EECS 285A- OPTICAL COMMUNICATION

Final project Report

Sangeetha Chandramouli

PROBLEM STATEMENT

You have 4 cities that needs to be connected by fiber. Your job is to design this network. Each channel can be 2.5Gb/s or 10Gb/s OOK modulated lasers. If you need amplification, you can place your amplifier at one of the sites where electrical power is available.

The SNR at the receiver has to be 13dB or better. You need to have a detailed analysis, SNR, dispersion, power, nonlinearity etc. You should have clear indication of how traffic split to multiple paths. Every detail of components, in particular losses, should be included.

CONSTRAINTS

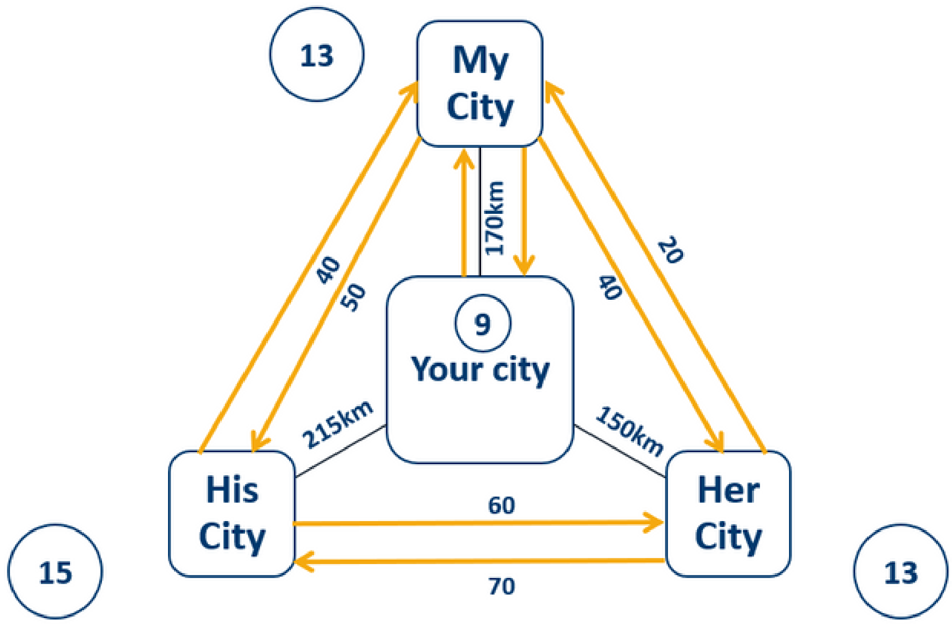
- Transmitter power can NOT exceed 3 dBm (2mW) per channel at the starting power.
- Power at the detector should be within the manufacturer specs, no detector burning high powers, no hypothetical results with extreme low powers.
- Amplifier gain CAN NOT exceed 20dB.
- Power per channel after an amplifier CAN NOT exceed 5mW (7dBm).
- Total nonlinear phase shift due to SPM SHOULD NOT exceed $\pi\pi/2$ radians.

BANDWIDTH REQUIREMENTS

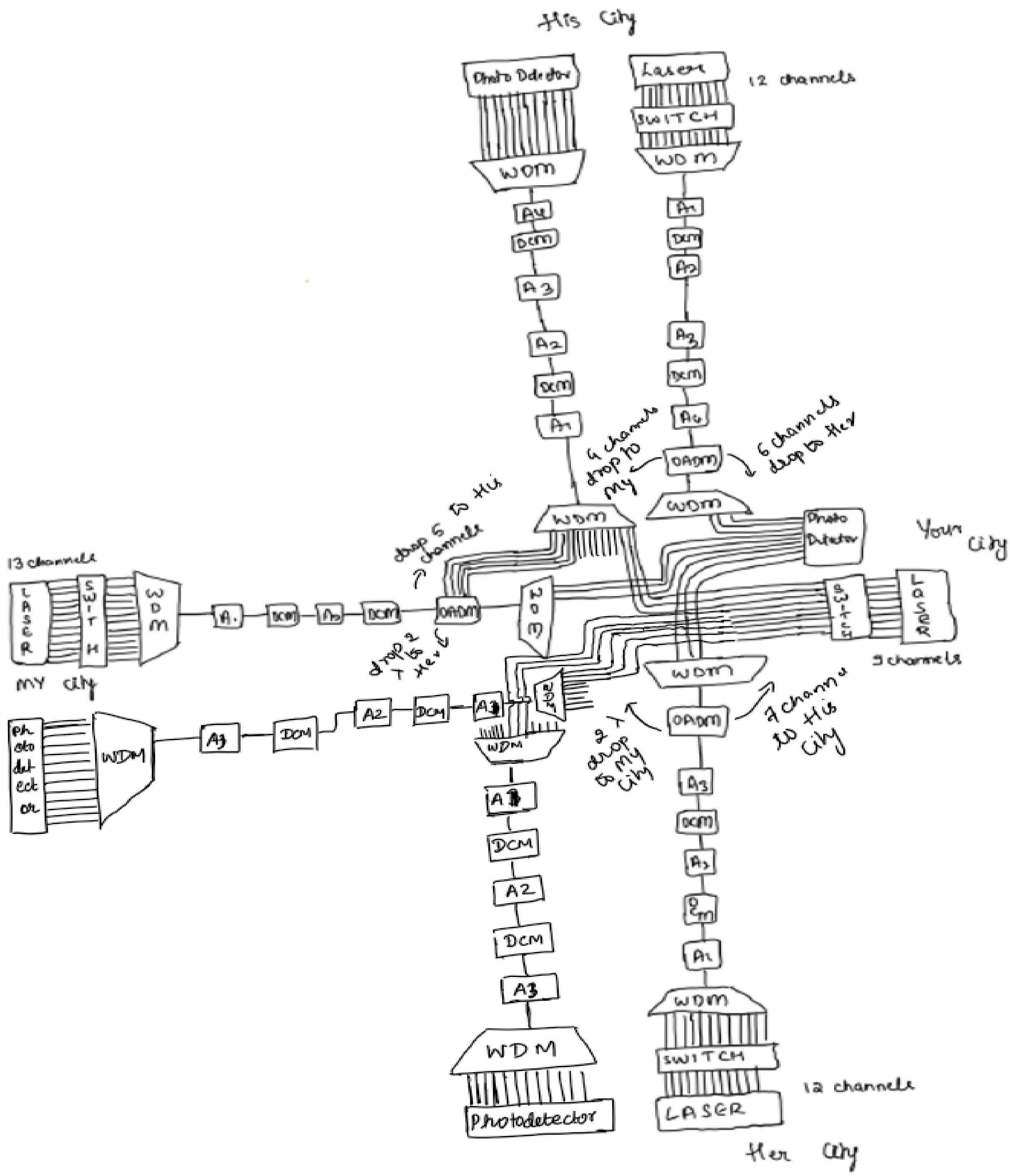
	My City	Your City	His City	Her City	Total
My City	0	40Gbps	50Gbps	40Gbps	**130Gbps**
Your City	30Gbps	0	30Gbps	30Gbps	**90Gbps**
His City	40Gbps	20Gbps	0	60Gbps	**120Gbps**
Your City	20Gbps	30Gbps	70Gbps	0	**120Gbps**
Total	**90Gbps**	**90Gbps**	**150Gbps**	**130Gbps**	

NUMBER OF CHANNELS CALCULATION

Assuming 10Gbps per channel, number of channels for each city is calculated by dividing the maximum (total number of bits) for each city divided by 10Gpbs.



