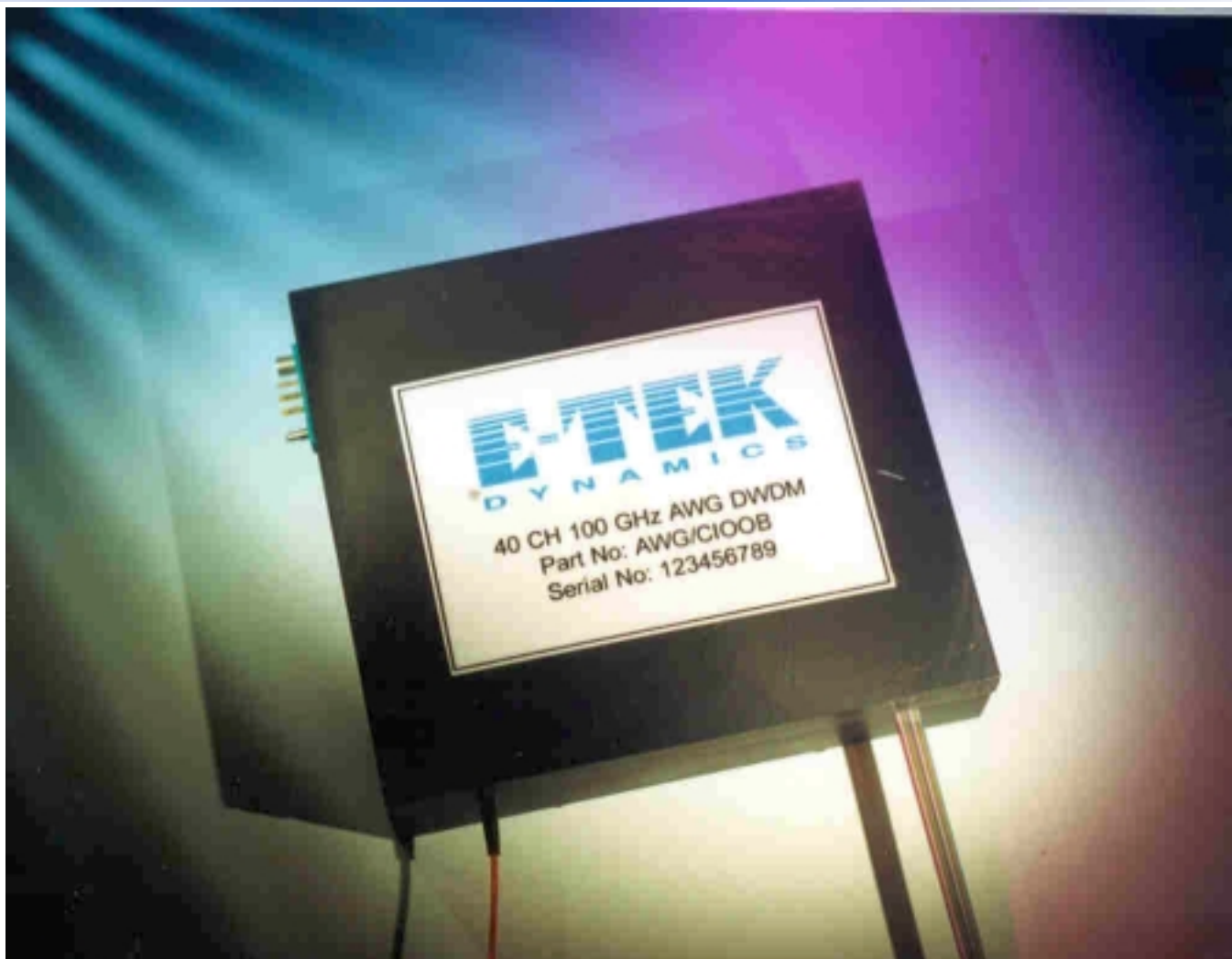


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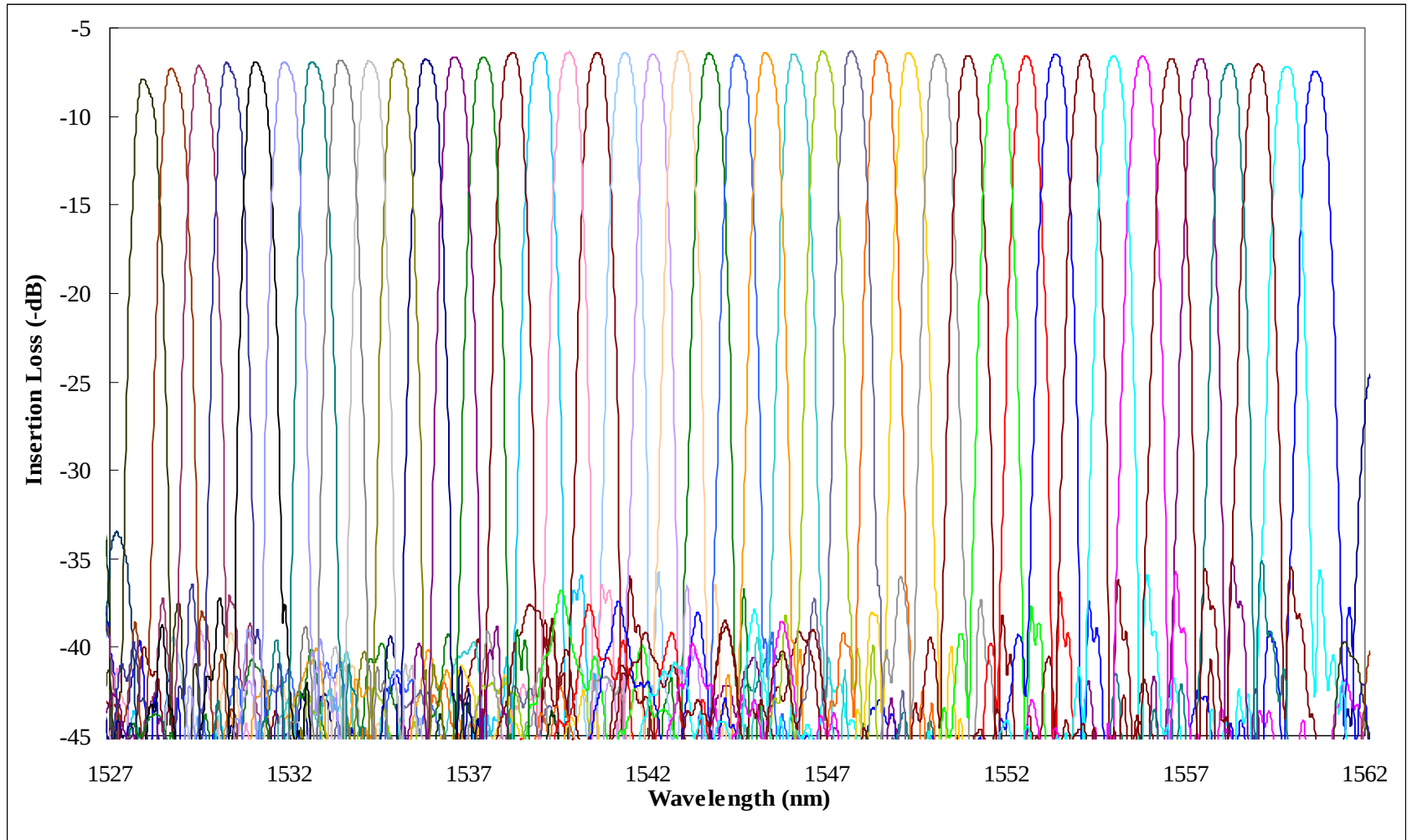
# Packaged Silicon AWG



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# Typical Spectrum of Packaged AWG Module



