Low-Cost Wide Wavelength Division Multiplexing (WWDM) for 10 Gb Ethernet

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Outline

WWDM for the LAN -

- **Introduction/Motivation**
- **SX Results at HP Labs**
- **LX Results/Plans**

WWDM DFB Source Study

- **Introduction/Motivation**
- **Results**

Conclusions/Challenges

High-Speed Local Area Networks

- 62.5/125 Multimode fiber used for premises (<500m)
- Single mode fiber used for campus LANs (up to ~10km)
- Gigabit Ethernet (1.25 Gbaud) is being widely deployed
- Need already exists for higher data rates in LANs

→ Low cost solutions needed for 10 Gb/s LANs

Potential Solutions for 10 Gb

- Parallel Optics
- Multilevel modulation schemes
- Serial TDM
- WWDM

12.5 Gbd Serial TDM (Assuming 8B/10B encoding)

CHALLENGES:

•Will only go ~ 50 meters on conventional 62.5-µm MM fiber

•Temperature control may be required

•High side mode suppression/low parasitic capacitance laser required

•Relaxation Oscillations ⇒ high laser drive ⇒ poor extinction ratio

•RIN due to reflections may not allow 12.5 Gbd w/out isolation

•Si may not be feasible for optoelectronic ICs (GaAs or SiGe required)

•10 Gb/s SERDES required

•Significant jitter issues

Parallel Optics

CHALLENGES:

- Higher cost of fiber ribbon cable limits cost effectiveness at long (km) distances.
- Current ribbon connector cost quite high
- SX solutions (VCSEL based) have eye-safety/power budget constraints
- LX solutions (FP edge emitter based) have MMF launch issues which are not easily addressed in ribbon fiber form factor.

WWDM for the LAN

Advantages

Longer Distances on MMF or SMF

Slower, Silicon Electronics

Unisolated, Uncooled Lasers

Slower detectors → Larger Detector Areas

Lower-speed packaging

Possible Configurations -

HP Labs SpectraLAN Project -

A. Short Wavelength (eg. 820, 835, 850, 865 nm)

VCSEL based Tx / GaAs PIN based Rx

Multimode Fiber: 4x1.25 Gbd = 5 Gbd over 220 m of 62.5-µm Fiber

4x2.5 Gbd = 10 Gbd over 110 m of 62.5-µm Fiber

B. Long Wavelength (eg. 1280, 1300, 1320, 1340 nm)

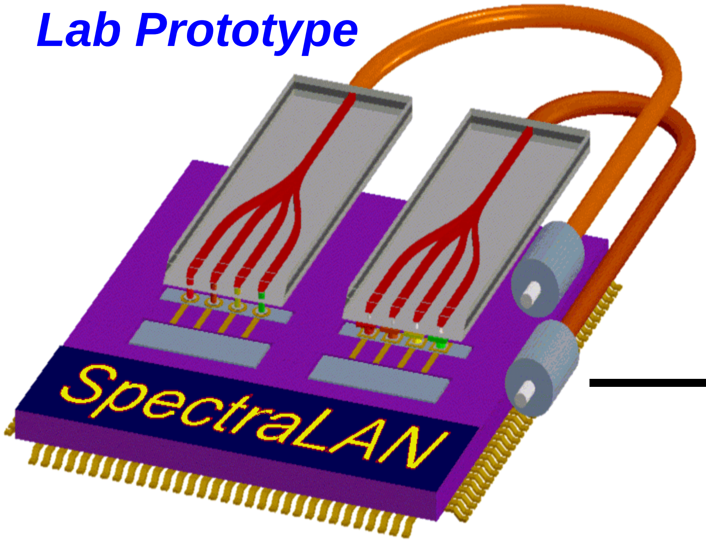
DFB based Tx / InGaAs PIN based Rx

Multimode Fiber: 4x3.125 Gbd = 12.5 Gbd over ~300 m of 62.5-µm Fiber

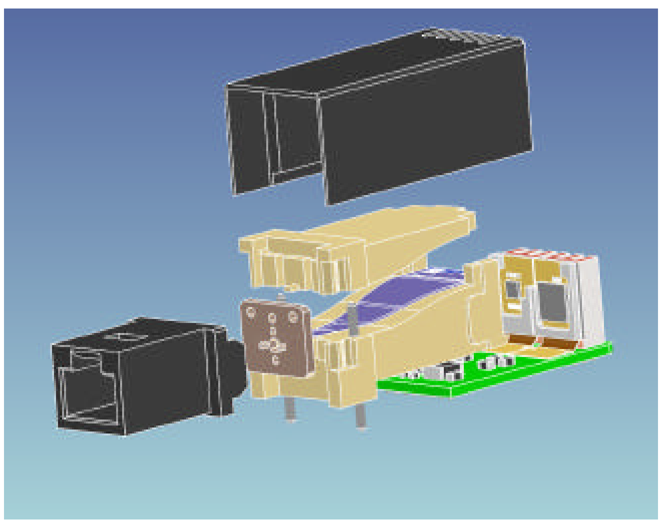
Singlemode Fiber: 4x3.125 Gbd = 12.5 Gbd over ~10 km of SMF