COMPLETE LAYOUT



COMPONENTS USED

Component	Insertion Loss(dB)	Gain(dBm)	Cost (U.S.D)
Amplifier	-	20	1550
Amplifier	-	17	1300
Amplifier	-	15	1200
Amplifier	-	10	1100
Amplifier	-	12	1175
DCM	3.4	-	810
DCM	9.8	-	929
DCM	4.8	-	870
Switch	2		8.4
OADM	1		
WDM	1		
DWDM	3		
Fiber	0.18/km		

FORMULAS USED

1. Net Loss/Gain(dB) = Fiber loss (per km) * length + insertion loss of components (dB) – Gain of amplifier (dBm)

2. Preceived = Ptransmitted/10loss (or) Gain(dB) (mW)

3 SNR = Preceived /(4 ×kb ×T ×Δf ×Fn + 2 ×q ×Δf ×Ip)

. SPM (γ) = 4 × n × L/λ × w22

4 Dispersion (ps/nm) = (Dispersion/km * length) – Total dispersion compensation of DCM

.

5

.

COMPONENT DATASHEET

Optical Fiber:

https://www.corning.com/media/worldwide/coc/documents/Fiber/PI-1450-AEN.pdf

Data Sheet

Prisma High Density EDFA

Description

The Prisma II optical network allows for best in class architectures with increased reliability, scalability, and cost-effectiveness. The High Density (HD) Erbium Doped Fiber Amplifier (EDFA) is designed to fit into a Prisma XD chassis or a standard full height Prisma II chassis (with the use of a host module). Up to two HD EDFA modules can be populated into a host module which requires a single service slot in the Prisma II chassis.

Figure 1. High Density EDFA

Features

- EDFA modules for optical amplification
- High density design allowing up to 16 EDFAs in a Prisma II XD chassis or up to 24 in a full height Prisma II chassis with redundant power supplies
- Energy-efficient design with low power consumption
- EDFA modules have both constant power and constant gain modes of operation
- Master/Slave redundancy using Controller Area Network with no external wiring needed
- Multiple setup and control options
    - Local Control via Local Craft Interface (LCI)
    - Local monitoring via Intelligent Communications Interface Module (ICIM)
    - Remote monitoring via ROSA status monitoring and control element manager

High Density EDFA Modules

Table 1. High Density EDFA Specifications

Optical	Unit	EDFA			Gain-Flattened EDFA		Gain-Flattened EDFA, Variable Gain			Notes
		17 dBm	20 dBm	22 dBm	17 dBm	20 dBm	17 dBm	20 dBm	21 dBm	
Output Power (maximum)	dBm	17	20	22	17	20	17	20	21	1
Gain	dB	12	15	17	Low High 7 12	Low High 10 15	5 - 17	8 - 20	5 - 15	
Input Power	dBm	0 to +10			-5 to -10 +10 to +10	-5 to -10 to to +5 +5	-14 to +12	-14 to +12	-10 to +16	
Input Wavelength	nm	1530 - 1565			1536 - 1562		1530 - 1562 1528 - 1562 for 17 dBm, 21 dBm			
Output Power Stability	dB	± 0.3			± 0.4		± 0.4			
Return Loss	dB	≥ 50 (exception for input port)			≥ 50		≥ 50			
Polarization Sensitivity	dB	0.3			0.3		0.3			
Noise Figure @ Input Power	dB	5.5 @ 0 dBm			6.5 @ 0 dBm		6.0 @ 0 dBm	6.0 @ 0 dBm	6.0 @ 5 dBm	
Output Power Variation with Wavelength	dB	±0.2			N/A		N/A			
Gain Flatness	dB	N/A			±0.75		±0.75 ±1.0, for 17 dBm and 21dBm over 1528 - 1562 nm			2
Optical Interfaces	-	SC/APC (2)			SC/APC (2)		SC/APC (2)			
Electrical										
Power Consumption	W	7.5	7.5	9.0	7.5	7.5	7.5	9.0	9.0	
Environmental										
Operating Temp Range										
Full Specs	°C °F	-20 to +65 -4 to +149								
Storage	°C °F	-40 to +85 -40 to +185								
Humidity Range	%	0 to 95								3
Mechanical										
Length x Height x Width	in. cm	8.8 x 3.48 x 1.03 22.35 x 8.84 x 2.62								

Notes:

1. The output power is measured after a typical jumper loss of 0.2 dB.
2. Gain flatness measured under default gain conditions.
3. Non-condensing external to the Prisma II or XD chassis.

Ordering Information

The part numbers for the High Density EDFAs are shown below. Please consult with your Account Representative, Customer Service Representative, or Systems Engineer to determine the best configuration for your particular application.

Table 2. High Density EDFA Modules

Description	Ordering Code	PID
+17 dBm EDFA	P2-HD-EDFA-17-SA	4037220
+20 dBm EDFA	P2-HD-EDFA-20-SA	4037221
+22 dBm EDFA	P2-HD-EDFA-22-SA	4037222
+17 dBm EDFA Gain-Flattened, Low Gain	P2-HD-EDFA-GF-17L-SA	4037224
+17 dBm EDFA Gain-Flattened, High Gain	P2-HD-EDFA-GF-17H-SA	4037225
+20 dBm EDFA Gain-Flattened, Low Gain	P2-HD-EDFA-GF-20L-SA	4037226
+20 dBm EDFA Gain-Flattened, High Gain	P2-HD-EDFA-GF-20H-SA	4037227
+17 dBm EDFA Gain-Flattened, Variable Gain	P2-HD-EDFA-VGF-17-SA	4043499
+20 dBm EDFA Gain-Flattened, Variable Gain	P2-HD-EDFA-VGF-20-SA	4043500
+21 dBm EDFA Gain-Flattened, Variable Gain	P2-HD-EDFA-VGF-21-SA	4042697

