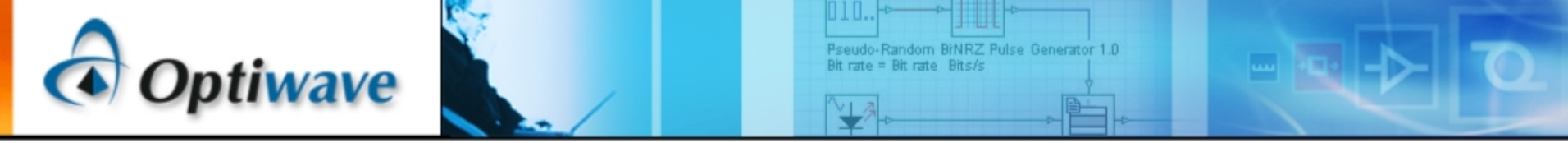
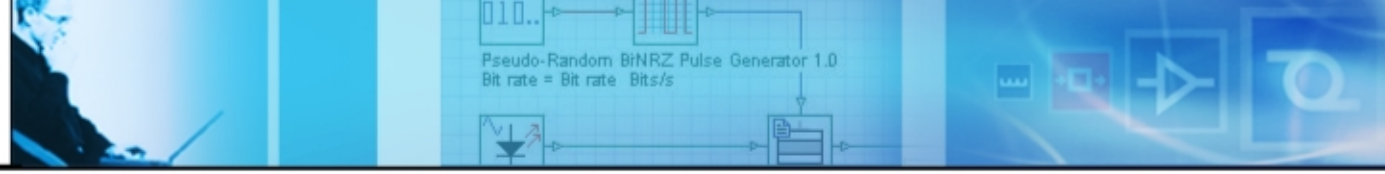


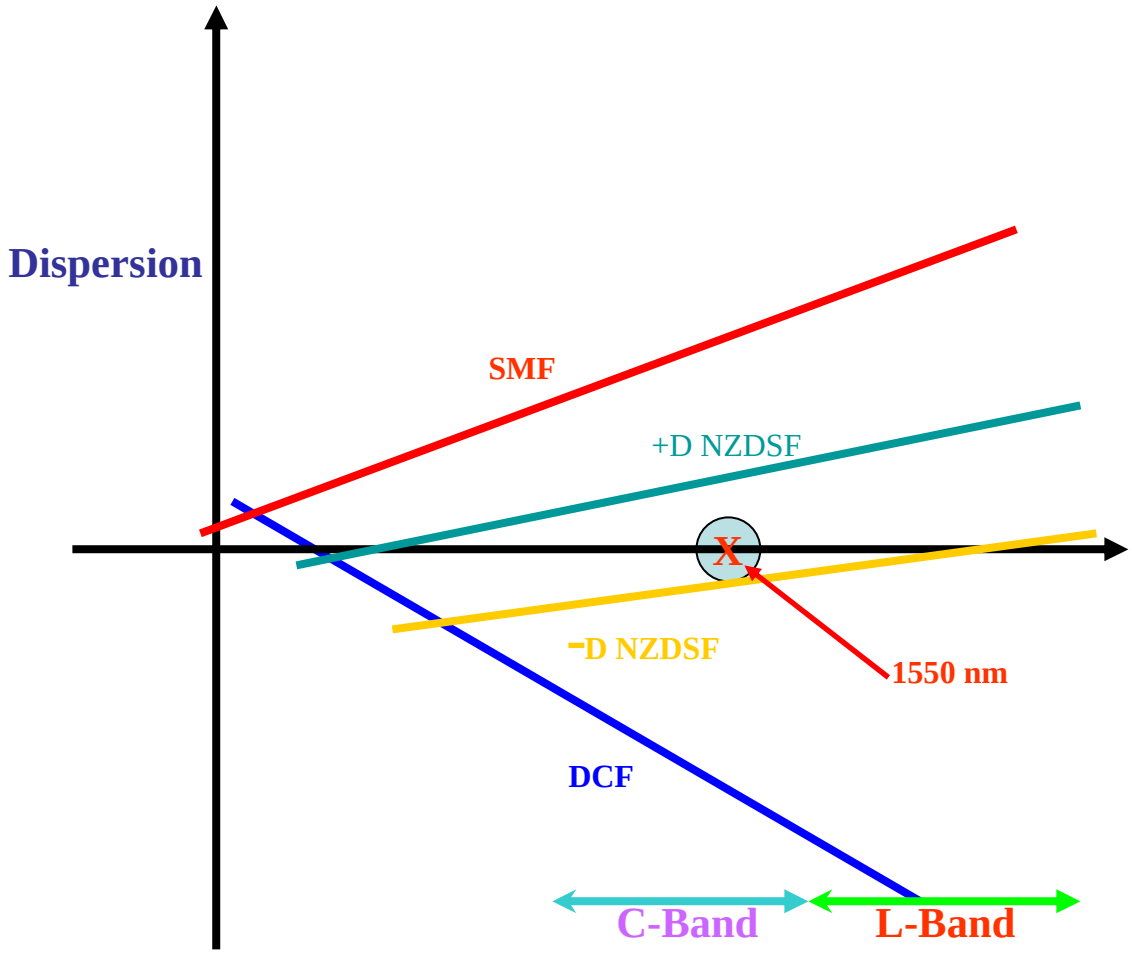
Designing Optical Fibers for WDM Applications



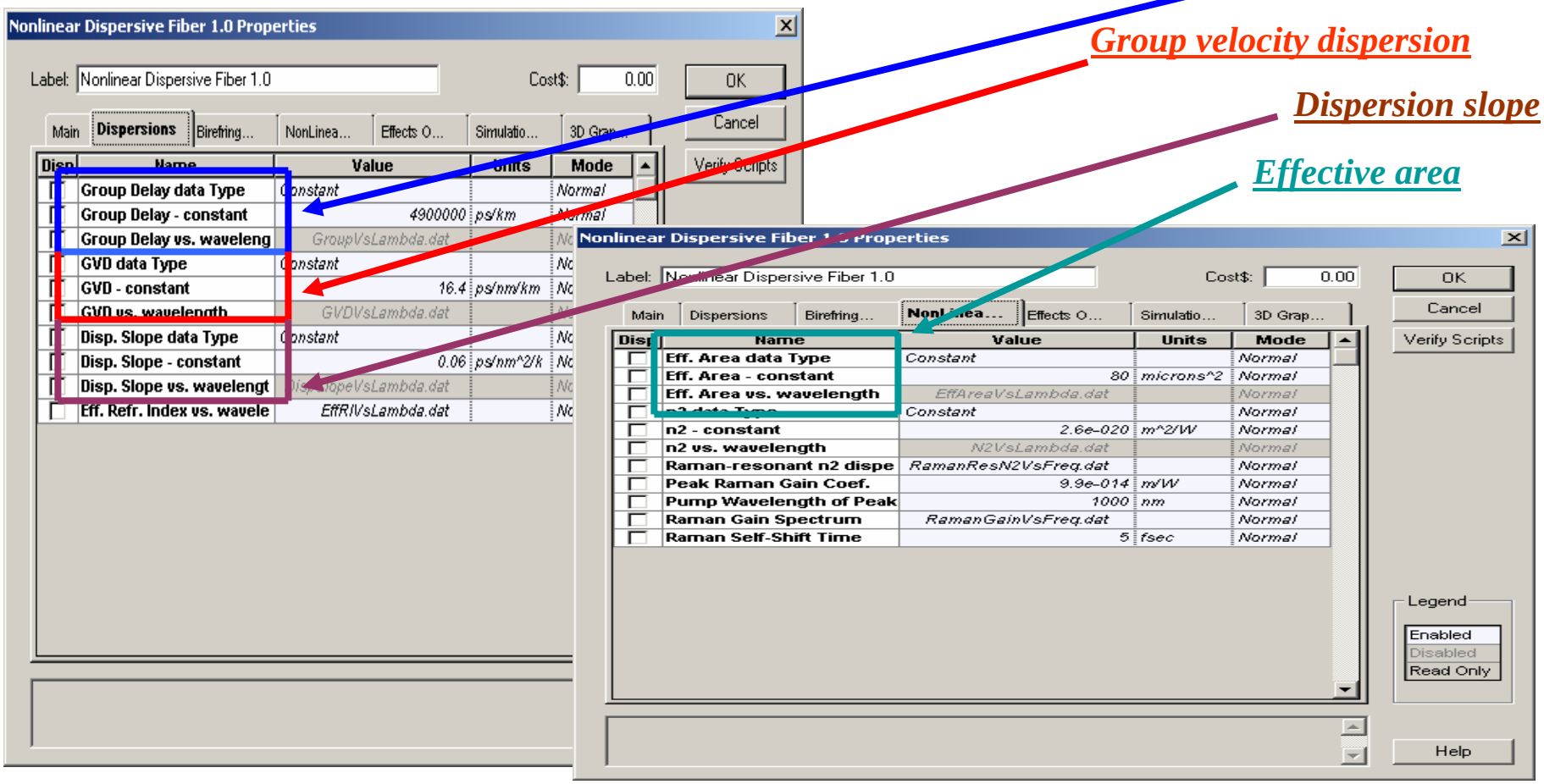
Out Line

- Fiber Parameters Required To Design an Optical System
- ***Different Fiber Types***
- SMF
- Standard DCF
- Highest Negative DCF
- DCF for Broadband Applications
- Non Zero Dispersion Shifted Fiber with Large Effective Area (+D NZDSF)
- Non Zero, Negative Dispersion Fiber for Metropolitan Network (-D NZDSF)
- Conclusion

