Memstar[SM]

Micromachined Solutions For Optical Networks

Optical Communications Reference Chart

Frequency Utilization for Fiber Application

Window	1st		2nd	5th	5th	3 rd	4th
Range	820 – 900		1280 – 1350	1350 – 1450	1450 – 1528	1528 – 1561	1561 – 1620
Band Name	--	Not used	S	--	--	C	L
Fiber Type	MMF		SMF	SMF AllWave™	SMF	SMF	DSF
Applications	LAN -Type		Single -λ	DWDM*	DWDM/ MAN	DWDM	DWDM

* DWDM may also include single wavelength applications

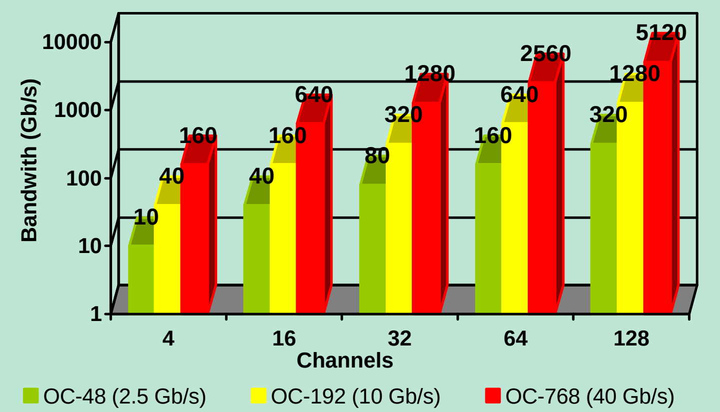
ITU Wavelength Grid 100 GHz spacing

Frequency (GHz)	λ (nm)	Frequency (GHz)	λ (nm)	Frequency (GHz)	λ (nm)	Frequency (GHz)	λ (nm)	Frequency (GHz)	λ (nm)
197100	1521.020	195000	1537.400	192900	1554.137	190800	1571.242	188700	1588.726
197000	1521.792	194900	1538.189	192800	1554.943	190700	1572.066	188600	1589.568
196900	1522.565	194800	1538.978	192700	1555.750	190600	1572.891	188500	1590.411
196800	1523.338	194700	1539.769	192600	1556.558	190500	1573.717	188400	1591.255
196700	1524.113	194600	1540.560	192500	1557.366	190400	1574.543	188300	1592.100
196600	1524.888	194500	1541.352	192400	1558.176	190300	1575.370	188200	1592.945
196500	1525.664	194400	1542.145	192300	1558.986	190200	1576.199	188100	1593.792
196400	1526.441	194300	1542.939	192200	1559.797	190100	1577.028	188000	1594.639
196300	1527.219	194200	1543.733	192100	1560.601	190000	1577.858	187900	1595.487
196200	1527.997	194100	1544.529	192000	1561.422	189900	1578.689	187800	1596.337
196100	1528.776	194000	1545.325	191900	1562.236	189800	1579.521	187700	1597.187
196000	1529.556	193900	1546.122	191800	1563.050	189700	1580.353	187600	1598.038
195900	1530.337	193800	1546.920	191700	1563.865	189600	1581.187	187500	1598.889
195800	1531.118	193700	1547.718	191600	1564.682	189500	1582.021	187400	1599.742
195700	1531.901	193600	1548.518	191500	1565.499	189400	1582.856	187300	1600.596
195600	1532.684	193500	1549.318	191400	1566.317	189300	1583.693	187200	1601.451
195500	1533.468	193400	1550.119	191300	1567.135	189200	1584.530	187100	1602.306
195400	1534.253	193300	1550.921	191200	1567.955	189100	1585.368	187000	1603.163
195300	1535.038	193200	1551.724	191100	1568.776	189000	1586.206	186900	1604.020
195200	1535.825	193100	1552.527	191000	1569.597	188900	1587.045	186800	1604.878
195100	1536.612	193000	1553.332	190900	1570.419	188800	1587.885	186700	1605.737