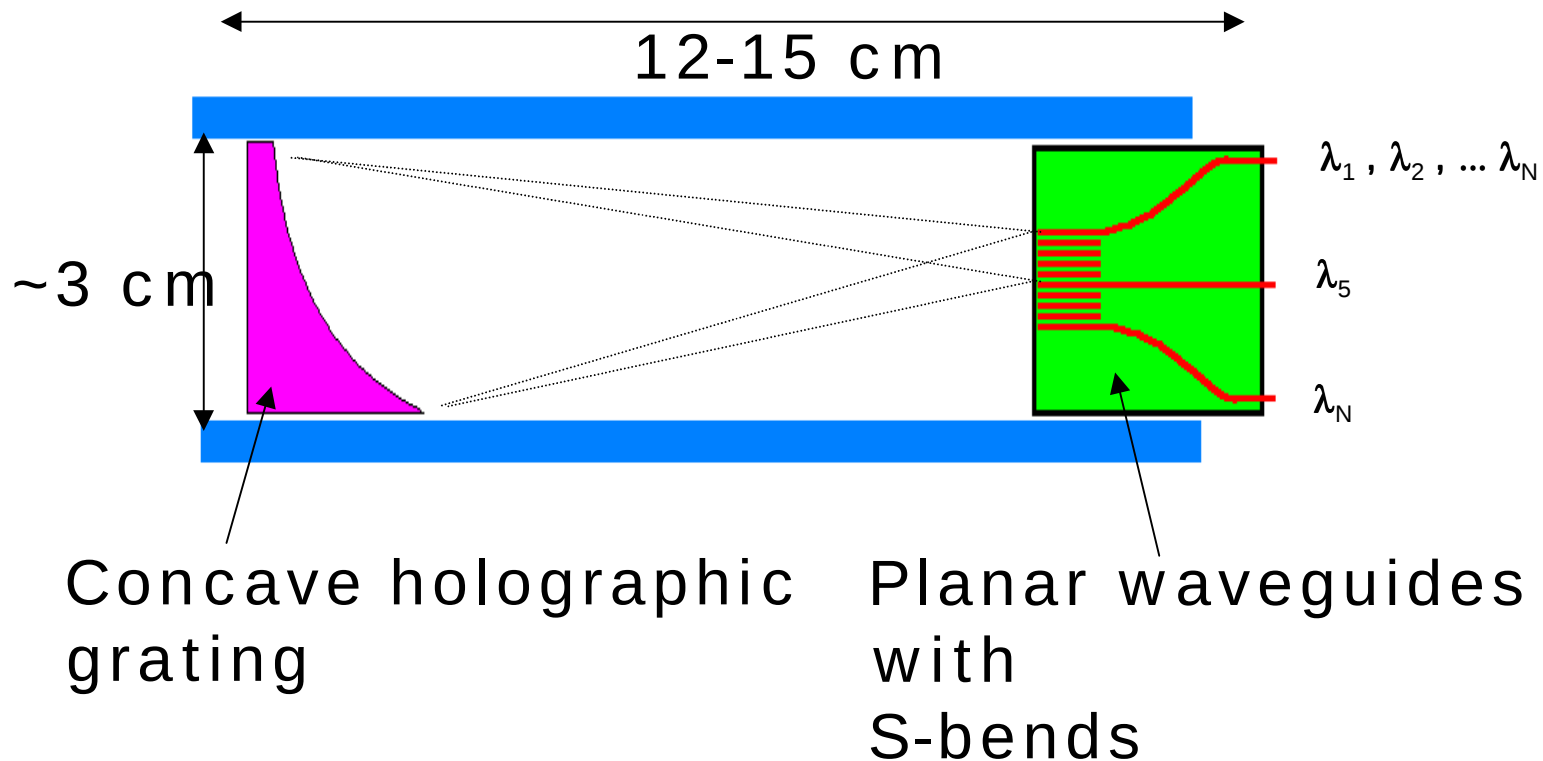
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# Holographic grating DWM

Simple structure, high channel count



# Holographic Grating Attributes

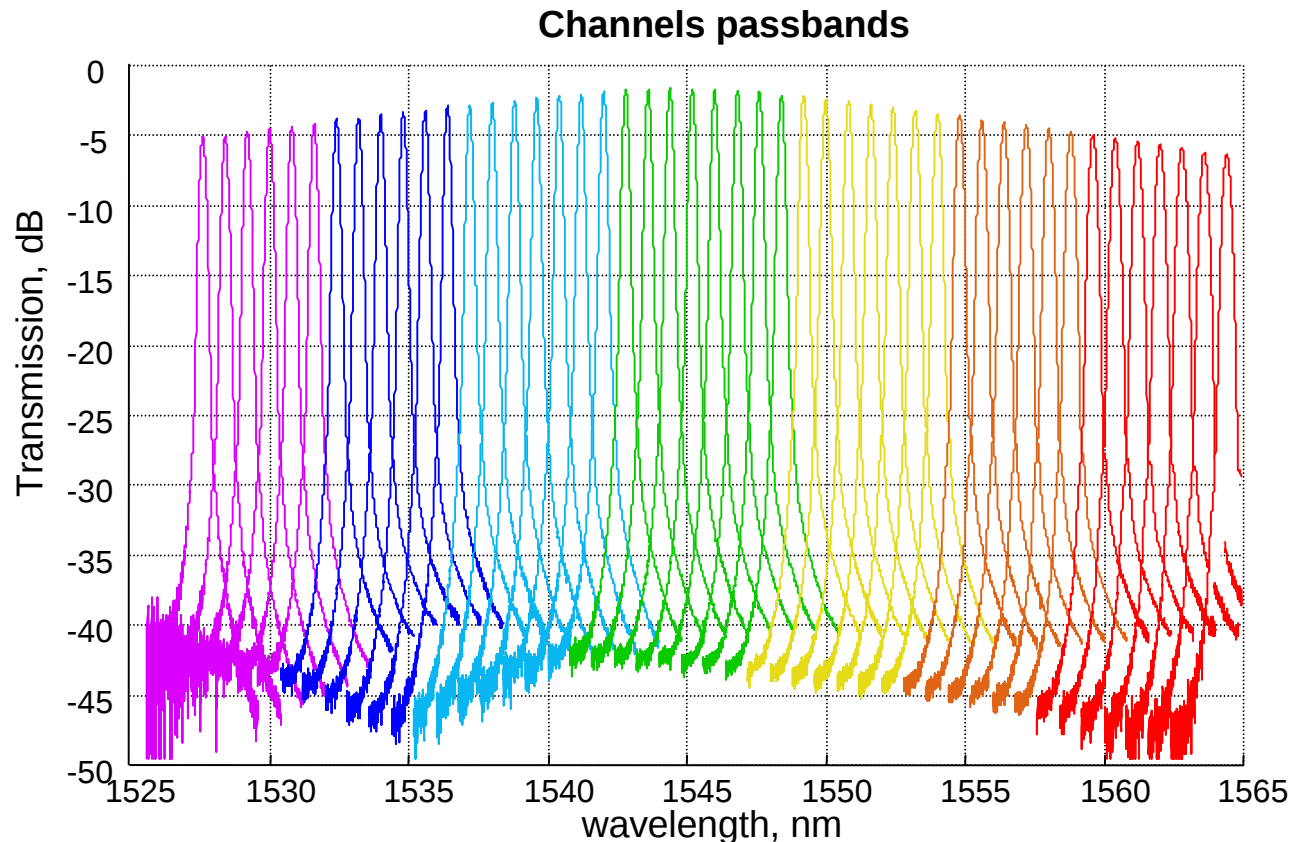
- High channel count, yet completely passive
- High isolation  $>40$  dB
- Less developed than PAWG