Different Fiber Types



FIBER Parameters REQUIRED to Design an Optical Systems



SMF

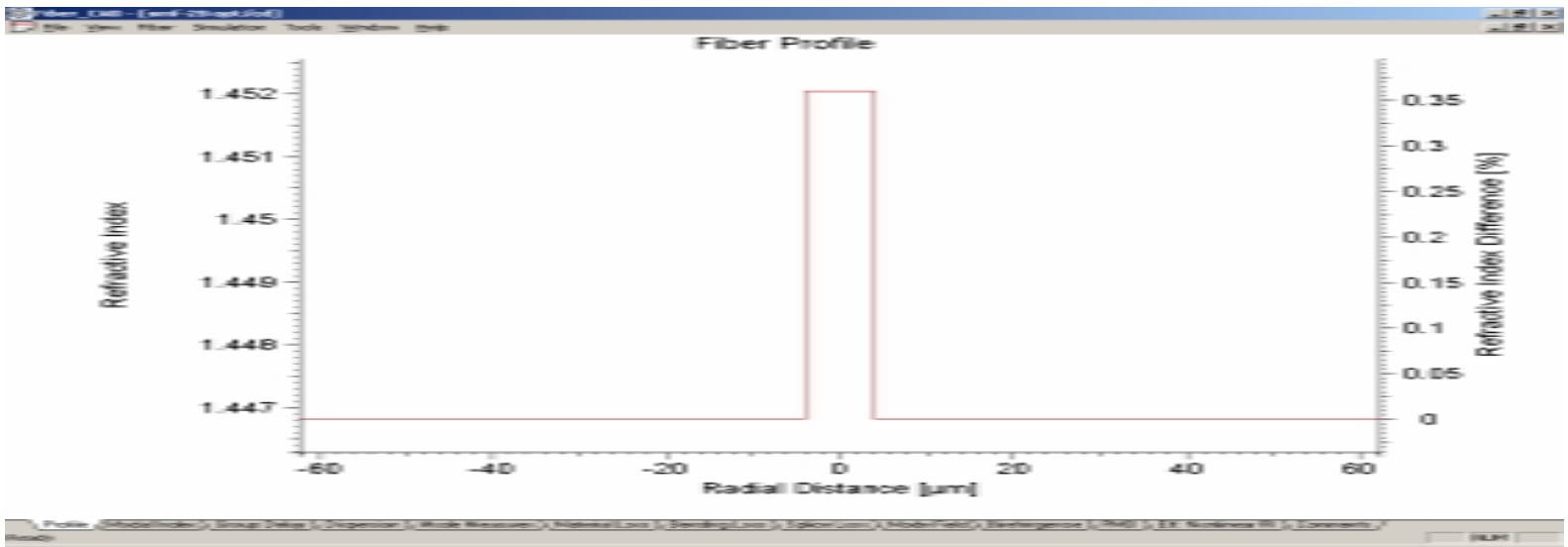
(For specific fiber vendor information, please contact Optiwave Corporation)

Fiber Parameters

Core Radius : 4.07 um

R.I. of Core : 1.45204

R.I. Of Cladding : 1.44681

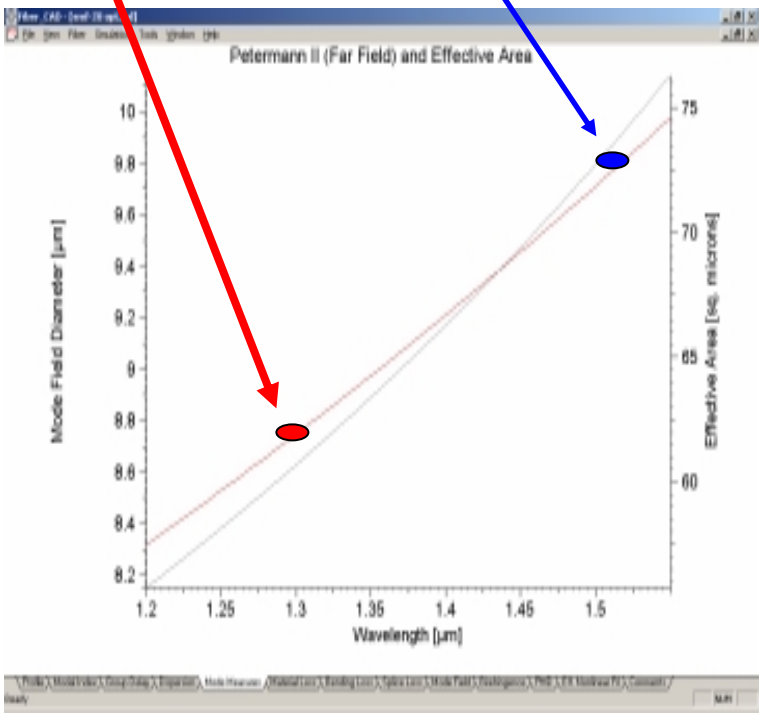


SMF (contd)

Calculated (Fiber_CAD)

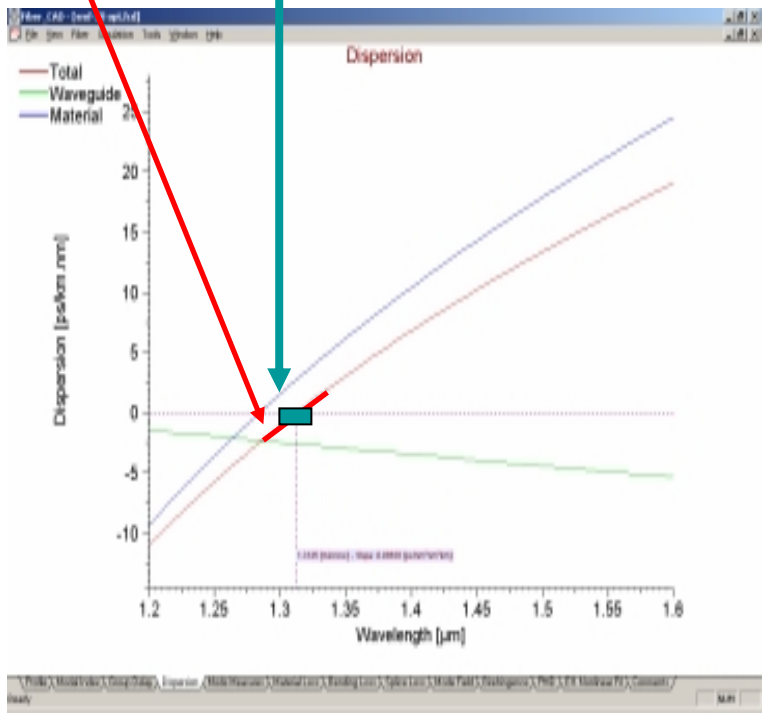
MFD : 8.8 um at 1310 nm

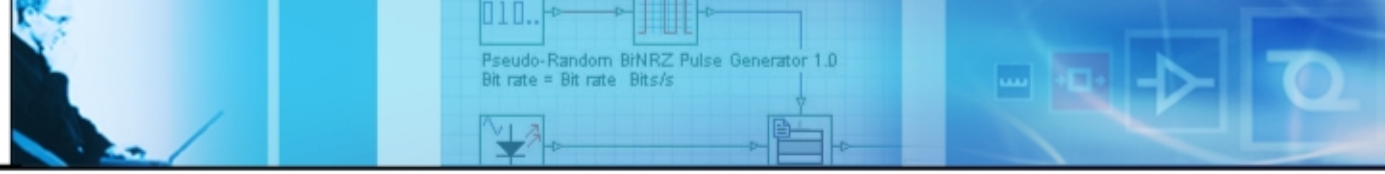
10 um at 1550 nm



Zero Dispersion Slope : 0.08 ps/km-nm^2 at 1313 nm

Zero Dispersion Wavelength : 1313 nm





SMF (contd)

Check

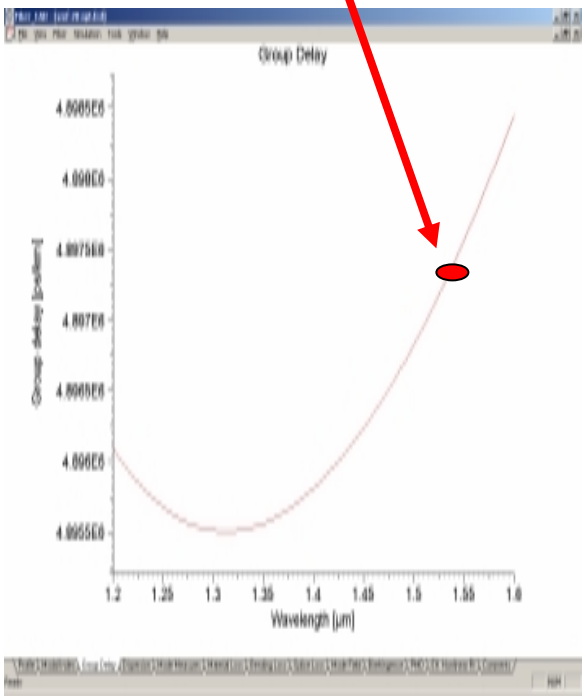
Calculated (Fiber CAD)		Vendor*
MFD : 8.8 um at 1310 nm	----------	8.8 um < MFD < 9.6 um at 1310 nm
10 um at 1550 nm	----------	9.6 um < MFD < 11.2 um at 1550 nm
Zero Dispersion Wavelength : 1313 nm	----------	1302 nm < Zero Dispersion Wavelength < 1322 nm
Zero Dispersion Slope : 0.08 ps/km-nm^2 at 1313 nm	---	Zero Dispersion Slope < 0.092 ps/km-nm^2

* The data of SMF were taken from the public-domain specifications at **the vendor's web-site (for vendor information, please contact Optiwave Corporation)**

SMF (contd)

