WDM Alternatives for 100Gb SMF Applications

IEEE HSSG Presentation

21 September 2006

Chris Cole

chris.cole@finisar.com

Finisar

Outline

- Data rate target proposal
- Signal rate alternatives
- 40km/80km cooled 1550nm alternatives and questions
- 10km un-cooled 1310nm (1550nm?) alternatives and questions
- IEEE LX-4 CWDM background
- ITU-T CWDM background
- HSSG CWDM proposal
- Summary
- Postscript on 100m 850nm VCSEL alternatives

Data rate target proposal

- An objective of 100Gb physical layer standard should be to enable **low cost** transceiver implementations over **existing fiber infrastructure**.
- Dispersion effects go up as the square of the increase in data rate, and practical WDM implementations introduce loss and crosstalk. 100Gb transmission over 10GBASE distances (10km, 40km, etc.) may have 10db or more additional penalty than 10Gb serial transmission.
- Simple 10 x multiplication of 10Gb Ethernet with FEC gives 111Gbps as the required 100Gb data rate. (G.709 FEC has max coding gain of 6dB.)
- Some 10Gb submarine links use a strong 25% (red) FEC code.
- Given the importance of coding gain to restoring 10Gb link budgets, and the uncertainty about the coding overhead required, it is prudent at this early stage to use a conservative target data rate.
- It is proposed that **120Gbps** be used as the initial target data rate for evaluating limitations of physical layer technologies.
- This is **not** a proposal for a specific bit rate or specific coding overhead (which is unlikely to be as high as 20%,) but a target to enable uniform discussion and comparison of various physical layer approaches.

Signal rate alternatives

signal rate GBd	120	60	40	30	24	20	15	12
bits/Bd * ch	1	2	3	4	5	6	8	10

- Required channel count versus signal rate for 120GBaud target.
- Realistic signal rate alternatives are 40Gbd and below.
- This is only a tool for uniform evaluation of physical layer technology limitations and trade-offs.
- Symbol definition:
  - (b) = data rate approximation that denotes a standard (ex. 10Gb)
  - (bps) = bits/sec = data rate = Baud * bits/Baud * channels
  - (Bd) = Baud = symbol rate = signal rate
  - (ch) = channels = wires or fibers * wavelengths or freq. carriers

40km/80km cooled 1550nm alternatives

- 10 channel alternative
  - 12GBd (NRZ)
  - 10ch EML cooled array
  - ITU DWDM C-band 200GHz spacing (1550.12 to 1564.68nm λs)
- 5 channel alternative
  - 24GBd (NRZ)
  - 5ch EML cooled array
  - ITU DWDM C-band 200GHz spacing (1550.12 to 1556.56nm λs)
- 3 channel alternative
  - 40GBd (duo-binary)
  - 3ch EML cooled array
  - ITU DWDM C-band 200GHz spacing (1550.12 to 1553.33nm λs)
- 2 channel alternative
  - 30GBd (4-level PAM)
  - 2ch EML cooled array
  - ITU DWDM C-band 200GHz spacing (1550.12, 1551.72nm λs)

40km/80km cooled 1550nm questions

- Will 100GB be used for 40km/80km applications?
- What coding processing and coding gain should be considered feasible?
- What receiver EDC should be considered feasible?
- What transmitter DC should be considered feasible?
- What multi-level modulation formats should be considered feasible?
- What EML array size should be considered feasible?