## Issues:

- Channel uniformity
- Passband flatness
- Polarization-dependent loss

# Measured HG Response (Not Flattened)

50 channels @ 100 GHz, not flattened

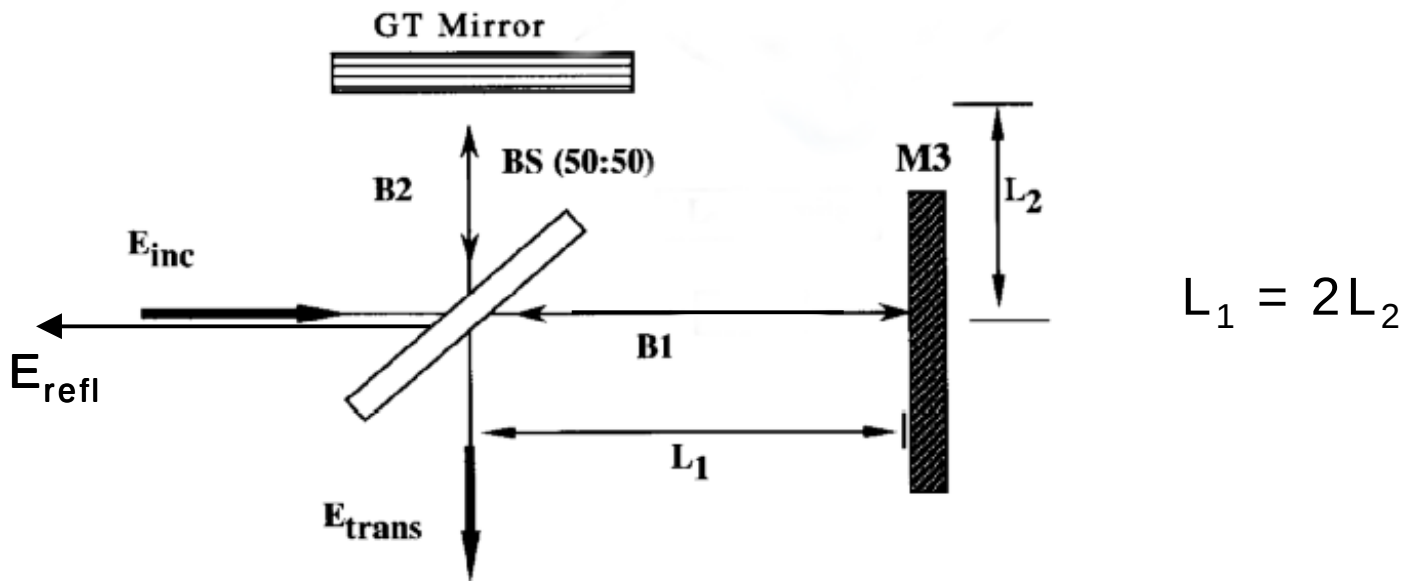


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# Basic Michelson-Gires-Tournois Interleaver Structure



After Dingel and Aruga, JLT vol. 17(8), pp. 1461, 1999.

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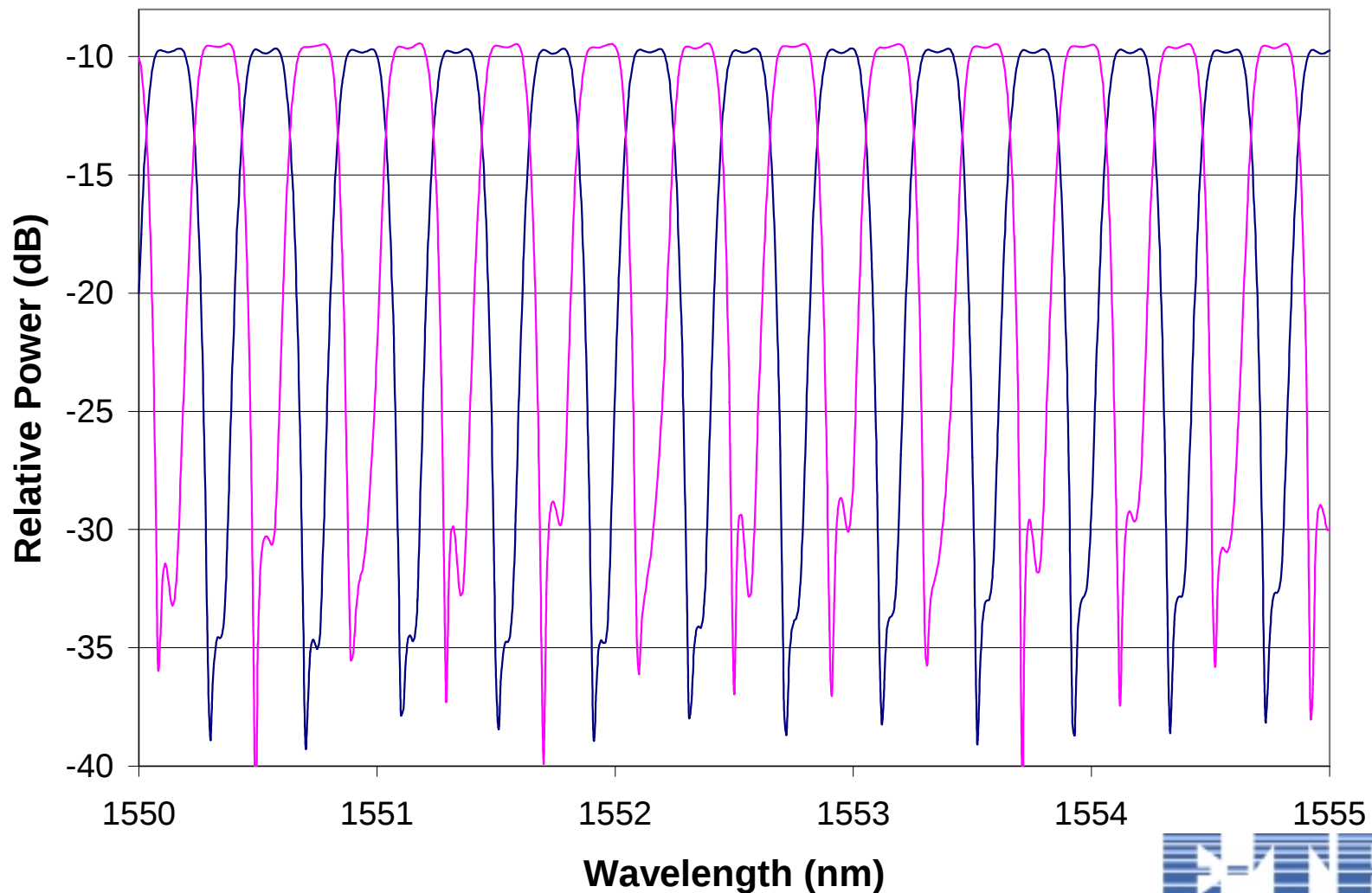
## Packaged Prototype 25-GHz Interleaver