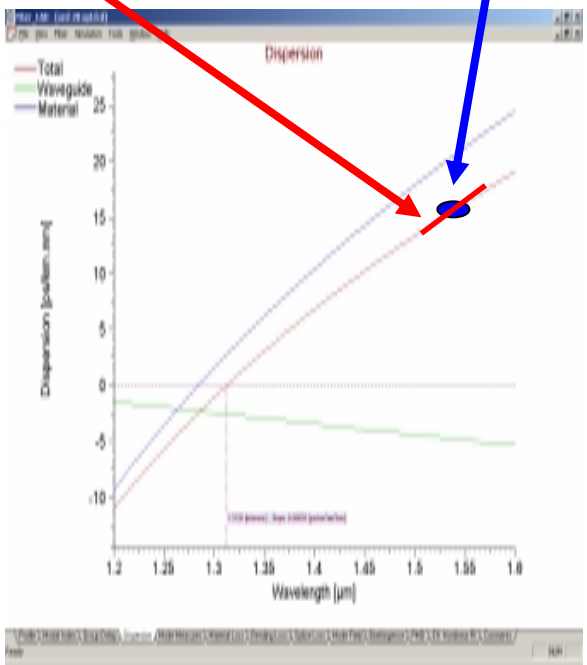
Simulation Parameters to Design an Optical Systems Using this Fiber (at 1550 nm)

Group Delay
4897570 ps / km

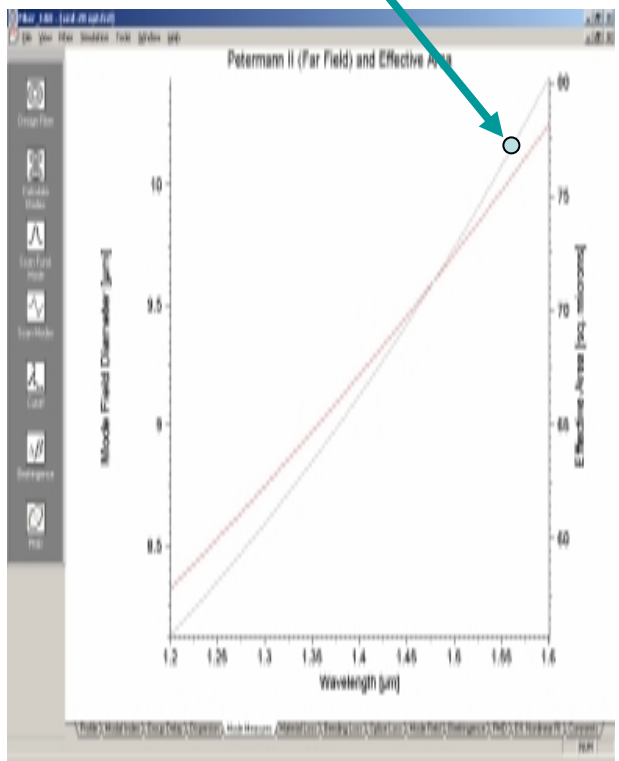


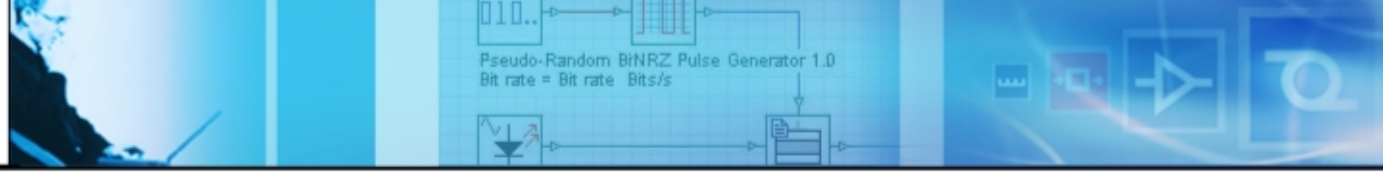
Dispersion
16.3 ps / km-nm

Dispersion Slope
0.069 ps / km-nm^2



Effective Area
76 um^2





Why DCF ?

(a) To Compensate Positive Dispersion of

SMF **(+D) NZDSF**

(b) To Compensate Negative Dispersion of

(-D) NZDSF

Dispersion Compensation Equation

$$D_{+} l_{-} + D_{-} l_{-} = 0$$

D_{+} = Dispersion coefficient of (+) dispersion fiber

l_{-} = Length of (+) dispersion fiber

D_{-} = Dispersion coefficient of (-) dispersion fiber

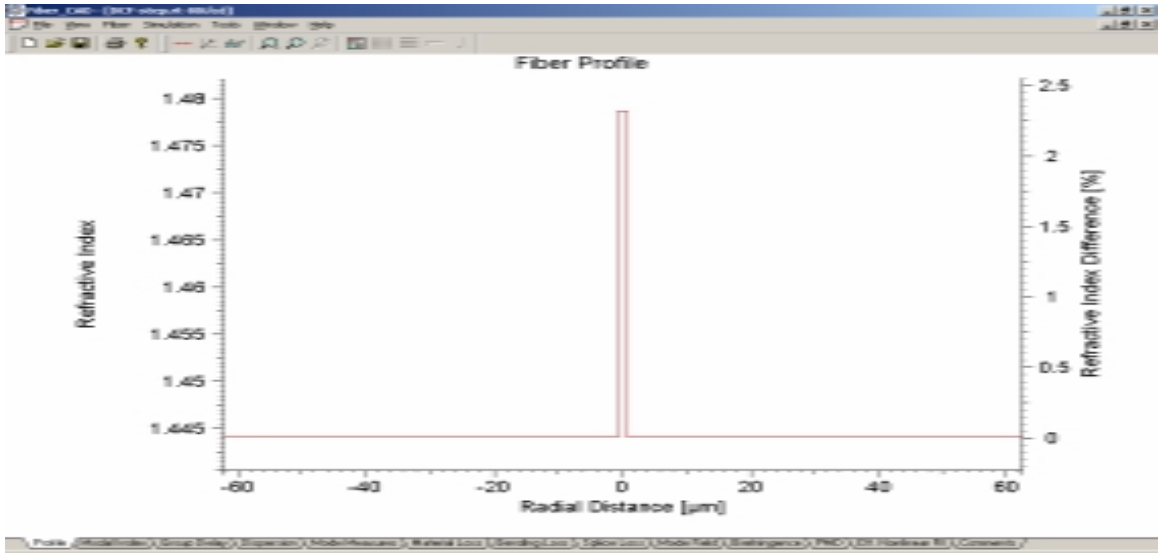
l_{-} = Length of (-) dispersion fiber

Standard DCF

Fiber Parameters

Core Radius : 0.7748 um

R.I. of Core : 1.47866



Standard DCF (contd)

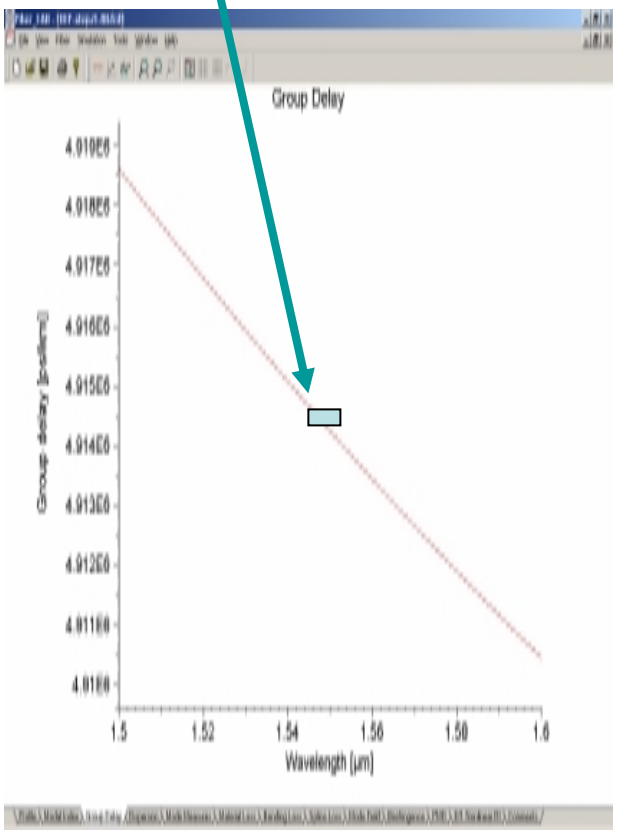
Simulation Parameters to Design an Optical Systems Using this Fiber at 1550 nm