10km un-cooled 1310nm (1550nm?) alternatives

- 10 channel alternative
  - 12Gbd (NRZ)
  - 10ch un-cooled DML array
  - ITU CWDM 20nm spacing (unspecified or 1431 to 1611nm λs)
- 8 channel alternative
  - 15GBd (NRZ)
  - 8ch DML or EML un-cooled array
  - ITU CWDM S, C,L-band 20nm spacing (1471 to 1611nm λs)
- 5 channel alternative
  - 24GBd (NRZ)
  - 5ch DML or EML un-cooled array
  - ITU CWDM O-band 20nm spacing (1271 to 1351nm λs)
- 4 channel alternative
  - 30GBd (NRZ)
  - 4ch DML or EML un-cooled array
  - IEEE LX-4 grid 25nm spacing (1275 to 1350nm λs)

10km un-cooled 1310nm (1550nm?) questions

- Will 100GB be used for 10km applications?
- What signal rate for DFB or other DML transmitters should be considered feasible?
- Should alternatives to NRZ be considered for DFB or other DML transmitters?
- What coding processing and coding gain should be considered feasible?
- What receiver EDC should be considered feasible?
- Can CWDM wavelength spacing below 20nm be considered feasible?
- Which CWDM grid should be used?

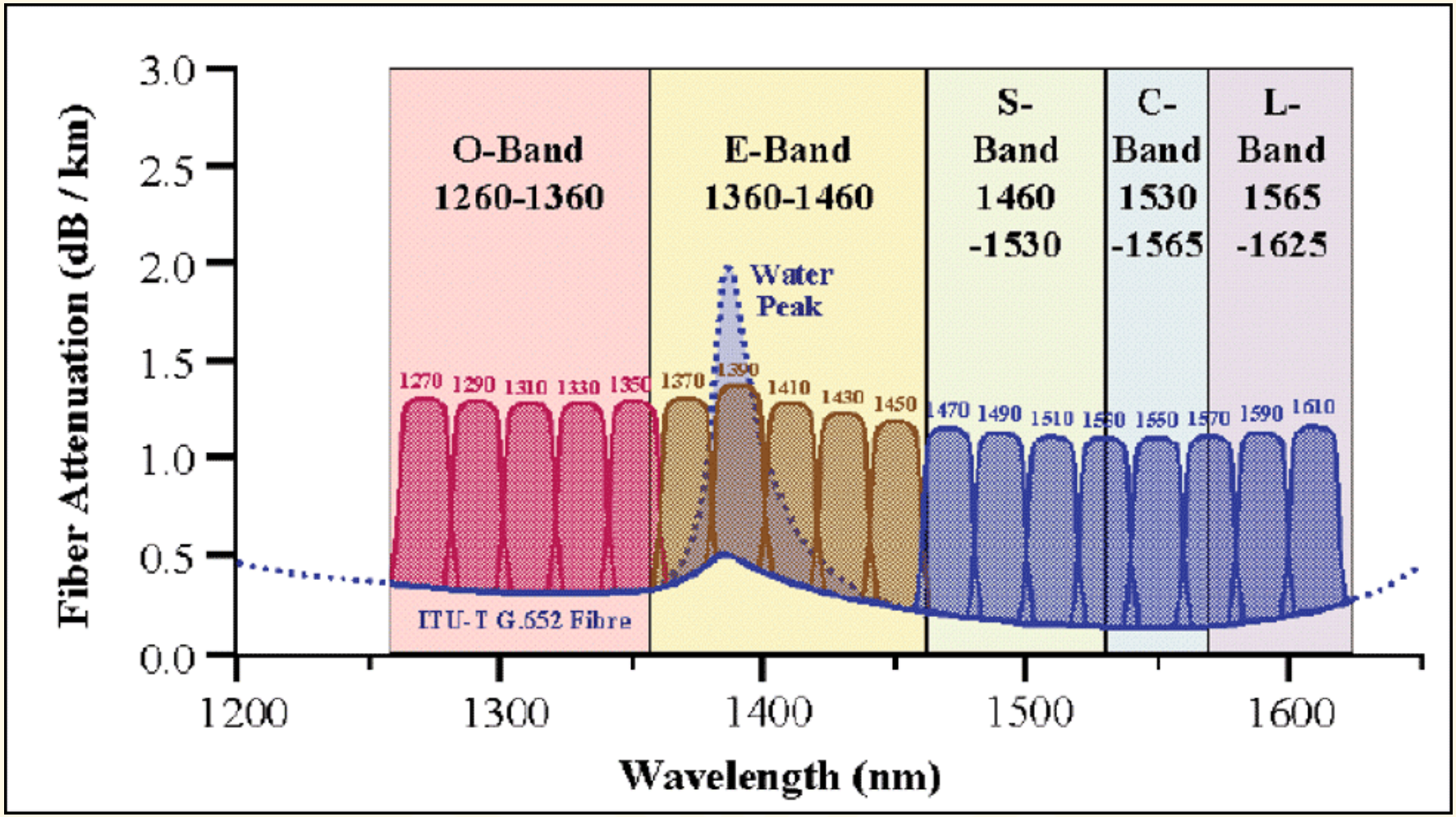
10GBASE-LX4 background

- Original research done at HP (Agilent) Labs.
- 802.3ae-2002 Physical Layer Specification Standard clause 53.
- David Cunningham original editor of WWMD PMD (initially clause 54.)
- Eric Grann final editor of WWMD PMD.
- Specifies 50um and 62.5um MMF, and 10um SMF.
- Has only seen deployment for MMF, but carries cost burden of SMF launch to meet both sets of specifications.
- Defines the following four 2.5Gb (3Gb) CWDM wave-lengths:
  - 1269.0 – 1282.4 nm
  - 1293.5 – 1306.9 nm
  - 1318.0 – 1331.4 nm
  - 1342.5 – 1355.9 nm
- Agilent proposed LX-4 wavelengths before ITU adopted G.694.2.
- Result is that 2.5Gb CWDM wavelengths are slightly different for datacom (IEEE) and telecom (ITU) based applications.

ITU-T G.694.2 and G.695 background