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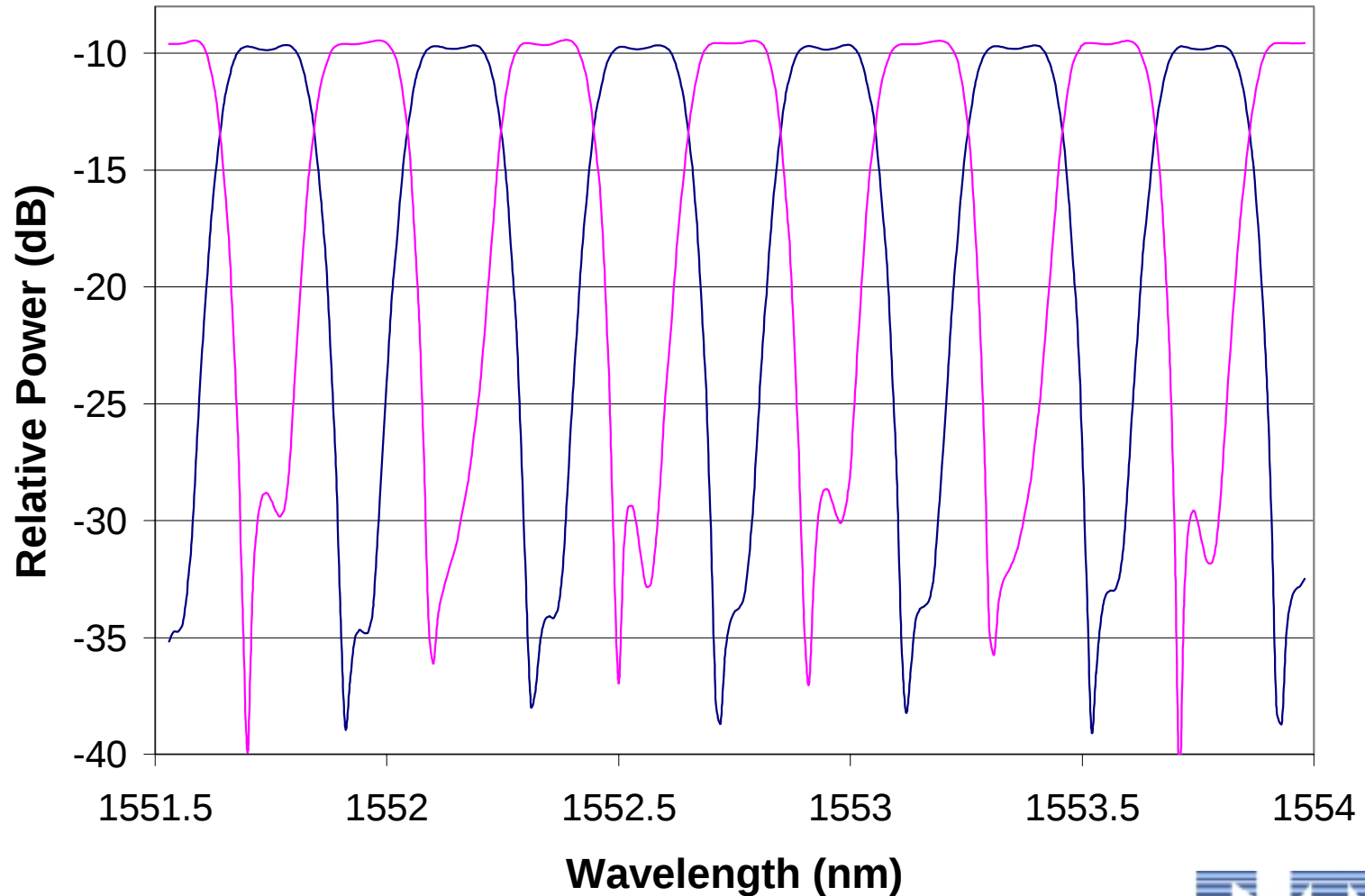
## 25-GHz Interleaver Characteristics



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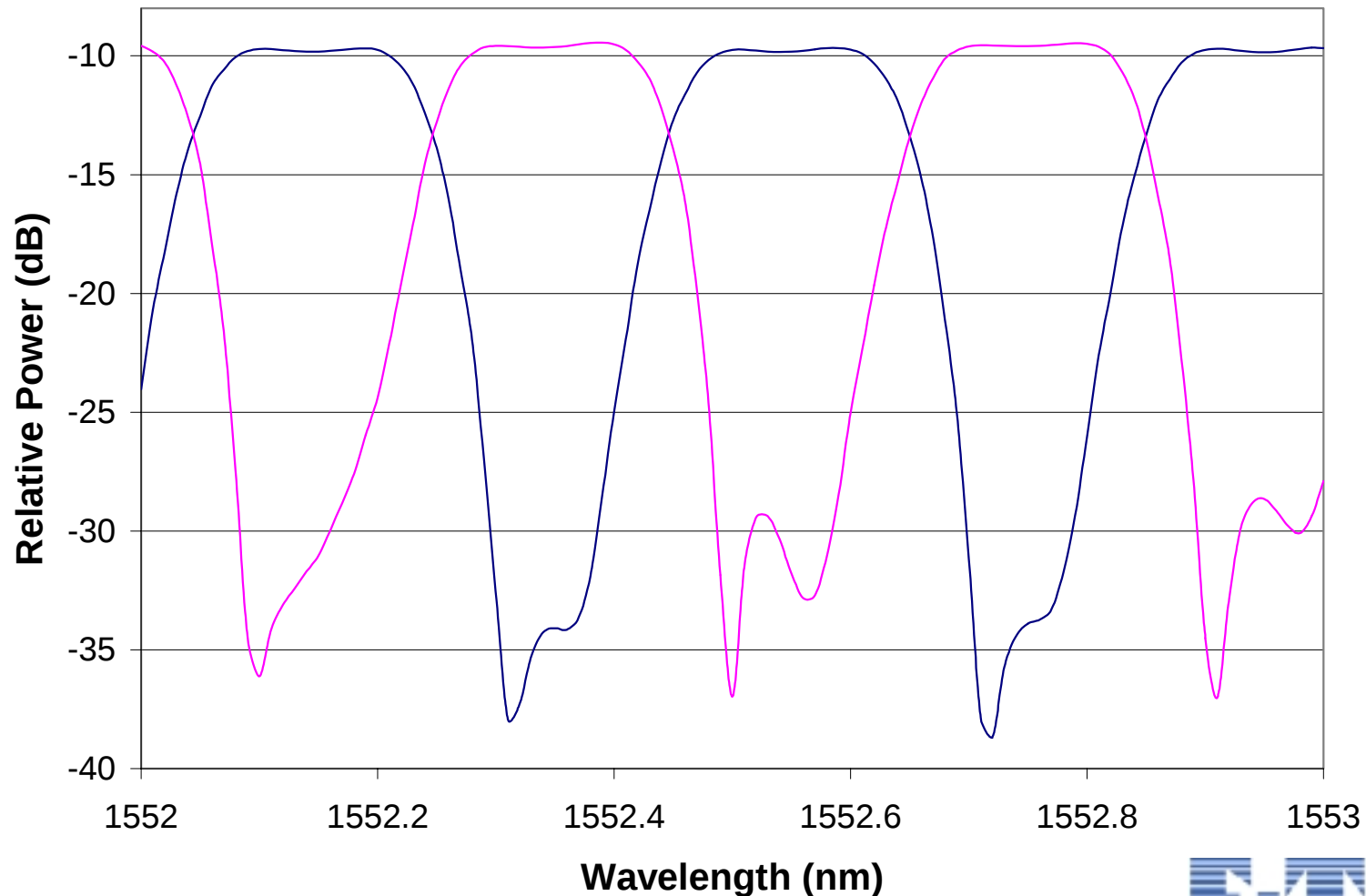


# 25-GHz Interleaver Characteristics



# 25-GHz Interleaver Characteristics

(Insertion Loss ~ 2 dB)