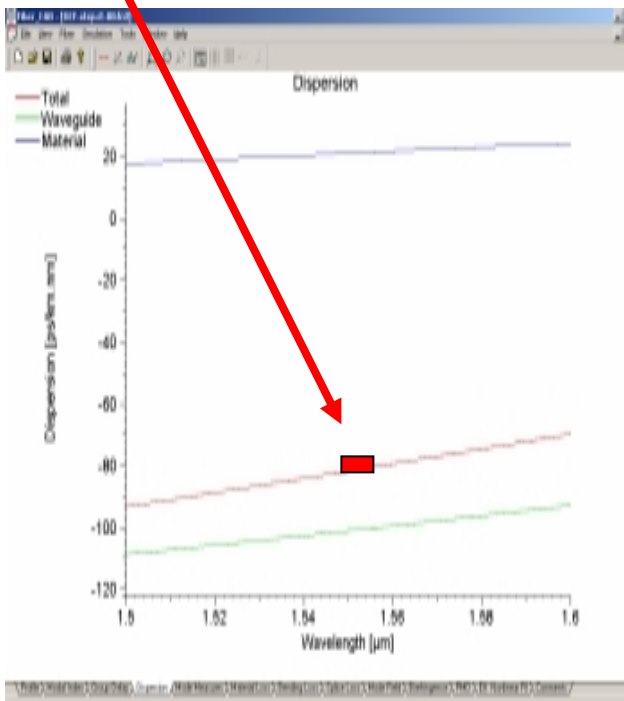
Group Delay
~ 4914230 ps / km

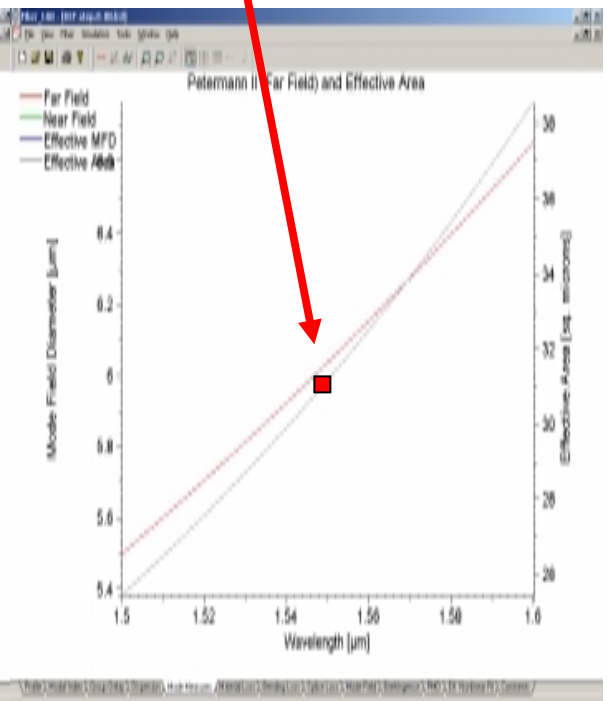
Dispersion
~ - 81 ps / km-nm

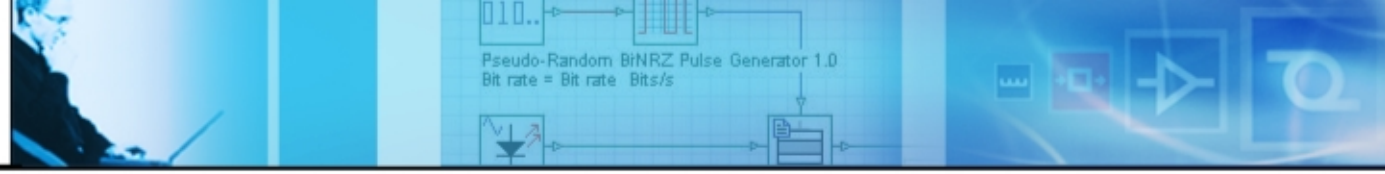
Dispersion Slope
~ 0.24 ps/km-nm^2 (constant)

Effective Area
~ 31 um^2









Standard DCF (contd)

Comparison with Published Results

	n(core)	n(clad)	Radius (um)	Group Delay (ps / km)	GVD (ps / km-nm)	GVD Slope (ps / km-nm^2)	Aeff (um^2)	Petermann-2 (MFD) (um)
Reference	1.46694	1.44402	1.10	NA	-50	NA	NA	6.0
	1.47188	1.44402	0.92	NA	-65	NA	NA	6.0
	1.47866	1.44402	0.775	NA	-80	NA	NA	6.0
Fiber_CAD	1.46694	1.44402	1.10	4917850	-53	0.07	31	6.0
	1.47188	1.44402	0.92	4915340	-67	0.26	34	6.18
	1.47866	1.44402	0.7748	4914080	-81	0.24	31	6.0

Fiber 1 *Fiber 2* *Fiber 3*

NA : Not Available

Reference : M.Basu, Ramanand Tewari & H.N.Acharya, Optics Communications, Vol.174 (2000), 119-125

Why Higher Negative DCF ?

Dispersion Compensation Equation

$$D_+ l_- + D_- l_- = 0$$

or, $$l_- = (D_+ l_+ / -D_-)$$

Therefore → **l_- to be small, D_- Should be LARGE**

Example: At 1550 nm for a **SMF*** : Dispersion coefficient ~ **17 ps/km-nm**

→ Total dispersion ~ 1700 ps/nm for 100 km of SMF

IF, for a **DCF** , Dispersion coefficient ~ **-17 ps/km-nm** → Requires 100 km of DCF

→ **Increases system cost**

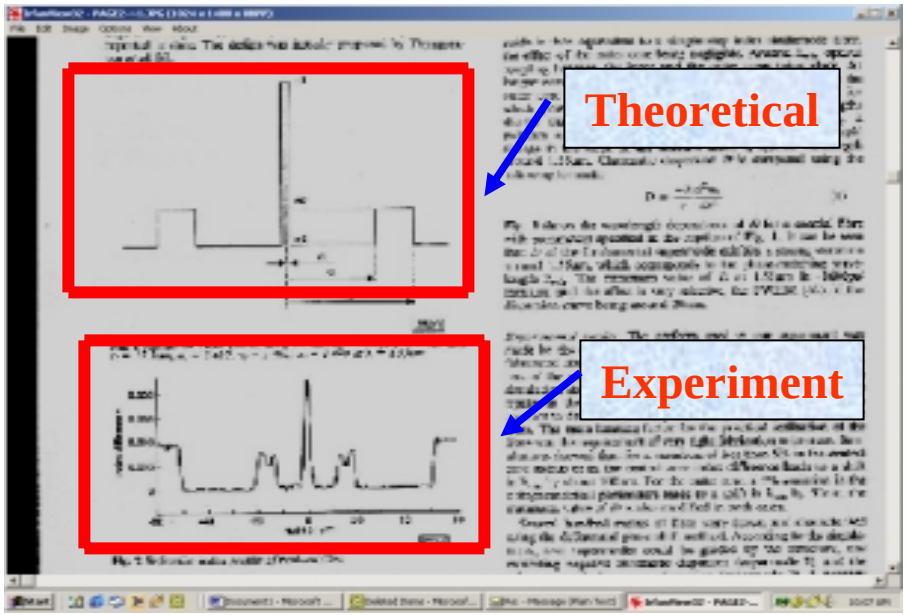
* For specific fiber vendor information, please contact Optiwave Corporation

HIGHEST NEGATIVE DCF

[Electronics Letters, Vol. 6, No.2, Sept. 2000]

Fiber Parameters

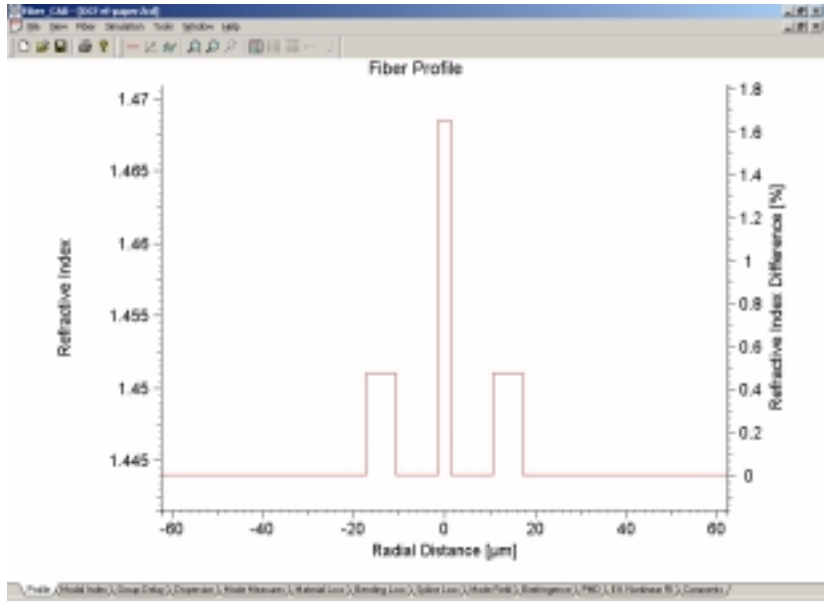
First Core Radius / R.I. : 1 . 34 um / 1 . 469
Second Core Width / R.I. : 6 . 6 um / 1.451
Distance between the cores : 9 . 36 um



Fiber_CAD

Fiber Parameters

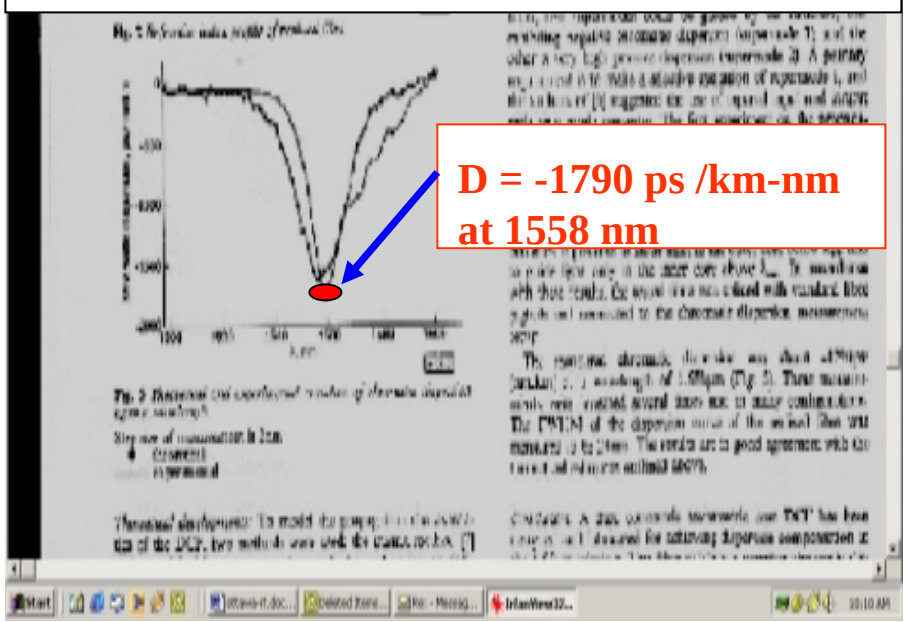
First Core Radius / R.I. : 1 . 34 um / 1 . 4685
Second Core Width / R.I. : 6 . 6 um / 1.451
Distance between the cores : 9 . 36 um