Americas Headquarters
Cisco Systems, Inc.
San Jose, CA

Asia Pacific Headquarters
Cisco Systems (USA) Pte. Ltd.
Singapore

Europe Headquarters
Cisco Systems International BV Amsterdam,
The Netherlands

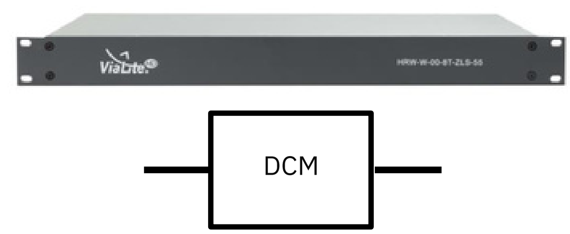
Cisco has more than 200 offices worldwide. Addresses, phone numbers, and fax numbers are listed on the Cisco Website at **www.cisco.com/go/offices.**

Printed in USA C78-726657-00 02/13

ViaLiteHD – Dispersion Compensation Module

Dispersion Compensation Module (DCM)

- 1U Rack chassis
- Standard lengths and customer specific
- Compatible with any RF frequency
- SC/APC as standard
- Standard 5-year warranty



A DCM/Dispersion Compensation Fiber (DCF) provides fixed chromatic dispersion compensation for diverse and disaster recovery DWDM networks.

ViaLiteHD DCMs are purely passive modules based on the ITU G.652 standard to provide negative dispersion for DWDM transmission systems, increasing transmission range and decreasing BER of optical links. It can be used to address dispersion on standard single mode optical fiber (SMF) across the entire C-Band and L-Band range.

The DCMs are available as part of *ViaLite*'s Ka-Band diversity antenna system. Each DCM can be supplied in 5 km increments, supporting medium to long distance fiber optic systems ranging from 30 km to 600 km.

Advantages Formats

- Low Insertion loss 1U Chassis
- 19" rack mountable
- Passive device

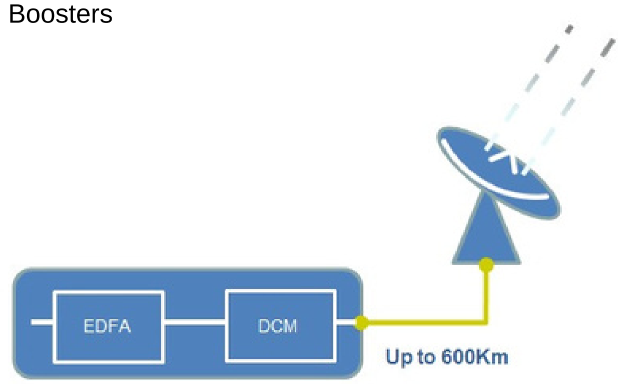
Related Products

- Low polarization mode dispersion DWDM Mux/De-Mux
- Excellent performance price ratio DWDM EDFA's and Boosters
- Signal performance improvements Delay Lines

L-Band HTS 700-2450 MHz

Applications

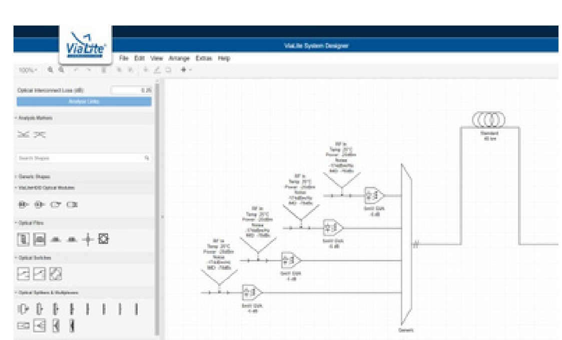
Fixed satcom earth stations and teleports
Ka-Band diversity systems
L-Band long distance links
G.652 100% C-Band compensation fiber
Long distance DWDM optimization
CATV Systems



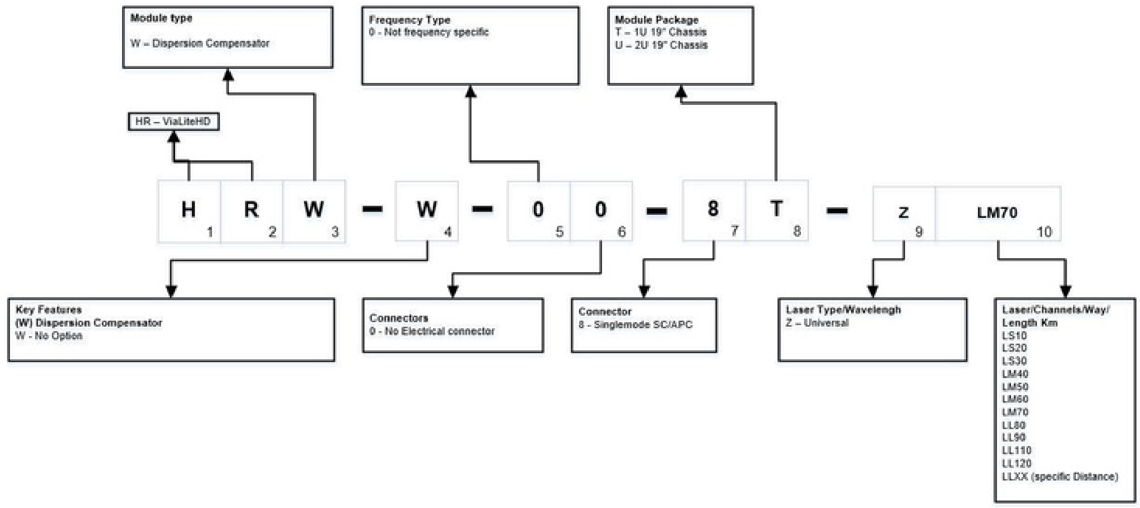
ViaLite System Designer

For complex designs where multiple DWDM products are required the System Designer tool is essential for predicting and validating performance results. The software uses a drag and drop approach from a pallet of products. Once designed, the analyzer can be run to give end-to-end system results and these can then be saved as a detailed PDF.

Please ask our sales team for more information.