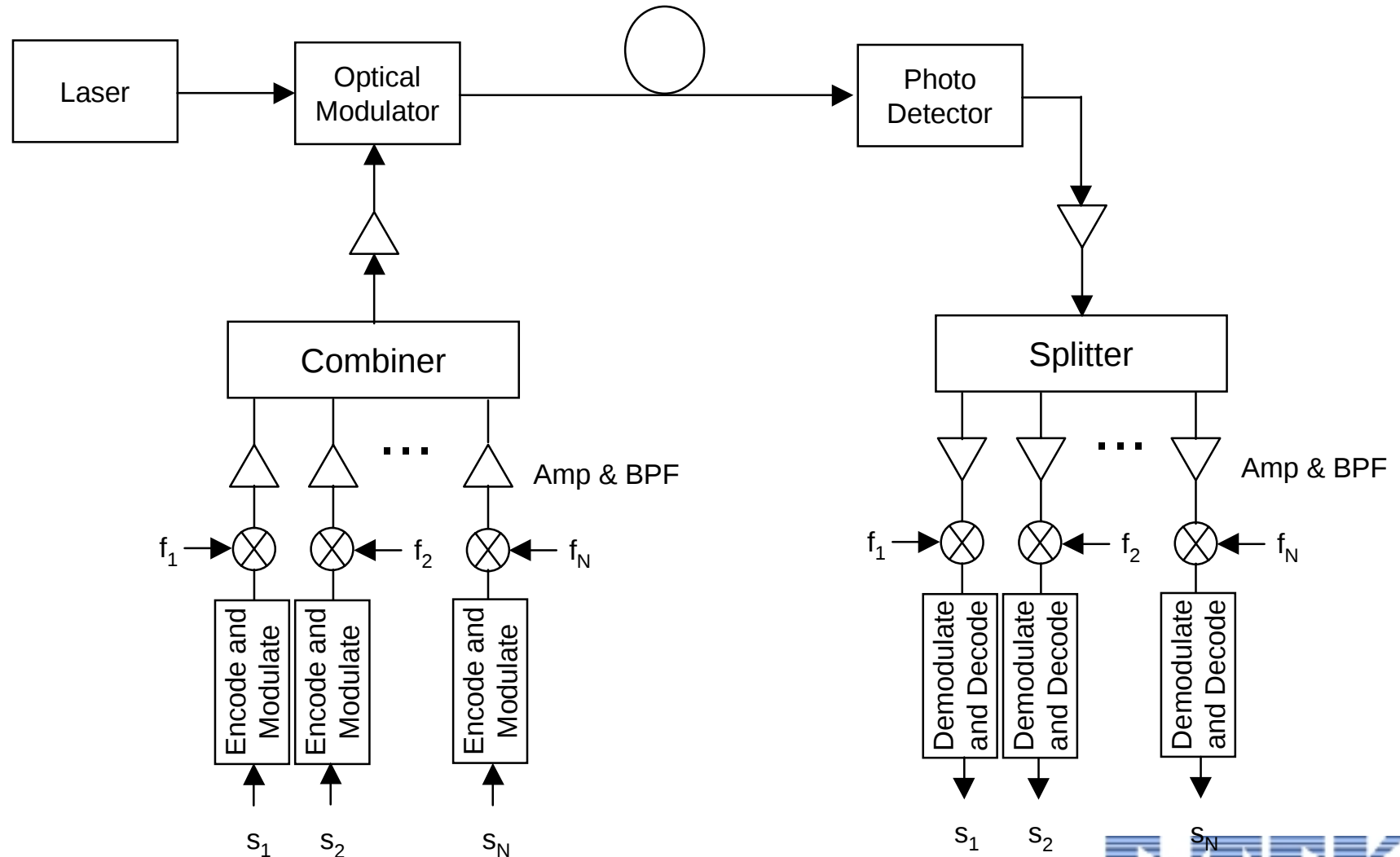


# System Demo with Kestrel

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- Using a 25-GHz interleaver and 10-Gbps optical FDM systems, a two-channel ultra-dense WDM system was demonstrated.
- BERs down to  $10^{-12}$  were achieved.
- No BER floor observed.
- Power penalty due to interleaver was negligible.