Transmission Data Rates Standardized

Synchronous Transport Signal (STS-x) SONET Signal	Synchronous Transport Module (STM-x) SDH Signal	Optical Carrier (OC-x) Optical Signal	Line Rate (Gb/s)
STS-1	STM-0	OC-1	0.052
STS-3	STM-1	OC-3	0.156
STS-12	STM-4	OC-12	0.625
STS-48	STM-16	OC-48	2.5
STS-192	STM-164	OC-192	10
STS-768	STM-256	OC-768	40

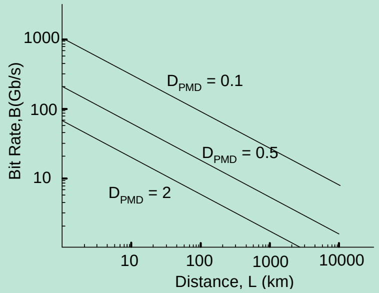
Bandwidth Capacity in WDM Systems



270 River Street, Troy NY 12180 USA www.memstar.com sales@memstar.com (518)-271-7844

Limitations in WDM Systems

Polarization Mode Dispersion

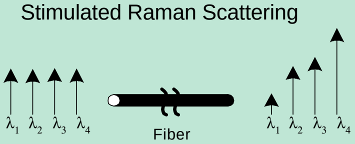


Limitations on the simultaneously achievable bit rates and distances imposed by PMD.

The time-averaged differential time delay between the two orthogonal SOPs in a link obeys the relation:

$$\langle \Delta \tau \rangle = D_{PMD} \sqrt{L}$$

Stimulated Raman Scattering



The fraction of the power coupled out of channel 0 to all the other channels is:

$$P_0 = \sum_{i=1}^{W-1} P_0(i) = \frac{g_R \, \Delta\lambda_S \, P L_e}{2 \Delta\lambda_C \, A_e} \frac{W(W-1)}{2}$$

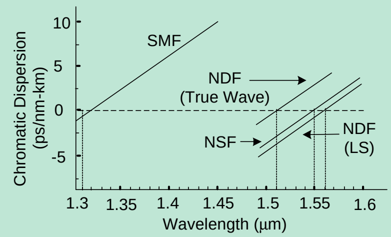
The power penalty for this channel is then: $-10 \log(1 - P_0)$

Stimulated Brillouin Scattering

The threshold power for a signal with a line width Δf_{source} of the source is:

$$P_{th} \approx \frac{21 b A_e}{g_B L_e}\left(1 - \frac{\Delta f_{source}}{\Delta f_B}\right)$$

Chromatic Dispersion

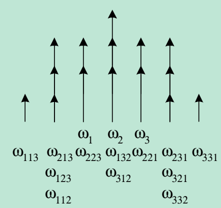


Chromatic dispersion characteristics of different types of single-mode fiber.

Assuming that the pulse spreading due to chromatic dispersion should be less than a fraction ε of the bit period, the transmission limitations imposed by chromatic dispersion can be obtained by:

$$B\lambda \sqrt{\frac{|D| L}{2\pi c}} < \varepsilon \quad \text{with} \quad D = -\left(\frac{2\pi c}{\lambda^2}\right)\beta_2$$

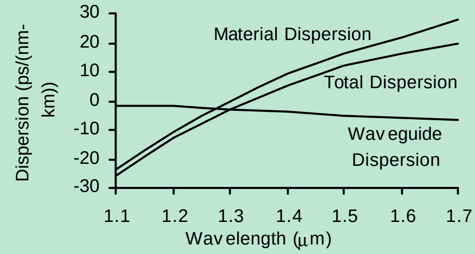
Four-Wave Mixing



In a real system where both loss and dispersion are present, the power penalty due to four-wave mixing can be obtained by:

$$P_{ijk} = \eta_{ijk}\left(\frac{\omega_{ijk}\, \bar{n}\, d_{ijk}}{3 c A_e}\right)^2 P_i P_j P_k L_e^2$$