Product configurator



Popular Products

HRW-W-00-8T-ZLM40
Dispersion Compensator, Singlemode SC/APC, 40 km

Technical specification

	Dispersion Compensation Module		
Working Wavelengths	1525 to 1565 nm		
Dispersion Length	10 to 120 km		
Nonlinearity (n2/Aeff)	1.4 x 10-9		
SBS Threshold (Max input)	+6 dBm		
Return Loss @ 1550 nm	-45dB (typ)		
Interface	SC/APC		
Optical Fiber insertion loss (1525~1565)	Typical (dB)	Maximum (dB)	Distance (Km)
	1.2	2.1	10
	1.8	2.7	20
	2.5	3.4	30
	3.2	4.1	40
	3.9	4.8	50
	4.5	5.5	60
	5.3	6.2	70
	6.0	6.9	80
	6.7	7.7	90
	7.4	8.4	100
	8.1	9.1	110
	8.8	9.8	120
	-5 °C to +70 °C		
Operating temperature range	-40 °C to +85 °C		
Storage temperature range	0% to 85%		
Working Humidity			

Accessories

Type	Key Features
RF over Fiber L-Band HTS DWDM Links  	• L-Band HTS (700-2450 MHz) • Up to 500 km systems available • 1 to 96 channels per fiber • Ideal for Ka-Band rain fade diversity • 5 mW Laser
RF over Fiber Timing modules  	• Radio timing signals: DCF, MSF signals JJY, BPC, HBG, TDF, WWVB, WWV, CHU, RJH, RWM, • IRIG-B • Loran-C & eLoran • 10kHz – 50 MHz signals • GPS (via GPS Link) • MiFID II standard
Rack Chassis  	• 3U accepts up to 13 RF or Support cards, plus an SNMP card and dual power supplies • A 1U chassis accepts up to 3 RF or Support cards or 2 cards and an SNMP card (with dual power supplies) • Up to 26 channels per 3U chassis (using dual RF cards) – reducing the amount of rack space required • Blind mate option • All modules hot-swappable and auto-reconfigure with SNMP option • On-card LNB and BUC power options • Power fed through rear chassis connector to card Bias Tees • System can be monitored and controlled remotely via SNMP using a web browser
Outdoor Enclosures  	• CE approved and EMC compatible • IP rated and NEMA approved • Plug and play format • Suitable for harsh environments • All modules hot swappable • Dual redundant power options • Interface for monitor and control (M&C) systems

C-band Femtosecond Fiber Laser Module

Applications

- OEM integration
- Telecommunication components
- characterization Optical high speed sampling
- Terahertz radiation
- Optical switching
- Materials characterization
- Optical metrology

Features

- Small footprint and ruggedized design
- Wavelength selectable from 1535 to 1565 nm
- Pulse width selectable from 0.1 to 15 ps
- Pulse width tunability
- Near transform-limited output
- Minimal pulse pedestal
- Low timing jitter
- RF synchronization output

The C-band femtosecond fiber laser module (FPL-M) is the most compact of commercially available passively mode-locked fiber lasers. The FPL-M series features a robust architecture that is insensitive to shock and vibra- tion, and provides exceptional stability and reliability for demanding OEM applications. Advanced engineering design and consistent manufacturing process ensure the highest quality standards for OEM volume production. The wavelength can be selected throughout the C-band. The pulse width is factory selectable from 0.1 to 15 ps, with near transform-limited pulse shape and a better than 20 dB pedestal. The timing jitter is as low as 60 fs. The repetition rate can be specified from 10 to 50 MHz with either a polarization-maintaining (PM) or non-PM fiber output. With up to 20 mW output power, the FPL series is the most economical solution for applications requiring low power, such as seeding amplifier systems. An RF synchronization output is provided as a trigger signal. The FPL-M series can be used either as a stand-alone laser source with a 5 VDC power supply or separate driver, or for integration as an OEM module.

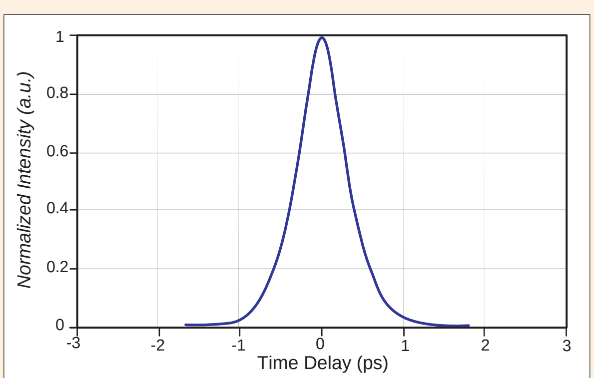
CALMAR LASER, INC. ● 755 N. Pastoria Avenue, Sunnyvale, CA, 94085 ● Tel. +1 408.733.7800 ● Fax. +1 408.733.3800 ● sales@calmarlaser.com ● www.calmarlaser.com

Technical Specifications

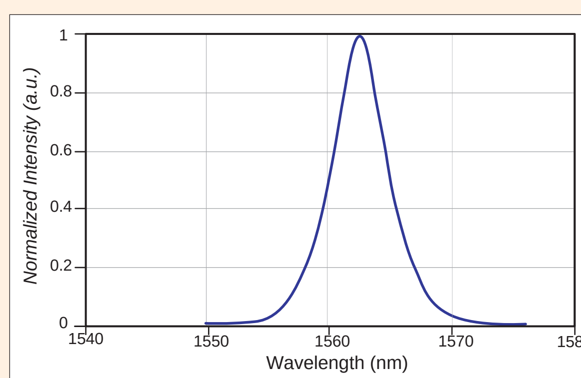
Model Number	FPL-M2CFF	FPL-M3CFF	FPL-M3CFFPM
Pulse Width (ps)*	0.3 ~ 5 (selectable)	0.1 ~ 1 (selectable)	0.1 ~ 1 (selectable)
Wavelength (nm)	1535 ~ 1565 (selectable)		
Repetition Rate (MHz)**	20		
Peak Output Power (W)	300 (typical)	10 K (at pulse width 0.1)	5 K (at pulse width 0.1)
Average Output Power (mW)	4 (typical)	20 (typical)	10 (typical)
Timing Jitter (fs)	60 (carrier offset 100 Hz ~ 1 MHz)		
Spectral Width (nm)	5 (typical @ 0.5 ps)	25 (typical @ 0.1 ps)	25 (typical @ 0.1 ps)
Fiber Type	SMF***	SMF***	Panda PM
Polarization Extinction Ratio (dB)	Not applicable	Not applicable	>20
Operating Temp (°C)	10 ~ 35		
Operating Voltage (VDC)	4.5 ~ 5.5		
Dimensions (cm)	9.5(w) x 12.7(d) x 2.0(h)	9.5(w) x 12.7(d) x 4.0(h)	

** Up to 15 ps pulse width available; once selected it is tunable by adjusting pump current. A sech2 pulse shape (convolution factor of 0.65) is used to determine the pulse width for the second harmonic autocorrelation trace.*
*** Other repetition rates within 10 to 50 MHz are available, specifications may change at different repetition rates.*
**** PM fiber is an option.*

Due to our continuous improvement program, specifications are subject to change without notice.