## Optical Frequency Division Multiplexing (Kestrel)

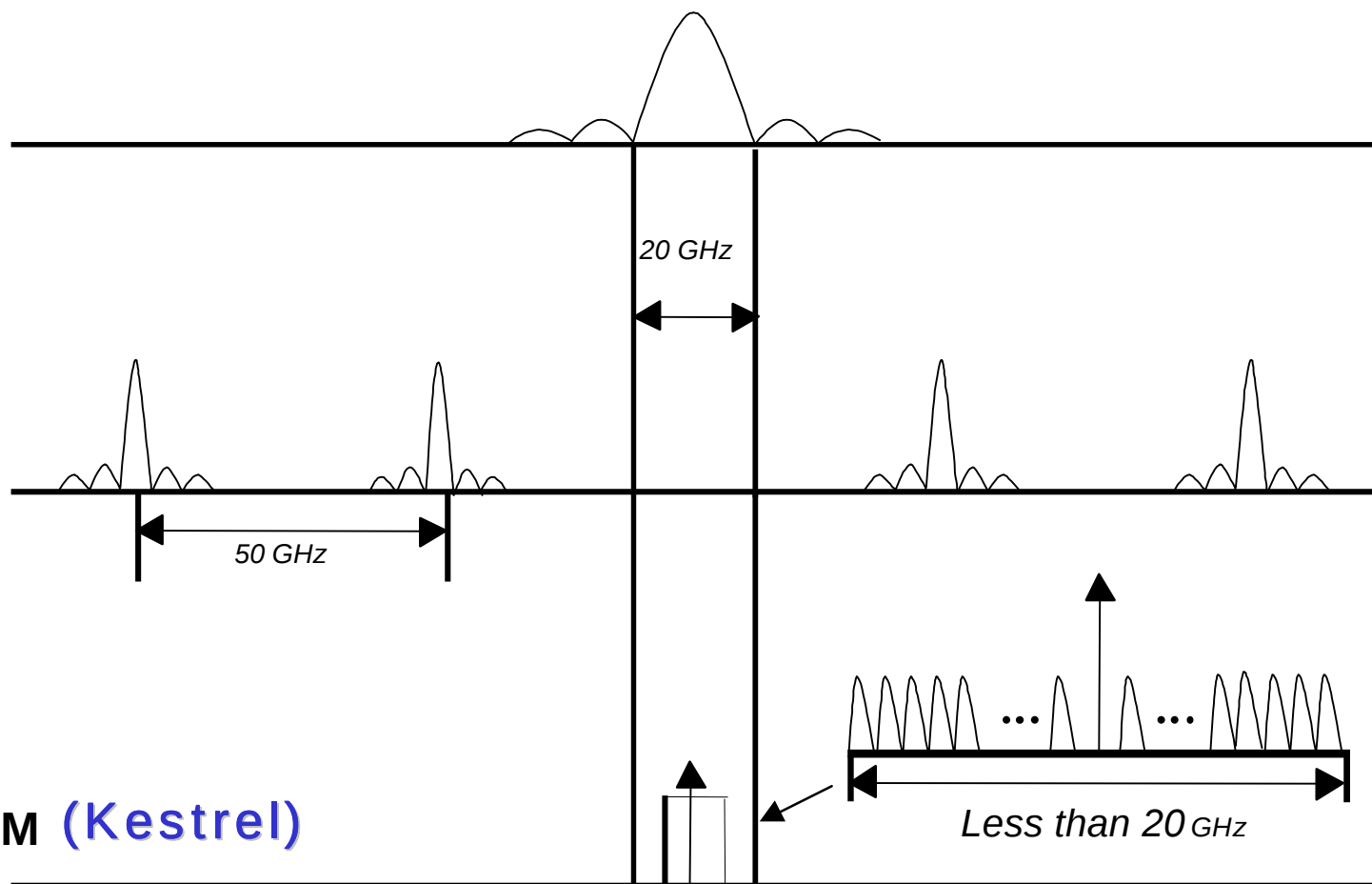


# Spectra For Three Different Methods Of Transmitting 10 Gbps

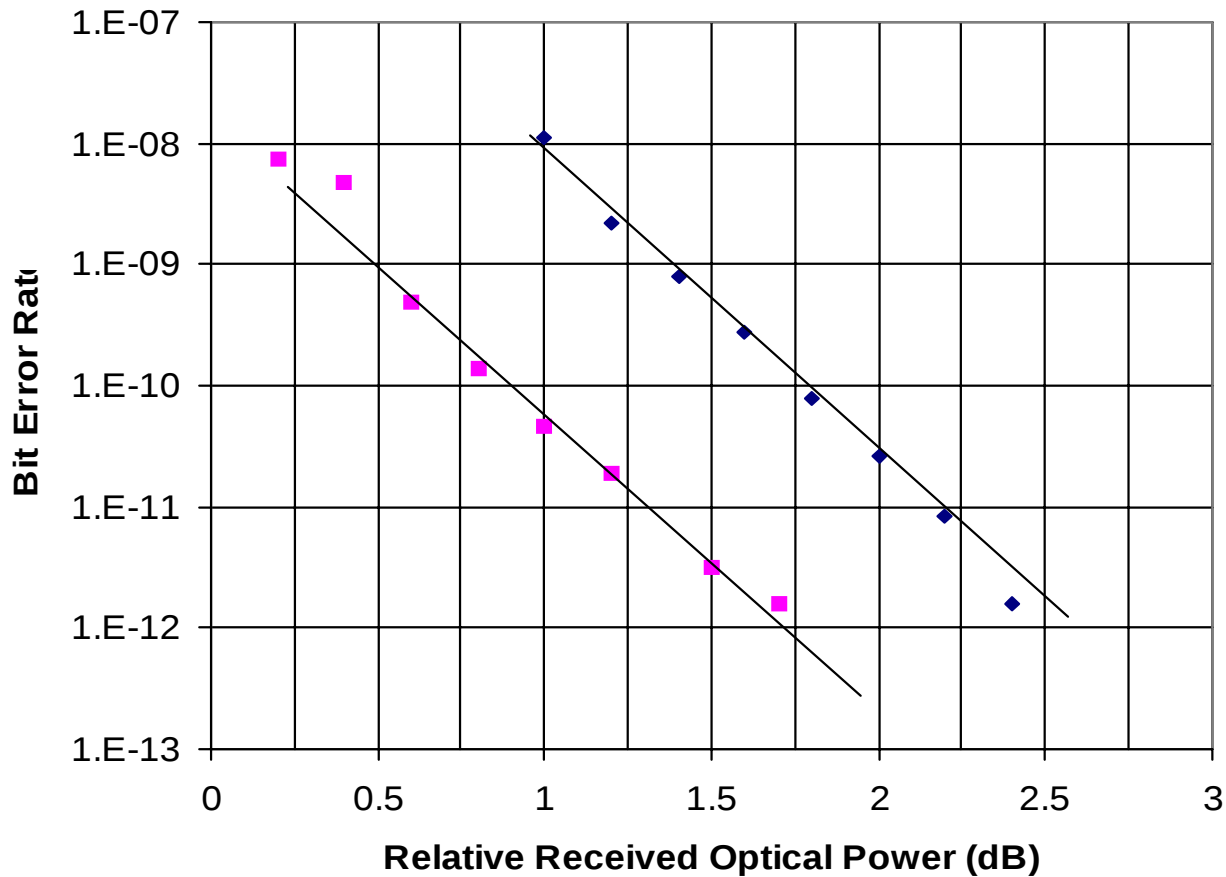
**TDM:  
OC-192**

**DWDM:  
4 OC-48's**

**Optical FDM (Kestrel)**

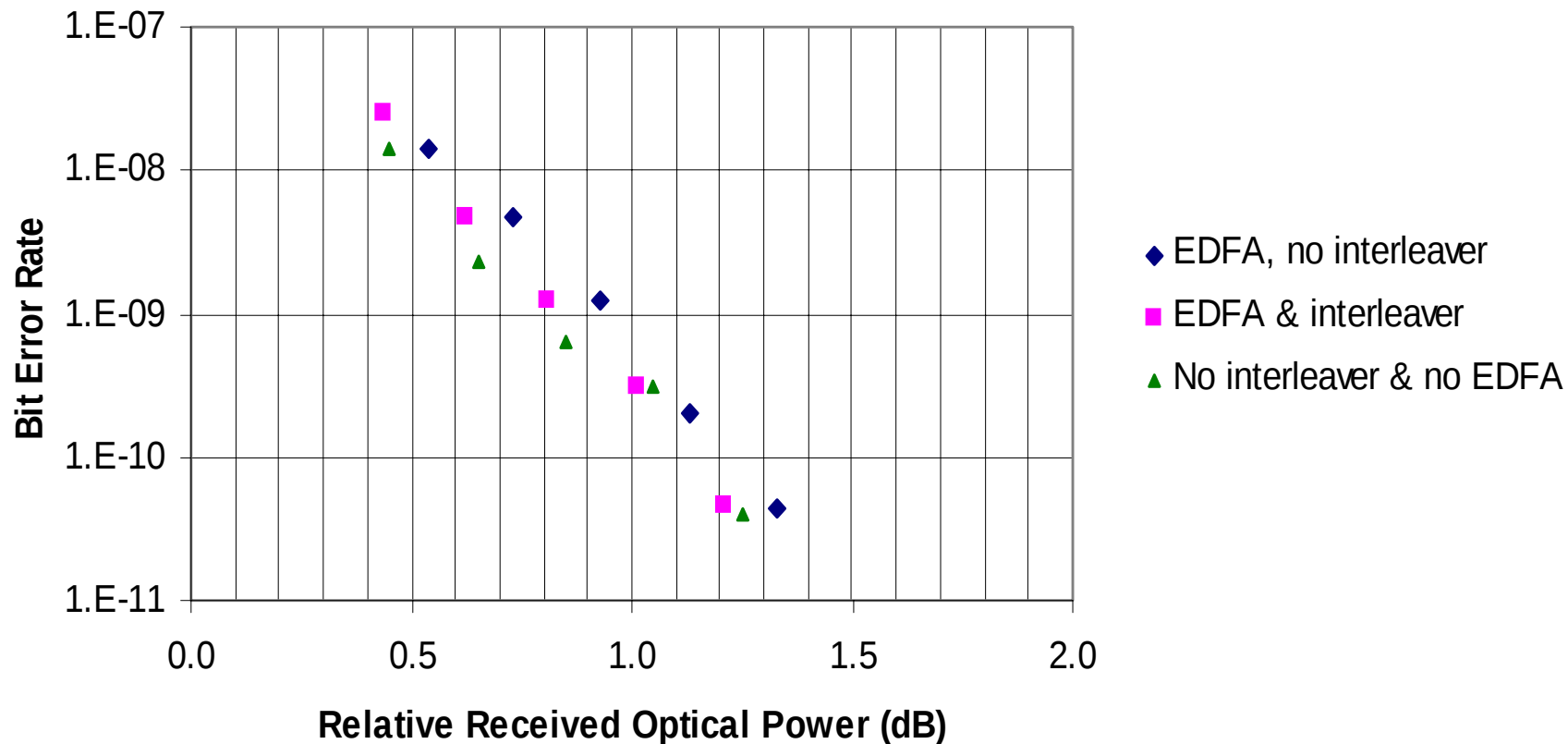


# DWDM System BER



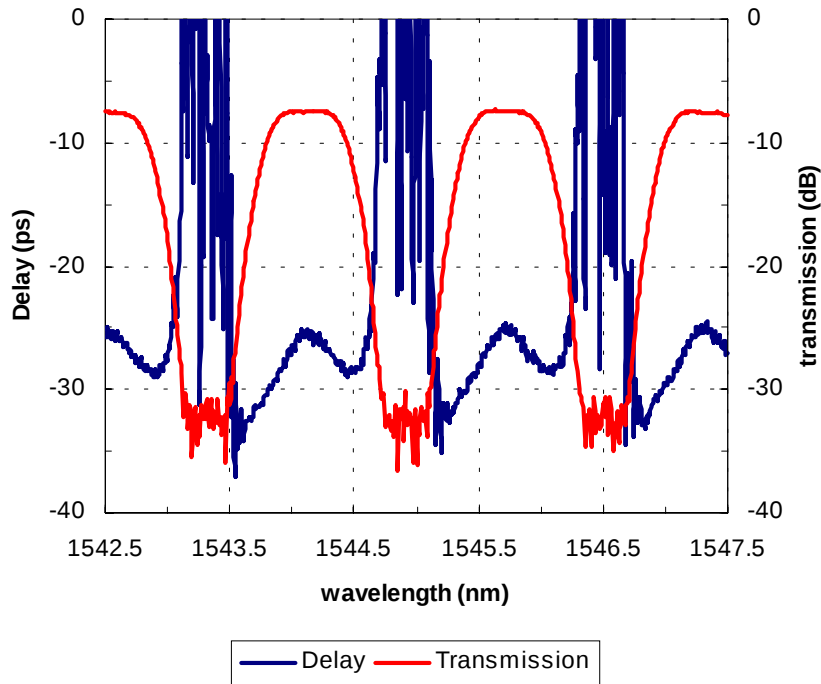
Laser frequency (THz):   ■ 193.081       ◆ 193.055

# Impact of Interleaver on BER

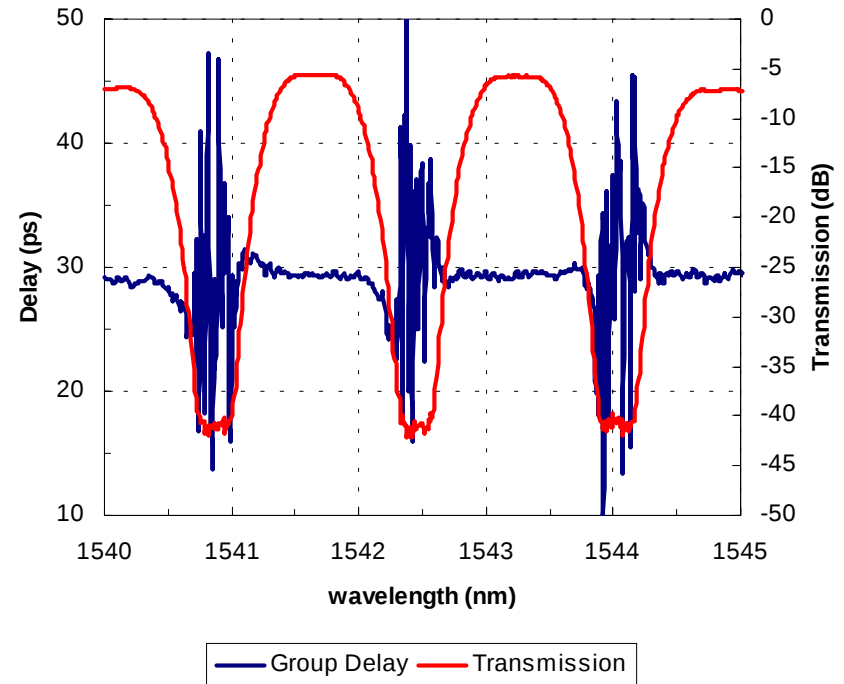


# INTERLEAVER DISPERSION

## Other Interleaver Dispersion Measurement



## E-TEK Interleaver Dispersion