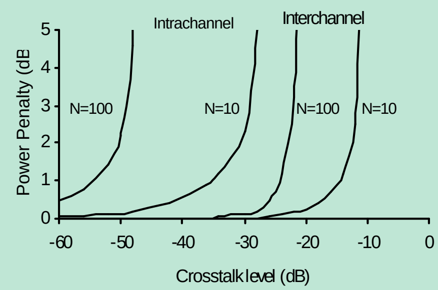
Material and Waveguide Dispersion



Material, Waveguide and Total Dispersion in standard single-mode optical fiber

The Total Dispersion is obtained from: $D = D_M - D_W$

Crosstalk



Signal-spontaneous noise limited intrachannel and interchannel crosstalk penalties as a function of crosstalk level –10log ε in a network. The parameter N denotes the number of crosstalk elements, all assumed to produce crosstalk at equal powers

Standards Development Organizations for Optical Communications

Application-Oriented	Product-Oriented	Level
ITU (International Telecommunication Union) www.itu.int	IEC (International Engineering Consortium) www.iec.org	International
ETSI (European Telecommunication Standards Institute) www.etsi.org	CENELEC (European Committee for Electrotechnical Standardization) www.cenelec.org	Europe
TTC (Telecommunication Technology Committee)	JISC (Japanese Industrial Standards Committee) www.jisc.org	Japan
EIA (Electronic Industries Alliance) www.eia.org / TIA (Telecommunications Industry Association) www.tiaonline.org		North America

Symbols and Parameters

Parameter	Symbol	Typical Value/Units
Bit Error Rate	BER	10^{-9} - 10^{-15}
Bit Rate	B	Mb/s or Gb/s
Brillouin Gain Bandwidth	Δf_B	20 MHz at 1.55 μm
Brillouin Gain Coefficient	g_B	4×10^{-11} m/W
Cross-talk		dB
Dispersion Parameter	D	ps/nm-km
Dispersion Shifted Fiber	DSF	D = 0 (1.55 μm)
Effective Area	A_e	50 μm^2
Effective Length	L_e	km
Four Mixing Efficiency	η	
Insertion Loss	IL	dB
Link Length	L	km
Material Dispersion	D_M	ps/nm-km
Nonzero Dispersion Fiber	NDF	-6 ≤ D ≤ 6 ps/nm-km (1.55 μm)
Optical Bandwidth	Bo	GHz
Optical Return Loss	ORL	dB
Polarization	P	Coulombs/m2
Polarization Depedent Loss	PDL	dB
Polarization Mode Dispersion	D_{PMD}	ps / $\sqrt{km}$
Raman Gain Coefficient	g_R	6×10^{-14} m/W
Speed of Ligth in Vacuum	c	3×10^{8} m/s
Standard Single Mode Fiber	SMF	D = 17 ps/nm-km (1.55 μm)
State of Polarization	SOP	
Waveguide Dispersion	D_W	ps/nm-km

References

- Ramaswami, R. and Sivarajan, K.. *Optical Networks.* Morgan Kaufmann Publishers, San Francisco, CA, 1998.

- Kartalopoulos, S.. *Introduction to DWDM Technology.* SPIE, The International Society for Optical Engineering. Bellingham, WA, 2000.

- Exfo, *Guide to DWDM Technology Testing.* Quebec, Canada , 2000

- ITU-T, *G.692 Recommendation, International Telecommunication Union*, www.itu.int

- ANSI, *American National Standards Institute*, www.ansi.org

- ODSI, www.odsi-coalition.com

- SPIE, *The International Society for Optical Engineering* , www.spie.org

- *Photonics Resources for Scientists and Engineer*, www.optics.org

- OIF, *Optical Internetworking Forum*, www.oiforum.com

- ISOC, *Internet Society*, www.isoc.org

- IETF, *Internet Engineering Task Force*, www.ietf.cnri.reston.va.us

- *Multiservice Switching Forum*, msforum.org

About Us

Memstar Corporation is a company dedicated to the development of micromachine and microsystem enabled products for the optical communications industry. Memstar provides fab-less development services for micromachined components and related subsystems. The company leverages proprietary technology covering novel device and packaging concepts, and unique characterization methods. Memstar's design methodology is focused on allowing short development cycles and cost containment.

Important Notice:

Memstar Corporation makes every reasonable effort toinsure the accuracy of the information presented in this reference sheet . However, we will not be responsible for any loss or damage resulting from reliance upon, and use of, any information presented in it.

Memstar SM