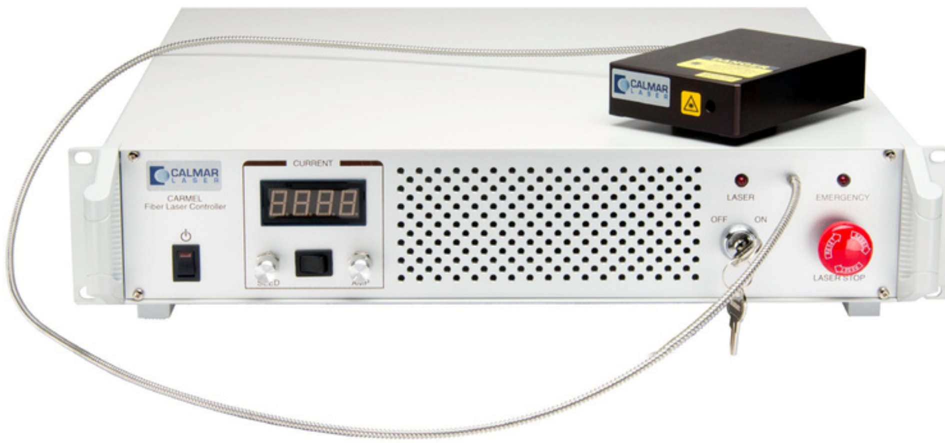
Autocorrelation Trace Corresponding to a Pulse Width of 0.5 ps



Optical Spectrum Corresponding to a Pulse Width of 0.5 ps

CALMAR LASER

1550 nm High Power Femtosecond Fiber Laser



Applications

- Multiphoton microscopy
- Optical metrology
- Two photon integrated circuit testing
- Materials characterization
- Terahertz radiation
- Nonlinear spectroscopy
- Micro-machining and materials processing
- Seeding high output lasers

Features

- High power stability (up to 2.5 W)
- < 90 fs pulse widths
- Outstanding beam quality (M2 <
- 1.1) Exceptional beam pointing
- stability Optional 780 nm output
- All air-cooled, no chiller required
- Remote system diagnostics
- Expected lifetime > 10,000 hours

The Carmel X-series is a range of high power, air-cooled, fiber-based femtosecond lasers with output powers from 0.2 to greater than 2.5 W and pulse widths of less than 90 fs in the industry's most compact, user-friendly package. The Carmel X-1550 provides the perfect 1550 nm source for a wide range of ultrafast laser applications, including multiphoton microscopy, optical metrology, two photon integrated cir- cuit testing and micro-machining. It is offered as both a scientific version with front panel controls and an OEM version controlled through an RS-232 interface. The Carmel X-1550 can be configured for dual wavelength output to enable alternating access to 1550 and 780 nm outputs (see the Carmel X-780/1550 data sheet for details).

The system features a rack mountable controller with a robust armored cable interface to the compact laser head, which facilitates its incorporation into OEM designs. A simple key switch interface provides for manual operation with full remote access through computer control. The X-series includes the capability of remote data logging, power monitoring, system diagnostics, and automated adjustments for prolonged lifetime and OEM preventative maintenance. The rugged design supports 24/7 operation with an expected lifetime of > 10,000 hours.

The building block of the X-series is Calmar's renowned ultrafast fiber seed laser platform, which utilizes the proprietary Mendocino satu- rable absorber technology developed and perfected over a twenty year period to deliver reproducible and reliable mode-locking at turn-on. The system provides an output pulse width of < 90 fs with minimal pulse pedestal and excellent long term pulse-to-pulse stability (<1% rms) over a wide operating temperature range (17-30°C). An exceptional output beam quality (M2 < 1.1) enables a near diffraction-limited spot size with suitable microscope objectives for demanding multiphoton and materials processing applications. Repetition rates can be specified from 10 to 80 MHz with an RF synchronization output provided as a trigger signal.

For multiphoton microscopy applications, the Carmel X-1550 provides an ideal ultrafast laser solution for optimum multiphoton fluores- cence and third harmonic cellular tissue imaging with minimal scatter and reduced risk of photodamage. The compact laser head and associated armored fiber cable make for straight forward integration into existing microscopes with minimal delivery optics.

If the performance parameters do not quite fit your application requirements, please contact us at sales@calmarlaser.com to discuss a customized solution

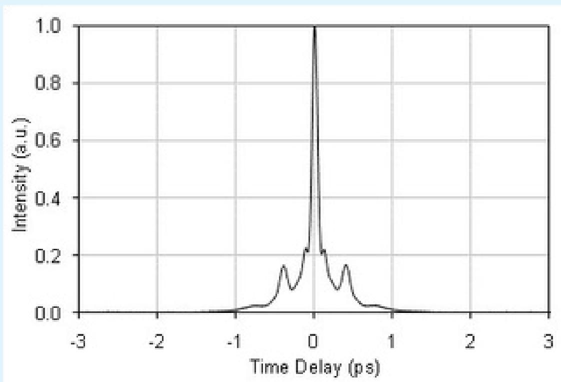
Technical Specifications1

[2]Model Number	CFL-ZCFF
OPTICAL	
Central Wavelength (nm)	1550 ± 4
Pulse Width3 (fs)	< 90
Average Power (W)	Up to 2.5
Repitition Rate4 (MHz)	10 - 80
Pulse Energy5 (nJ)	Up to 50
Spectrum Width (FWHM, nm)	> 30
Power Stability over 8 hours6 (%, RMS)	< 1.0
Beam Quality, M2	< 1.1
Beam Diameter at Exit (typical, mm)	1.2 (beam roundness > 90%)
Polarization Extinction Ratio (dB)	> 18
Output/Termination	Free space, collimated beam
ELECTRICAL	
Electrical Synchronization (V)	~ 0.5, SMA connector
Supply Voltage	85 - 264 VAC at 47 – 63 Hz, autoranging
Power consumption (W)	200
MECHANICAL	
Operating Temperature (°C)	17 - 30
Storage Temperature (°C)	0 - 50
Connection between Controller and Head7	1 m fixed armored cable
Laser Head Dimensions (cm)	9.0(W) x 18(D) x 3.5(H)
Laser Controller Dimensions (cm)	48.2(W) x 46.7(D) x 10(H); 19 inch 2U
Laser Head Weight (kg)	0.8 (typical)
Laser Controller Weight (kg)	13.6 (typical)
Cooling	Controller air-cooled by low noise fan
Warm-up Time (min)	< 10
I/O CONTROL	
Communication Interface8	RS-232 Serial Port, Monitor Port
Front Panel Control Interface	Power Switch, Laser Key Switch, Emergency Stop Button