Measurement



Special Thanks to Agilent Technologies: R. Fortenberry, F. Liang, A. Noorila, J. Zhang for dispersion measurement



**Agilent Technologies**

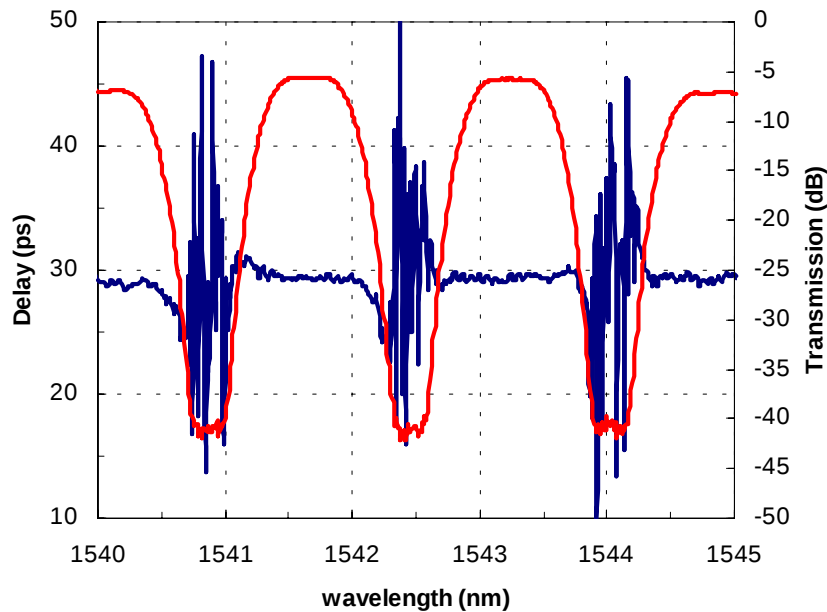
Innovating the HP Way

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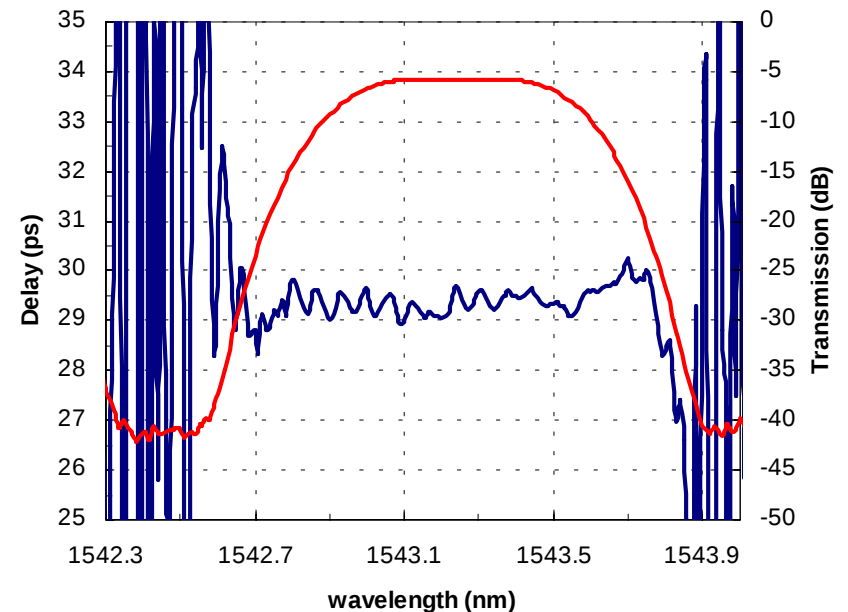
# Less Than 1ps DGD

E-TEK Interleaver Dispersion Measurement



— Group Delay — Transmission

E-TEK Interleaver Dispersion Measurement



— Group Delay — Transmission

Special Thanks to Agilent Technologies: R. Fortenberry, F. Liang, A. Nooriala, J. Zhang for dispersion measurement