HIGHEST NEGATIVE DCF (contd)

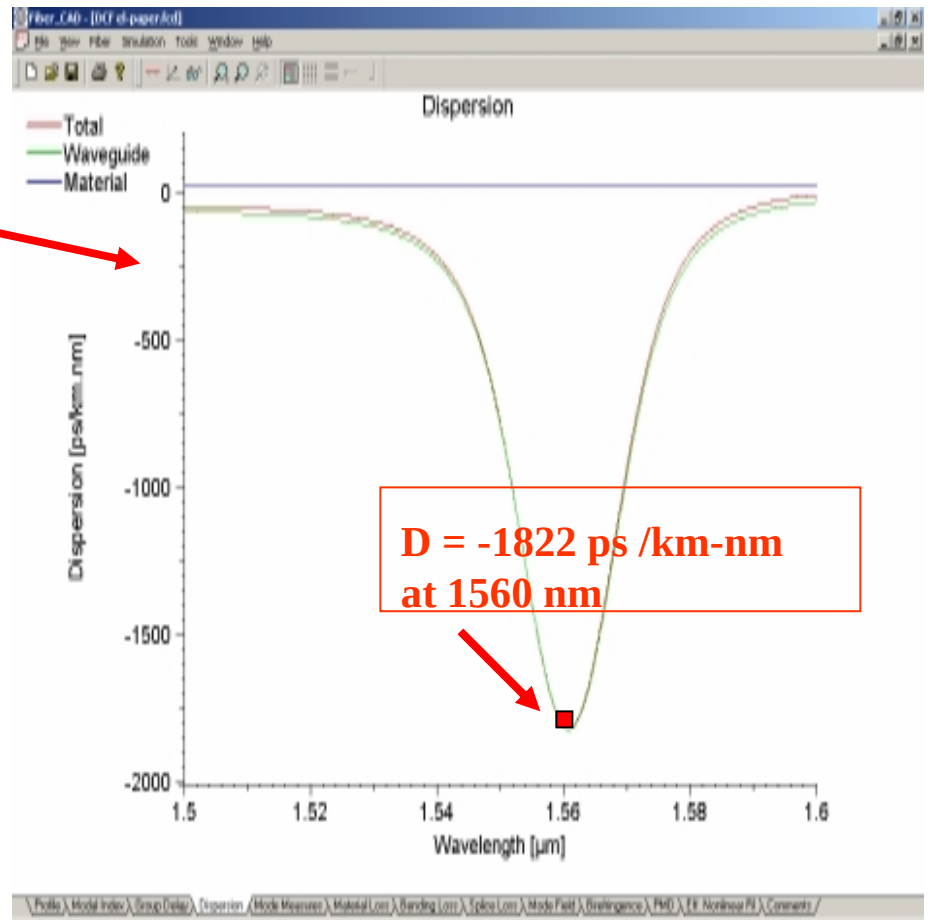
Comparison with Published Results

Electronics Letters, Vol. 6, No.2, Sept. 2000



D = -1790 ps /km-nm
at 1558 nm

Fiber_CAD



D = -1822 ps /km-nm
at 1560 nm

HIGHEST NEGATIVE DCF (contd)

Simulation Parameters to Design an Optical Systems Using this Fiber

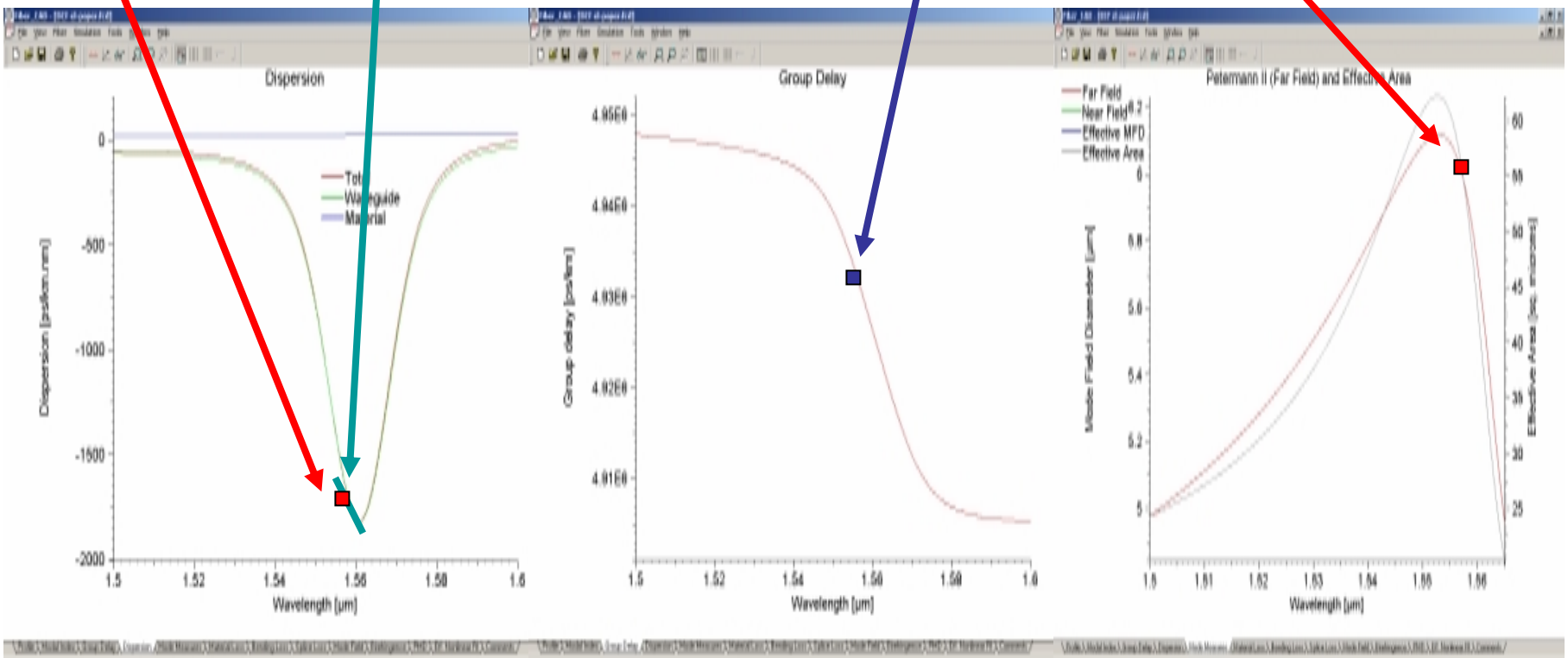
At 1557 nm (~192.54 Thz)

Dispersion ~ - 1630 ps / nm-km

Dispersion Slope ~ -95.4 ps /nm^2-km

Group Delay ~ 4930770 ps/ km

Aeff ~ 55.5 um^2



Why Broadband DCF ?

Compensation of Dispersion

Entire C – band **or / and** **Entire L - band**

Complete Dispersion and Slope Compensation

$$S_{dcf} = (-D_{dcf} / D_{tf}) \times S_{tf}$$

S_{dcf} : **Dispersion slope** of dispersion compensation fiber

D_{dcf} : **Dispersion** of the dispersion compensation fiber

D_{tf} : **Dispersion** of the transmission fiber

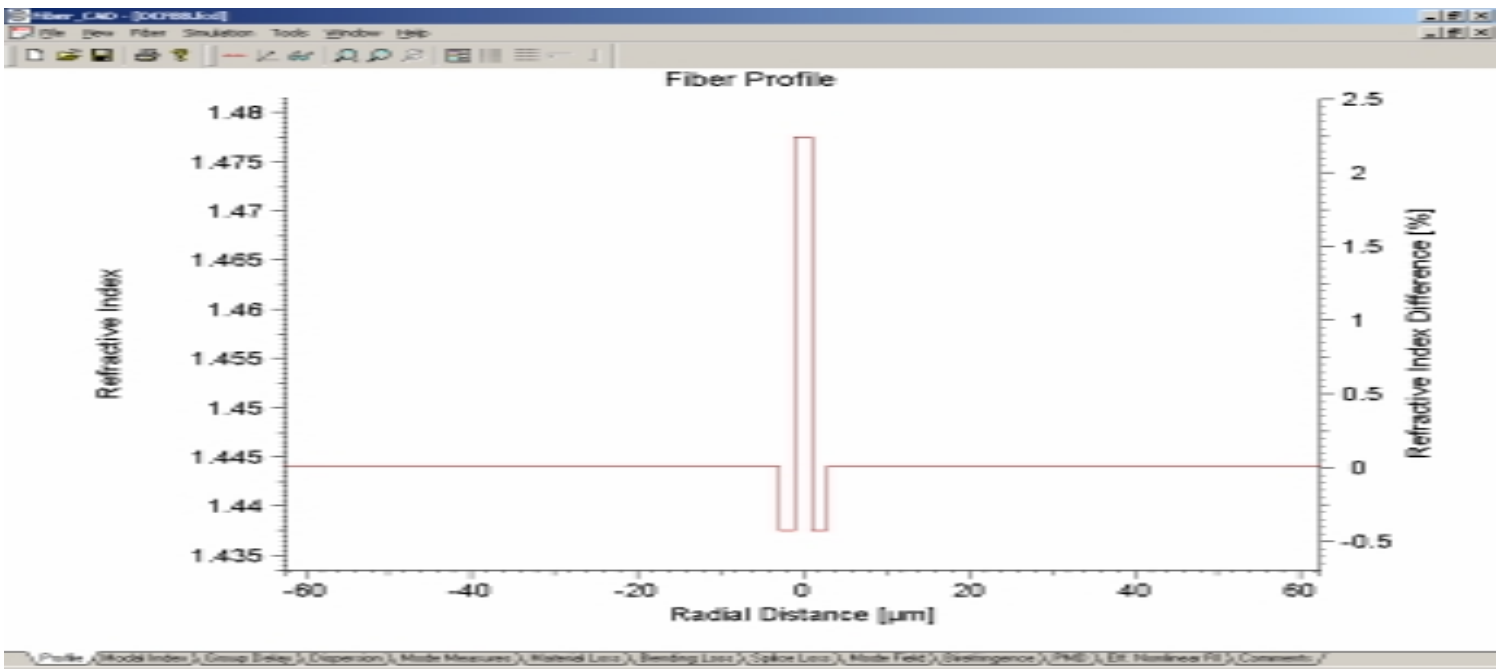
S_{tf} : **Dispersion slope** of the transmission fiber