Short-wavelength (SX) SpectraLAN Modules

Lab Prototype

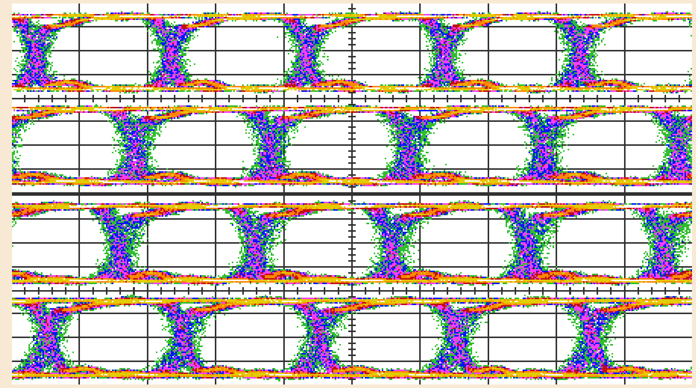


SFF module



1.25 Gbd per channel

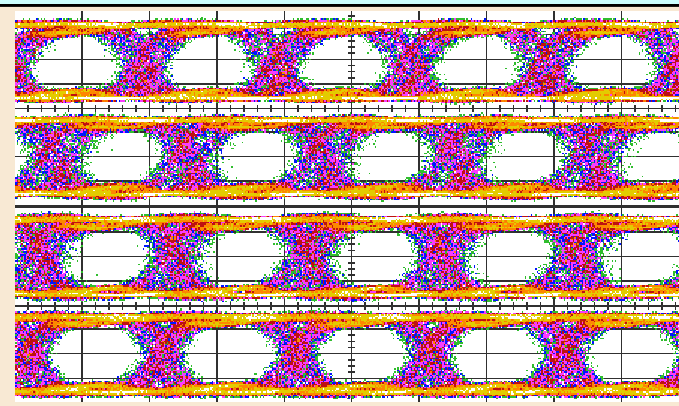
865 nm
850 nm
835 nm
820 nm



After **300m** 62.5-µm Fiber

2.5 Gbd per channel

865 nm
850 nm
835 nm
820 nm



After **100m** 62.5-µm Fiber

Advantages of 1300-nm

I. Bandwidth-Distance Product

2.5 Gb/s in 62.5-µm MMF: 110 m @850nm
300 m @1300nm

II. Power Budget

~ 7.8 dB advantage over 850 nm (6 dB eye safety, 1.8 dB from lower photon energy

III. Single Mode Fiber Compatibility

850-nm sources are incompatible with standard SMF

IV. Supply Voltage

Lower bandgap means lower forward voltage on lasers

SpectraLAN™- LX Piece Parts

Data	4 duplex channels, 3.125 Gbd/channel
Fiber	Dual use SMF/MMF
Package	MTRJ duplex connector, BGA surface mount
Sources	Uncooled, unisolated DFB lasers
Wvlngth	1280,1300,1320,1340 nm
MUX	4-to-1 silica waveguide combiner
Detectors	InGaAs PIN photodiode array
DEMUX	Compact injection molded plastic
ICs	4-channel TX; 4-channel RX (Si)

WWDM DFB Source Study

Goal -

- Experimentally verify that DFBs with low SMSR and no isolator have:
  - RIN < -117 dB/Hz
  - BER < 10^{-12}
  - Small mode-partition noise power penalty (6 km SMF)
- Examine RIN and corresponding BER at high ambient temperature

Measurements

- Sample set of 21 DFB lasers
- Measurements performed on each laser:
  - L-I-V (Light Power-Current-Voltage) - To establish appropriate drive level for remaining tests.
  - Optical spectrum - To establish the SMSR
    - * CW
    - * with 2.488 GBd modulation
  - Relative intensity noise (RIN)
    - * after short SMF patchcord
    - * with 3-dB coupler and receiver on one arm
    - * at elevated ambient temperature
  - Received Eye Diagrams
    - * back-to-back
    - * after 6 km SMF
  - Bit Error Rate (BER)
    - * back-to-back
    - * after 6 km SMF

Note: Performed BER and Eye Measurements at 2.488 GBd due to RCVR

WWDM DFB Source Study - Conclusions

- 1300-nm DFBs with no specification on SMSR and no isolator suitable for WWDM
- Measured RIN < -125 dB/Hz over all SMSR
- Measured RIN < -118 dB/Hz @ 70° C ambient
- Measured PP < 1 dB due to MPN over 6 km SMF
- Measured BER < 10^{-12} over 6 km SMF
- BER results improved with waveguide combiner
- Total PP < 2 dB over 6 km SMF

WWDM - Advantages/Challenges

* Essentially Current DFB/ Gb Ethernet LX technology
  - All component, IC technology currently available
  - Cost model is believable

* Riskier Aspects of technology well in hand
  - Large (and growing) experience base with multi-Gb/ multi-channel ICs (multi-year parallel optics effort)
  - Precision die attach is in production at HP

* Database of DFB source measurements which indicate that uncooled, unisolated lasers with no SMSR spec will be suitable for WWDM.

WWDM - Advantages/Challenges

* 4-chip PDA not proven in production ---> potential cost factor

* Power variation between channels over temperature needs to be investigated/verified

* Electrical/thermal crosstalk at 3.125 Gbd needs to be investigated/verified