- CWDM grid is defined in ITU-T G.694.2, consented in 2002.
  (DWDM grid is defined in ITU-T G.694.1.)
- ITU-T G.695 defines the CWDM optical interfaces, consented in 2003 together with a revision to the G.694.2 grid.
- Mike Hudson original editor of G. 695
- 1271nm to 1611nm, 20nm spacing, 13nm width, 18 channels.
- 1.25Gbps and 2.5Gbps rates.
- Typical applications are 40km and 80km over SMF.
- 4, 8 and 16 channel uni-directional applications.
- 2+2, 4+4, 6+6 and 8+8 bi-directional applications.
- 16 and 8+8 channel applications require “full bandwidth fiber,” i.e. fiber with reduced water peak attenuation.

ITU G.694.2 Grid



Francis Audet, "Understanding CWDM," EXFO application note.

10Gb and higher HSSG CWDM proposal

- It would be beneficial if 10Gbps and higher rate CWDM wavelengths were common between IEEE standards and ITU application codes.
- Next ITU Study Group 15 meeting will be 10/30/06 to 11/10/06 in Geneva.
- Finisar plans to submit a contribution to ITU-T SG15 to start discussion on best way to extend G.695 wavelengths to 10Gbps and higher.
- It is proposed that the IEEE HSSG establish a liaison with ITU SG15 to work towards defining a common set of specifications.
- It is proposed that HSSG contributors consider using the ITU-T G.694.2 CWDM grid wavelengths in their proposals. This can take advantage of the extensive SMF CWDM optical transmission work done in ITU-T G.695, and provide a uniform framework for evaluating alternatives.

P.S. 100Gb 850nm 100m VCSEL alternatives

- 10 channel alternative
  - 12GBd (NRZ)
  - 10ch VCSEL array
  - Parallel ribbon fiber (ex. 24 MPO)
- No supplier sees other feasible 850nm VCSEL alternatives such as CWDM or high speed (20Gb or greater,)
- … but most customers dislike parallel (ribbon fiber) optics.
- Does that mean there will be no 850nm VCSEL 100Gb standard?