DCF for Broadband Applications

Fiber Parameters

Core Radius / R.I. : 1 um / 1 . 4775

Width of Depressed Cladding / R.I. : 1 . 8 um / 1 . 4375



DCF for Broadband Applications (contd)

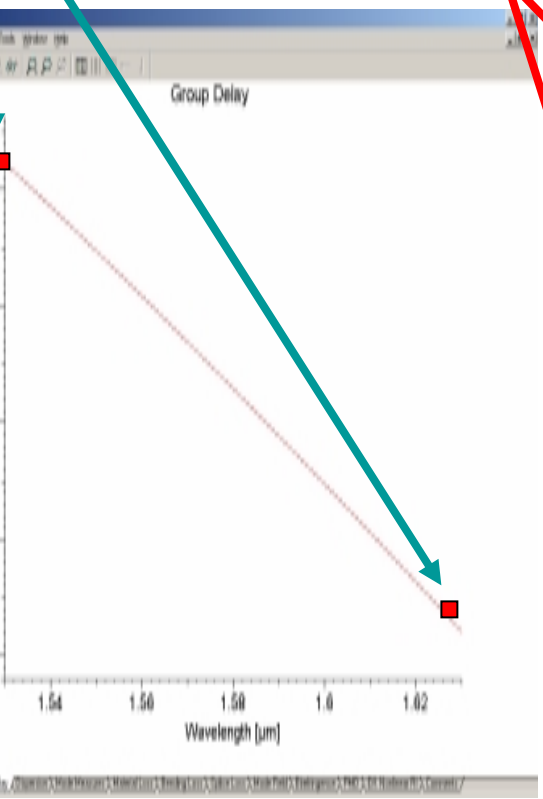
Simulation Parameters for Designing Optical Systems Using this Fiber

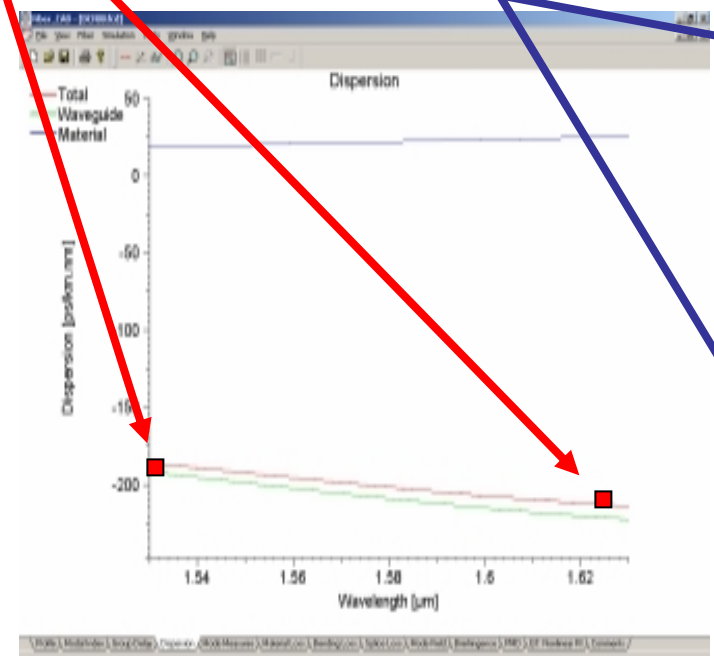
up Delay : 4946140 to 4927090 ps / km from 1530 to 1625 nm

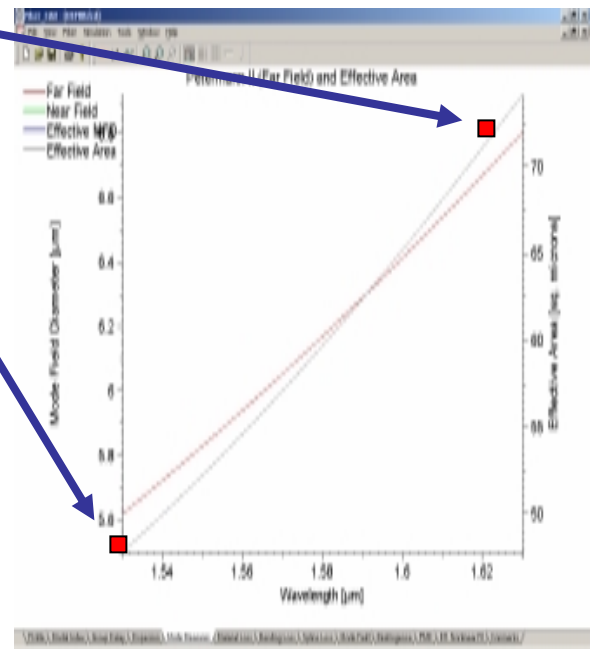
Dispersion : - 213 to -186 ps / km-nm from 1530 to 1625 nm

Dispersion Slope : -0.28 ps / km-nm^2 (constant)

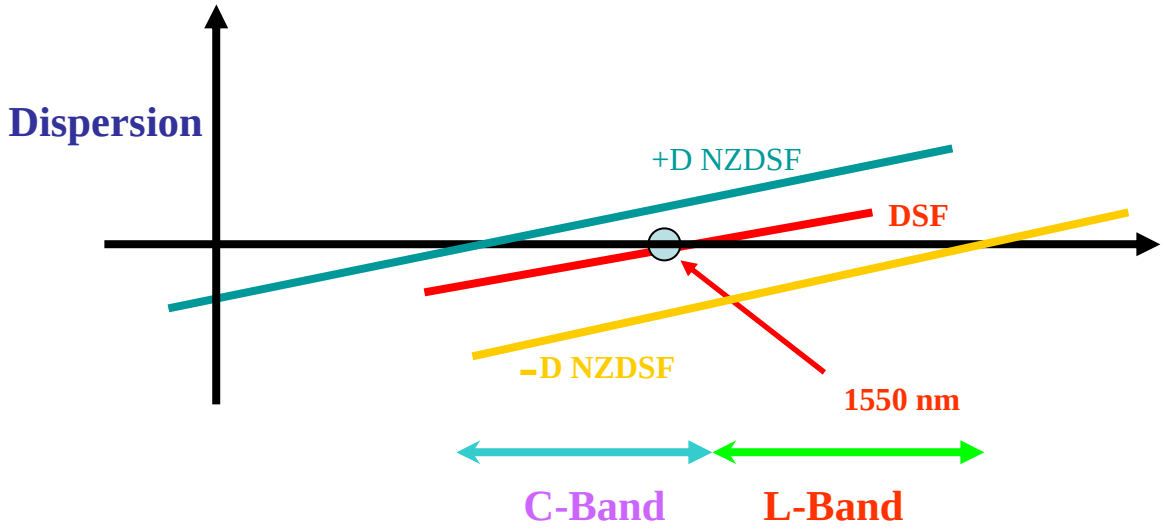
Effective Area : 47.5 to 72.5 um^2 from 1530 to 1625 nm







Why (+D) NZDSF with Large Effective Area ?



DSF : # Only for single wavelength transmission at 1550 nm – For DWDM application – NOT SUITABLE

Nonlinear phenomena like Four Wave Mixing (FWM), is dominant when dispersion is ZERO

(+D) NZDSF and **(-D) NZDSF** : # Dispersion is finite (2-10 ps / km-nm) in C and L-bands

FWM is greatly reduced enabling less channel spacing

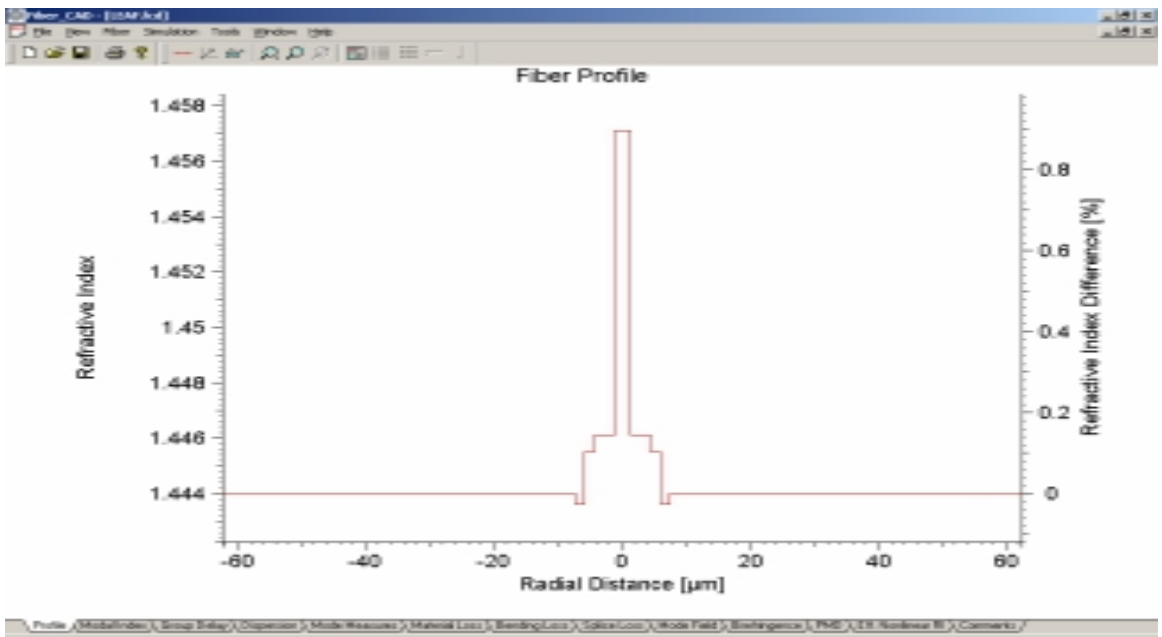
Cross Phase modulation (XPM) can be reduced by taking large effective Area