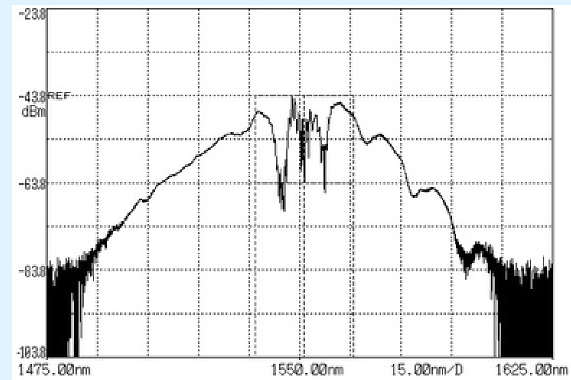
1. Due to our continuous improvement philosophy, all product specifications are subject to change without prior notice. Please contact sales@calmarlaser.com for customized specifications.
2. Z depends on the output power: Z = 04 (> 0.25W), 05 (> 0.5 W), 10 (> 1 W), 20 (> 2.0 W), or 25 (> 2.5W). Power needs to be specified at the time of purchase.
3. A sech2 pulse shape (deconvolution factor of 0.65) is used to determine the pulse width from the second harmonic autocorrelation trace.
4. The repetition rate needs to be specified at the time of purchase. For other repetition rates, please contact sales@calmarlaser.com.
5. The absolute pulse energy will depend on the version and specified repetition rate.
6. Requires an ambient temperature control of ± 1.0ºC and appropriate mounting for the laser head.
7. For other cable length options, please contact sales@calmarlaser.com.
8. Standard on the OEM version, for the scientific version please contact sales@calmarlaser.com.

CALMAR LASER

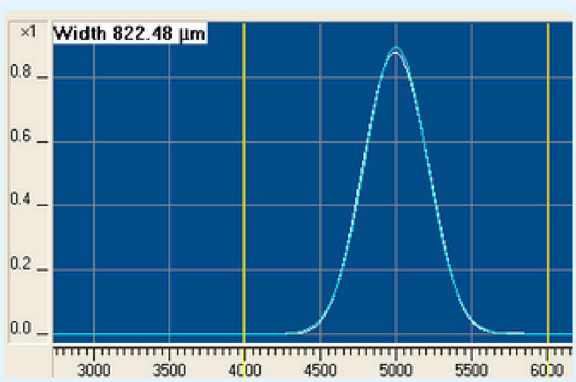
Optical Characterization



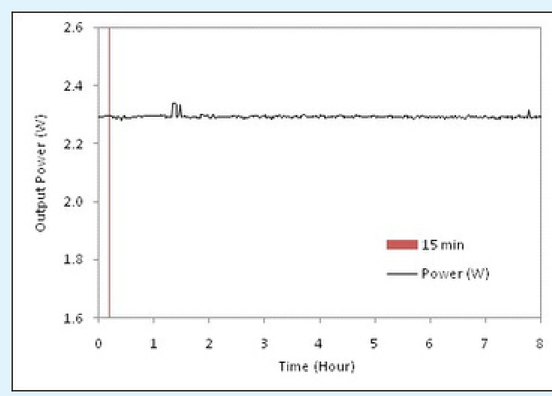
Typical Autocorrelation Trace



Typical Optical Spectrum

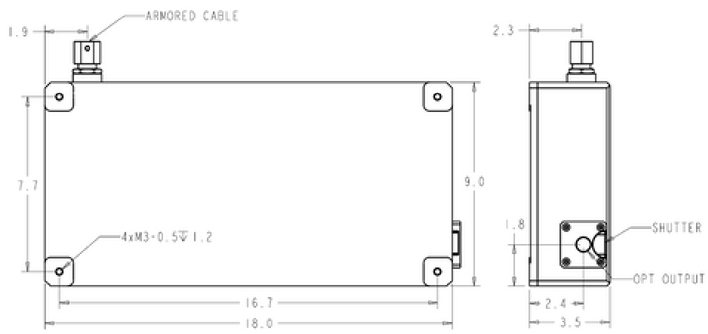


Typical Beam Profile

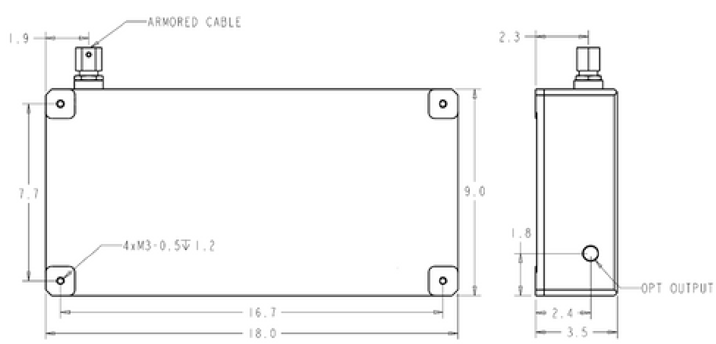


Typical Power Stability

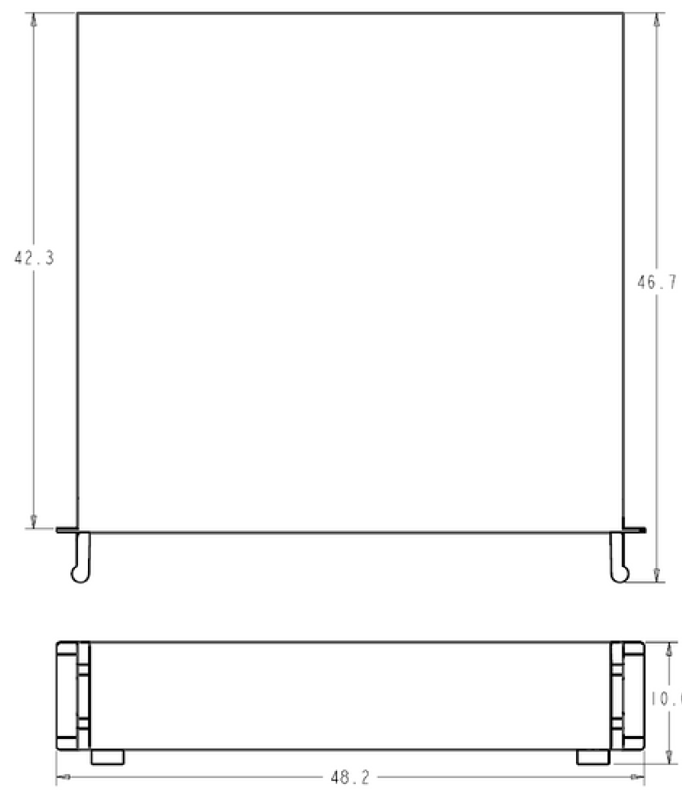
Mechanical Dimensions



Dimensions of Laser Head for Scientific Model (cm)



Dimensions of Laser Head for OEM Model (cm)



Dimensions of Laser Controller (cm)

DANGER
INVISIBLE LASER RADIATION
AVOID EYE OR SKIN EXPOSURE
TO DIRECT OR SCATTERED RADIATION
CLASS IV Laser Product

shop.ozoptics.com
www.ozoptics.com

219 Westbrook Road
Ottawa, ON, Canada, K0A 1L0

Toll-free: 1-800-361-5415
Telephone: 1-613-831-0981
Fax: 1-613-836-5089
sales@ozoptics.com

WAVELENGTH DIVISION MULTIPLEXERS

Features:
- PM fiber versions
- Visible wavelength (Red/Green/Blue) versions
- High power handling
- Low Insertion Losses
- Low return loss
- Wide wavelength range: 375–2000nm
- High power handling
- Coarse and dense WDM versions
- Miniature inline Versions
- LOW COST!