**Agilent Technologies**

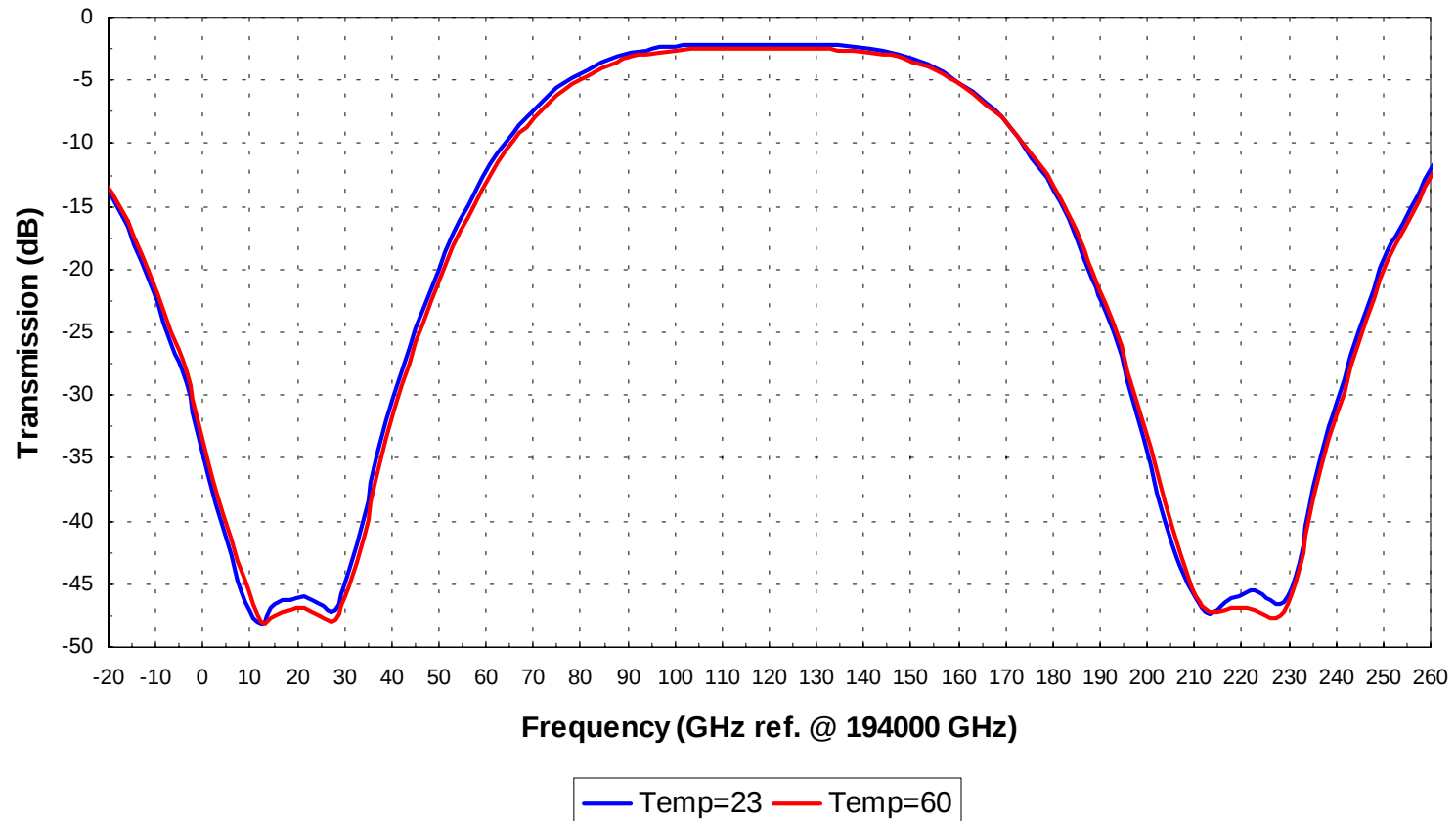
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# Interleaver Temperature Dependence

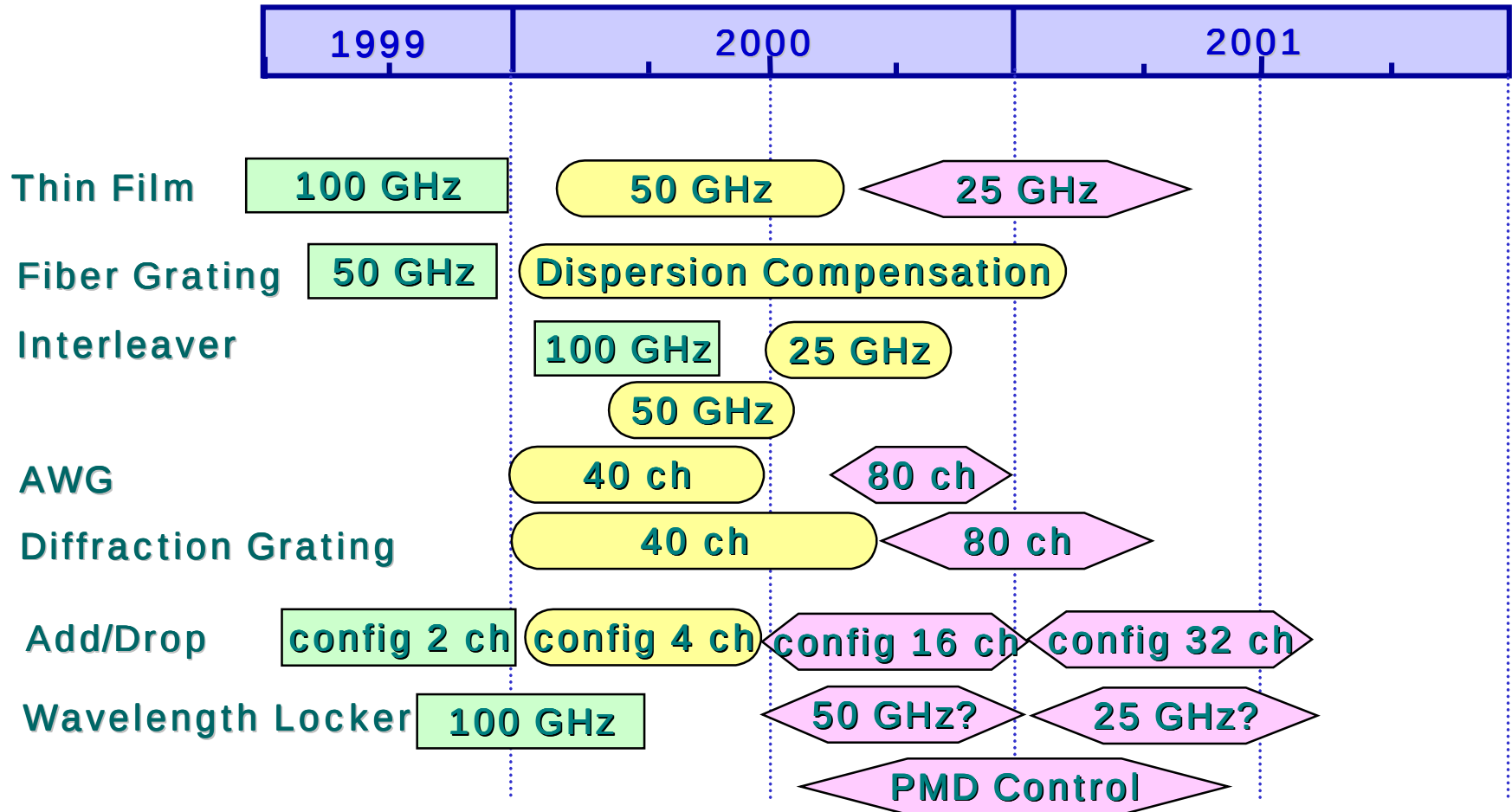
Temperature Dependent of Type II 100 GHz Interleaver



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# DWDM Component Development Road Map



KEY: production development research

4/3/00

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# OPTICAL NETWORK EVOLUTION