Smaller dispersion slope to provide broad transmission window

Non Zero Dispersion Shifted Fiber with Large Effective Area (+D NZDSF)

Fiber Parameters

First	Core Width / R.I. :	1.15 um	/ 1.4571
Second	Core Width / R.I. :	3.2 um	/ 1.4461
Third	Core Width / R.I. :	1.6 um	/ 1.4455
Fourth	Core Width / R.I :	1.5 um	/ 1.4436



Non Zero Dispersion Shifted Fiber with Large Effective Area (Contd)

Simulation Parameters to Design an Optical Systems Using this Fiber

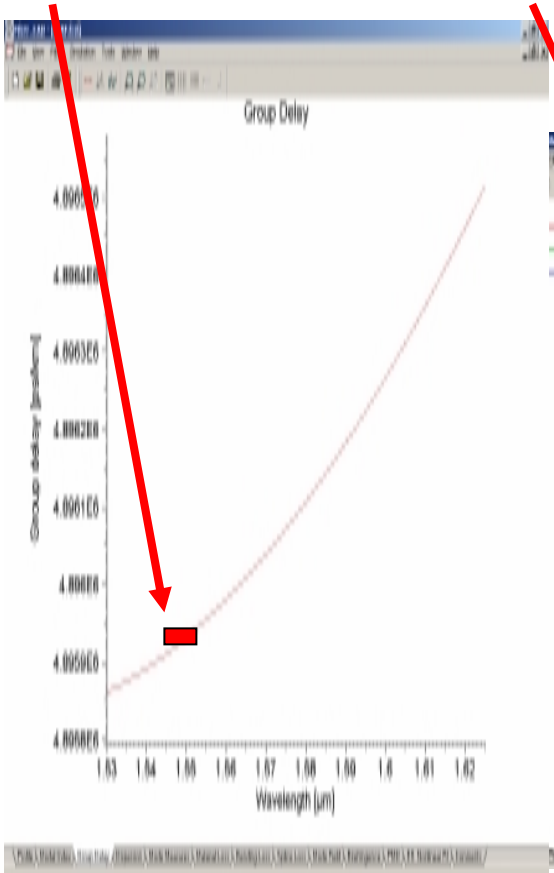
At 1550 nm

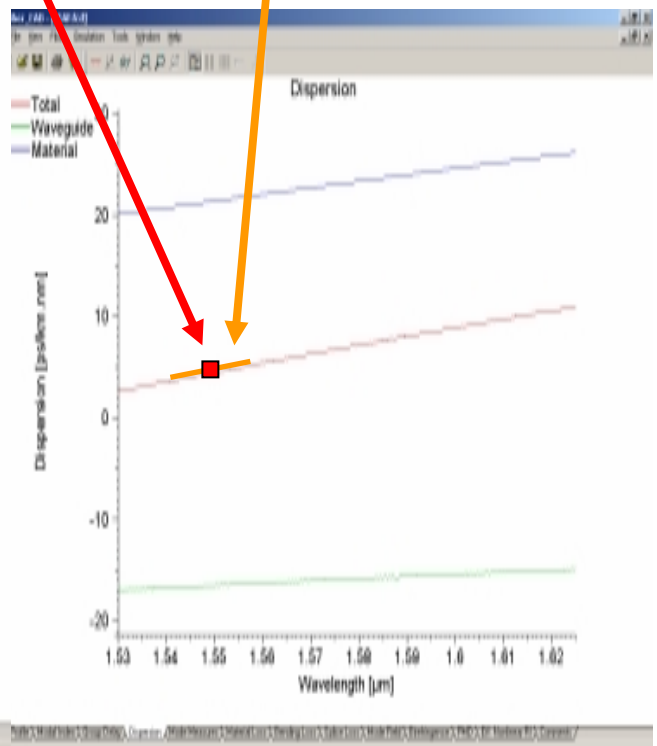
Group Delay
4895930 ps / km

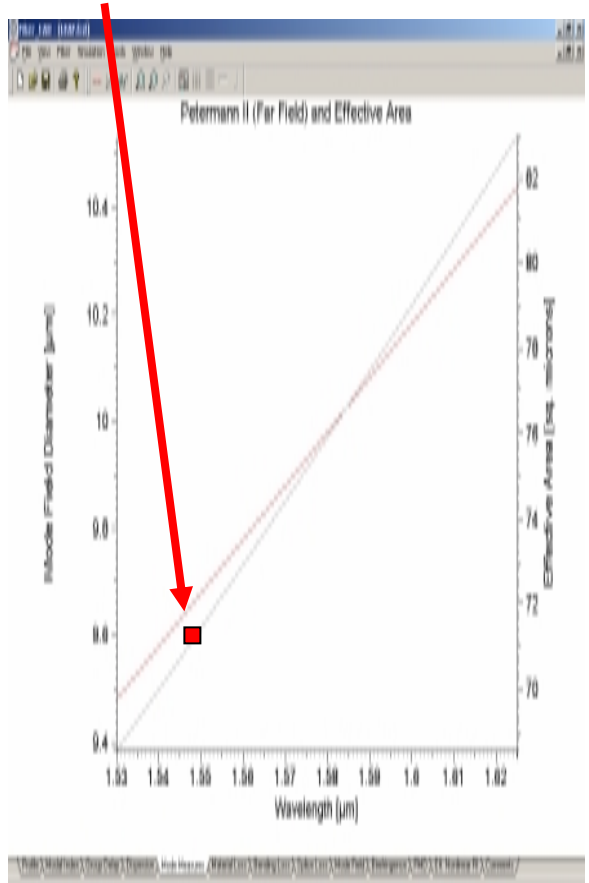
Dispersion
4.53 ps / km-nm

Dispersion Slope
0.086 ps / km-nm^2 (constant)

Effective Area
71.4 um^2







Non Zero Dispersion Shifted Fiber with Large Effective Area (Contd)

Comparison

Vendor*

9.2 um < MFD < 10.00 um at 1550 nm

Dispersion

2.0 to 11.2 ps / km-nm
over the range
1530 to 1625 nm

Effective Area

72 um^2 at 1550 nm

Calculated (Fiber CAD)

MFD : 9.68 um at 1550 nm

Dispersion

2.55 to 10.86 ps / km-nm

over the range

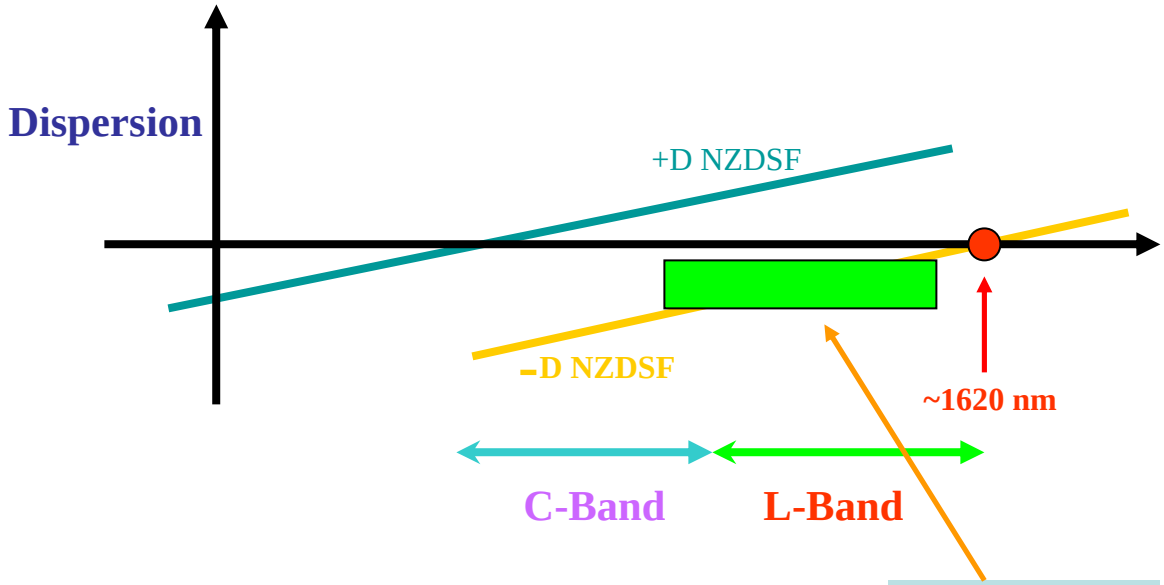
1530 to 1625 nm

Effective Area

71.4 um^2 at 1550 nm

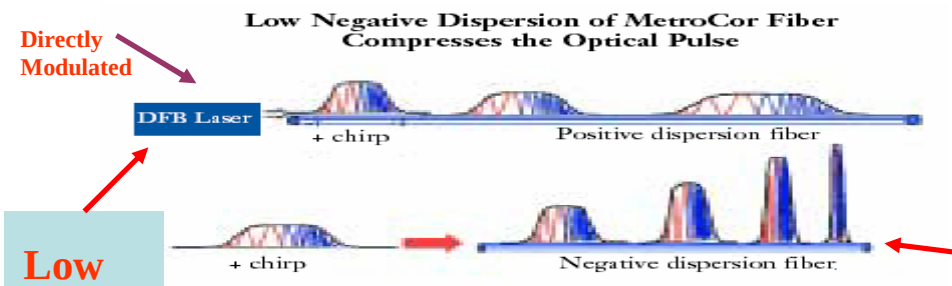
* The data of the fiber were taken from the public-domain specifications at **the vendor's website. For vendor specific information, please contact Optiwave Corporation.**

Why (-D) NZDSF ?