Applications:
- Fluorescence Microscopy
- Confocal Microscopy
- Laser Spectroscopy
- Fiber Lasers
- Erbium Doped Fiber Amplifiers
- Imaging systems
- Drop/Add Filters for Telecommunications
- 980nm Pumping
- OCTsystems

Product Description:
Wavelength division multiplexers (WDMs) are used to combine light of different wavelengths into a single fiber. The light from each fiber is first collimated. The collimated beams are then combined using a dichroic filter, with typically the longer wavelength transmitted from port T, the shorter wavelength reflected from port R. The combined beams are then focused into the output fiber at Port 1.

OZ Optics manufacturers wave division multiplexors for both telecom and non-telecom applications. Of special interest are our WDMs for combining visible wavelengths. Our RGB multiplexors combine light at red, green and blue wavelengths into singlemode or polarization maintaining fiber. Systems combining as many as six different visible wavelengths have been produced. This makes them ideal for applications such as confocal microscopy, white light imaging, full colour holograpy and others.

One advantage of OZ Optics WDM's is that different fiber types can be used on the

input

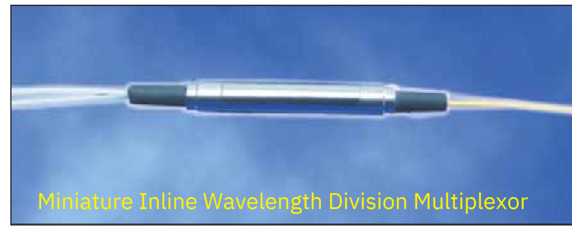
and output ends of the device. This is especially useful in fiber amplifier applications, when the Erbium doped fibers have a different core diameter and numerical aperture. WDM's with 1dB typical insertion losses have been made this way. OZ Optics also offers source to fiber wavelength division multiplexers, where the sources are mounted directly onto the device. This improves the overall system efficiency, and reduces costs.

Our miniature size WDMs are ideal for telecommunication applications such as drop/add filters for either coarse WDM (CWDM) or dense DWM applications. They are also used for combining 980 to 1080nm pump light with 1550nm signals in erbium doped fiber amplifiers (EDFAs).

Laser diode power combiners come in a small, rugged package and are available either with female receptacles to accept different connectors or pigtail style, with the fiber directly attached. Pigtail style combiners are recommended for optimum stability, minimum insertion losses, and low backreflection. Receptacle style systems are best suited for applications where the output coupler is used with a multimode fiber. If a receptacle style combiner is used with a singlemode fiber, then the user may experience low coupling efficiency.

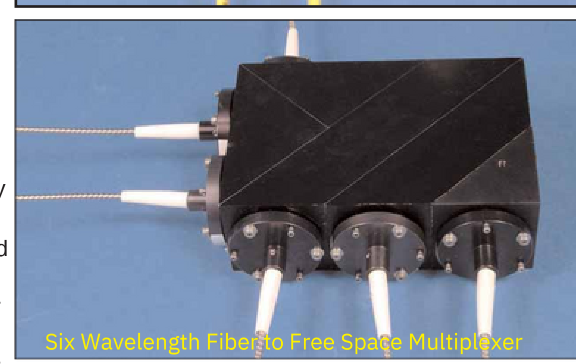
OZ Optics also manufactures polarization maintaining WDM's. The device typically maintains polarization to better than 20dB for 1300 and 1550nm applications. Higher extinction ratios are available on request.

OZ Optics specializes in manufacturing custom designed WDM's. Contact OZ Optics for further information.


Miniature Inline Wavelength Division Multiplexor


Cube Style Wavelength Division Multiplexor


RGB Wavelength Division Multiplexer


Six Wavelength Fiber to Free Space Multiplexer


Laser Diode Power Combiner

Standard Product Specifications:

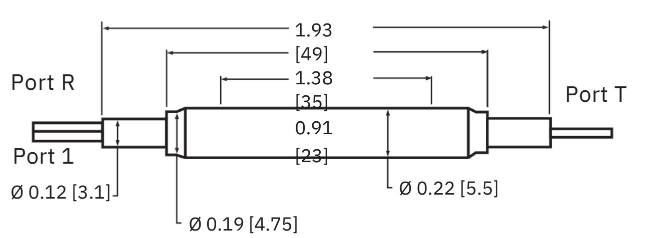
Parameter	Units	Condition	Value		
WDM Type			**WDM-12P WDM-13P**	**WDM-12N CWDM-12N DWDM-12N**	**WDM-11P**
Description			Standard Pigtail Style	Miniature Inline Style	Laser Diode Combiner
Available Wavelengths	nm		400-1650	400-1650[1]	400-1650
Return Losses	dB	400-1200 nm	40	40	40
		1200-1650 nm	40, 50, or 60	40, 50, or 60	40, 50, or 60
Insertion Losses (Typical)[2]	dB	400-1200 nm	1.0	1.0	Not applicable[3]
		1200-1650 nm	0.8	0.8	
Insertion Losses (Maximum)[2]	dB	400-1200 nm	1.2	1.2	Not applicable[3]
		1200-1650 nm	1.0	1.0	
Insertion Losses (60dB Return Loss Option)	dB	1280-1650 nm	0.7 max	0.7 max	Not applicable[3]
Polarization Extinction Ratio	dB	400-600 nm	18	15	18
		600-1150 nm	20	18	20
		1250-1550 nm	20, 25, or 30	20 or 25	20
Power Handling	mW	SM or PM fiber, 1550nm	500[4]	200[4]	200[4]
Operating Temperature	°C		-20 to +60		

[1] Applies to WDM-12N parts only. For CWDM and DWDM parts, available wavelenths range from 180 to 1650nm.

[2] For components whose wavelengths are separated by more than 20nm and less than 200nm

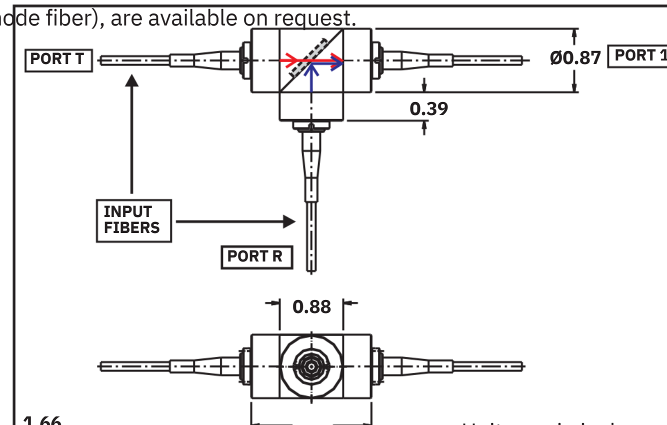
[3] For laser diode power combiners, actual insertion losses depend on the laser diodes selected for the application.