(-D) NZDSF : # Dispersion (-1 to -10 ps / km-nm) in L and C-bands

Low Negative Dispersion



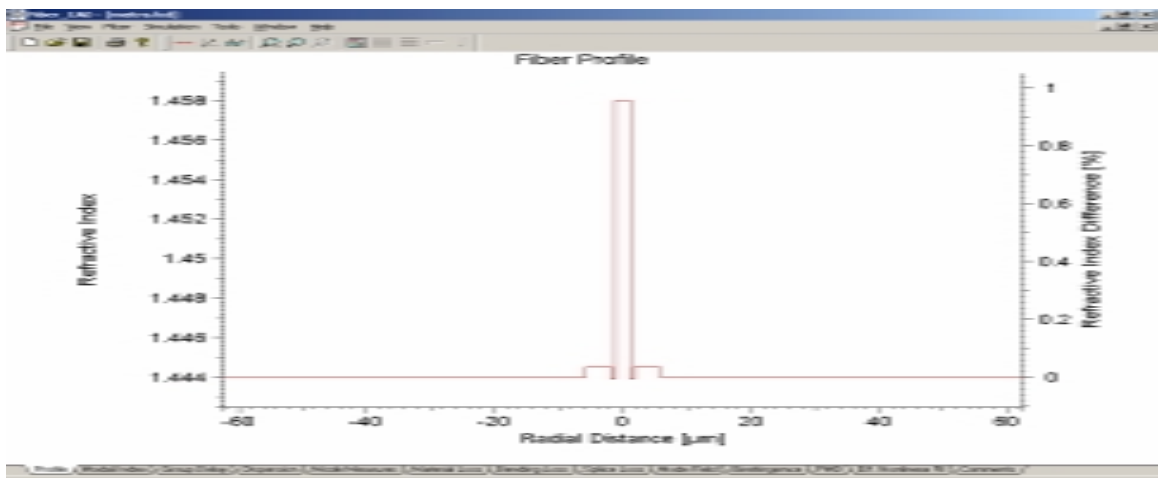
Low Cost

Greater distances can be attained without Dispersion Compensation

Negative Dispersion Fiber for Metropolitan Network (-D NZDSF)

Fiber Parameters

First	Core Width / R.I. :	1.15 um	/ 1.458
Second	Core Width / R.I. :	0.6 um	/ 1.4439
Third	Core Width / R.I. :	4.0 um	/ 1.4445



Negative Dispersion Fiber (contd)

Simulation Parameters to Design an Optical Systems Using this Fiber

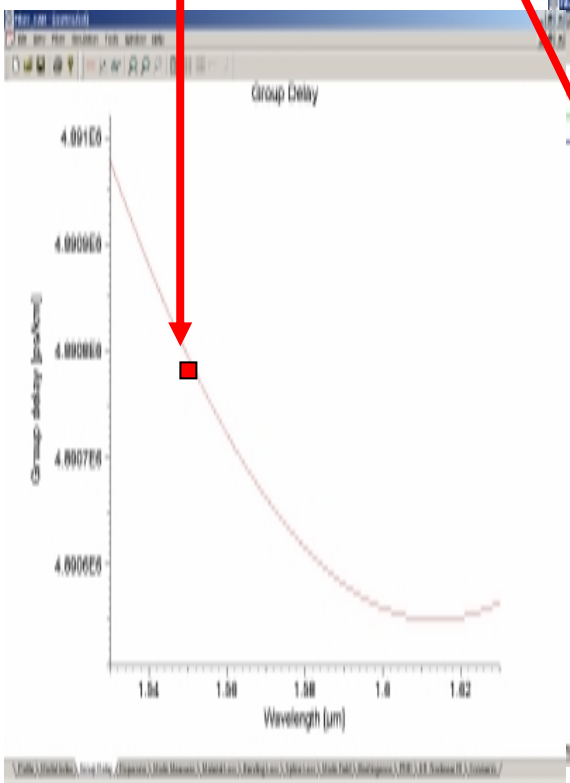
At 1550 nm

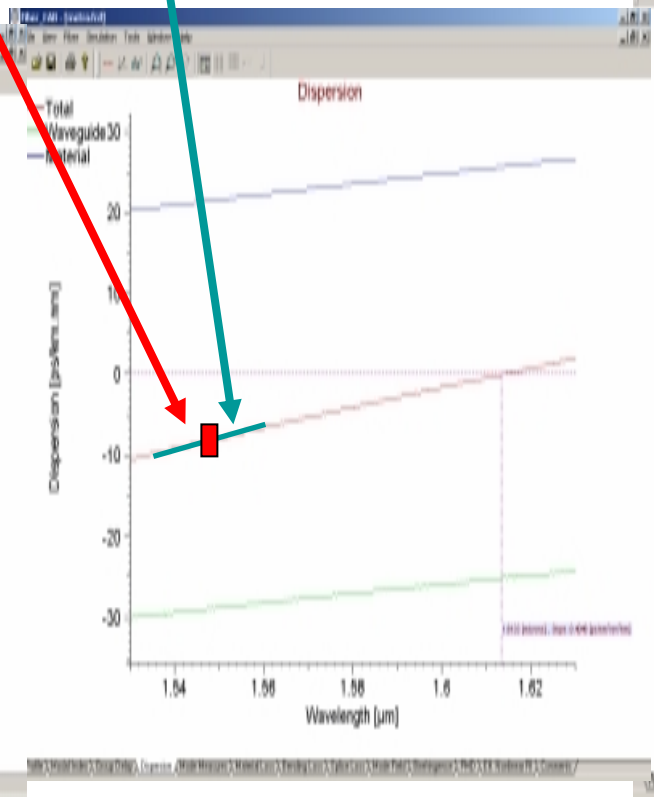
Group Delay
489079 ps / km

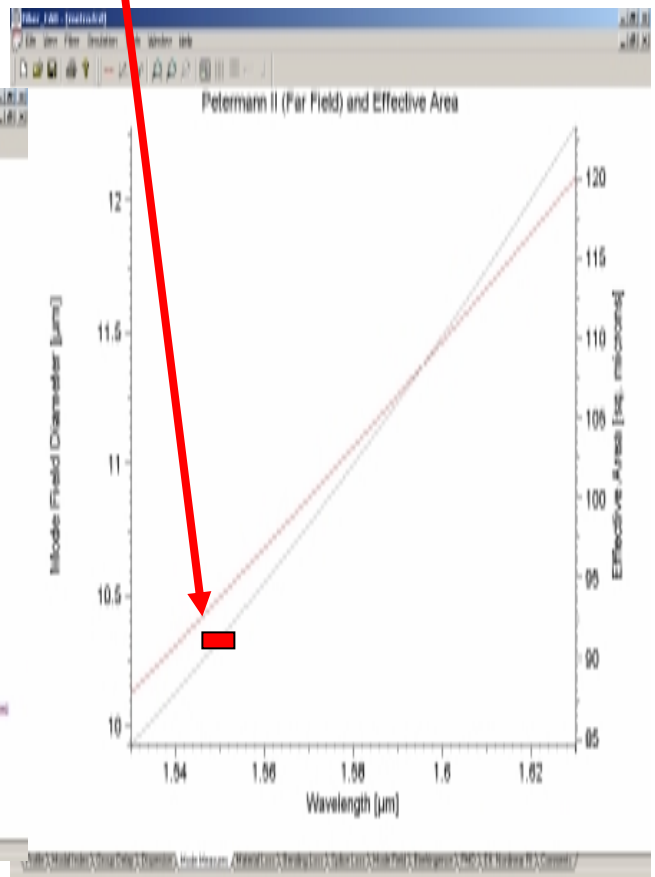
Dispersion
- 7.9 ps / km-nm

Dispersion Slope
0.128 ps / km-nm^2 (constant)

Effective Area
91 um^2







Negative Dispersion Fiber (contd)

Comparison

Vendor*

7.60 um < MFD < 8.60 um at 1550 nm

Dispersion

-10.0 to -1.0 ps / km-nm
over the range
1530 to 1605 nm

Calculated (Fiber CAD)

MFD : 10.5 um at 1550 nm

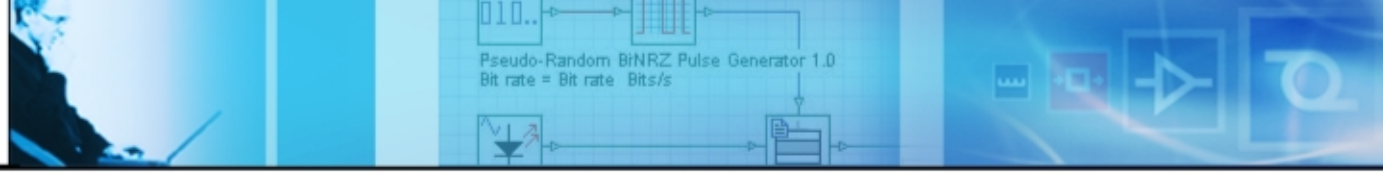
Dispersion

-10.6 to - 1.0 ps / km-nm

over the range

1530 to 1605 nm

* The data of the fiber were taken from the public-domain specifications at **the vendor's website. For vendor specific information, please contact Optiwave Corporation.**



Conclusion

- Commercial fiber data sheets give the values of group delay, GVD Slope and Effective Area only at One wavelength. Therefore it is not possible to simulate a WDM optical system which require these data at several wavelengths.

- ***However, an understanding can be developed by simulating these data for a fiber close to the commercially available fiber by using commercially available software such as Fiber_CAD.***