[4] Higher power versions (up to 5 Watts into singlemode fiber, higher into multimode fiber), are available on request.



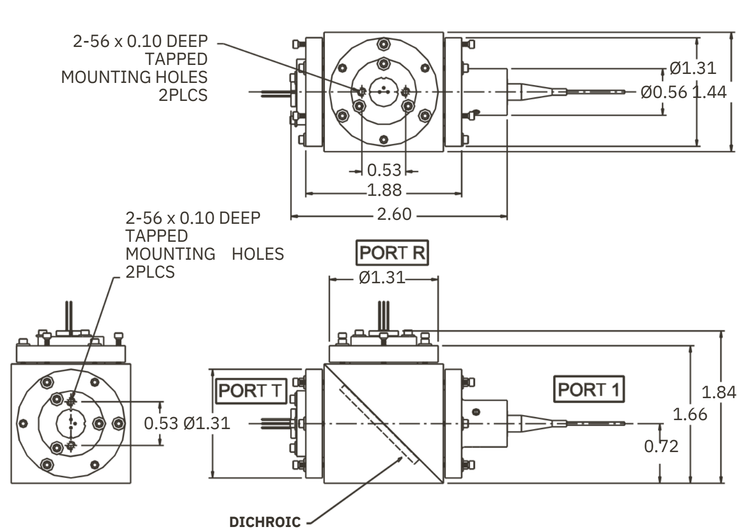
Units are in inches [mm]

Figure 1: Miniature Inline WDM Dimensions



Units are in inches

Figure 2: Standard Wave Division Multiplexer Dimensions



Units are in inches

Figure 3:Laser Diode Power Combiner Dimensions

Ordering Information For Standard Parts:

For more Standard Parts, please see our Online Catalog http://shop.ozoptics.com

Bar Code	Part Number	Description
10923	WDM-12P-111-1300/1550-7/125-PPP-60-3U3U3U-3-1	Wavelength division multiplexer for 1300 & 1550nm with 1 meter long, 3mm OD jacketed 7/125 PM fiber pigtails, 60dB return loss and ultra FC/PC connectors.
12808	WDM-12P-111-1480/1550-8/125-PPP-60-3A3A3A-3-1	Wavelength division multiplexer for 1480 & 1550nm with 1 meter long, 3mm OD jacketed 8/125 PM fiber pigtails, 60dB return loss and angled FC/PC connectors.
12809	WDM-12P-111-980/1550-8/125-PPP-40-3A3A3A-3-1	Wavelength division multiplexer for 980 & 1550nm with 1 meter long, 3mm OD jacketed 8/125 PM fiber pigtails, 40dB return loss and angled FC/PC connectors.

Ordering Information For Custom Parts:

OZ Optics welcomes the opportunity to provide custom designed products to meet your application needs. As with most manufacturers, customized products do take additional effort so please expect some differences in the pricing compared to our standard parts list. In particular, we will need additional time to prepare a comprehensive quotation, and lead times will be longer than normal. In most cases non-recurring engineering (NRE) charges, lot charges, and a 1 piece minimum order will be necessary. These points will be carefully explained in your quotation, so your decision will be as well informed as possible. We strongly recommend buying our standard products.

Questionnaire For Custom Parts:

1) What wavelength range are you interested in?
2) What type of fiber is being used? Singlemode, Multimode or PM?
3) What power levels are being used in your system?
4) What coupling efficiency do you require?
5) Are you using a polarized or randomly polarized light source?
6) What return losses are acceptable in your system?
7) What connector type are you using?
8) How do you intend to use this product?

Note concerning part numbers: Depending on the configuration of the desired design, the fiber types, lengths, and connectors may be different on each channel. Therefore it is important to correctly identify each port in the proper order. When specifying wavelengths, list them from shortest to longest. When identifying fiber types, start from the shortest wavelength to the longest wavelength, and identify the combined port last. This rule is also used when specifying the connector types and fiber lengths

Description | **Part Number**

Wavelength Division Multiplexer: WDM-1*NA*-111-*Wi/Wo* *a/b* *ABC*-*LB*-*XYZ*-*JD*-*L*

N = Number of wavelengths to combine (2, 3, 4, ect)

A Package style
P for standard pigtail style
N for miniature inline style

Wi/Wo = Operating Wavelengths in nanometers

a/b Fiber core/cladding size, in microns
9/125 for 1300/1550nm corning SMF-28 singlemode fiber
8/125 for 1550nm PANDAstyle PM fiber
See tables 1 to 5 of the *Standard Tables*
http://www.ozoptics.com/ALLNEW_PDF/DTS0079.pdf
for other sizes

ABC, Fiber types: on each port
M = Multimode
S = Singlemode
P= Polarization Maintaining

L = Fiber length, in meters

JD =Fiber jacket type:
1 = 900 µm OD Hytrel jacket
3 = 3 mm OD Kevlar reinforced PVC cable

X,Y,Z =Connector type on each end
3S=Super NTT-FC/PC
3U=Ultra NTT-FC/PC
3A=Angled NTT-FC/PC
8=AT&T-ST
SC=SC
SCA=Angled SC
LC=LC
LCA=Angled LC
MU=MU
X=No Connector

LB =Backreflection level:
40, 50 or 60dB for singlemode or PM fibers only. (60dB for 1290 to 1620nm wavelength ranges only)
35dB for multimode fibers

Pigtail Style Laser Diode Combiner: WDM-11P-*a/b*-*F*-*Wi/Wo*-*LB*-*X*-*JD*-*L*

a/b Fiber core/cladding size, in microns
9/125 for 1300/1550nm corning SMF-28 singlemode fiber
8/125 for 1550nm PANDAstyle PM fiber
See tables 1 to 5 of the *Standard Tables*
http://www.ozoptics.com/ALLNEW_PDF/DTS0079.pdf
for other sizes

F Fiber types: on the output port
M = Multimode
S = Singlemode
P= Polarization Maintaining

Wi/Wo= Operating Wavelengths in nanometers

LB=Backreflection level:
40, 50 or 60dB for singlemode or PM fibers only. (60dB for 1290 to 1620nm wavelength ranges only)
35dB for multimode fibers

L Fiber length, in meters

JD Fiber jacket type:
1 = 900 µm OD Hytrel jacket
3 = 3 mm OD Kevlar reinforced PVC cable

X,Y,Z=Connector type on each end
3S=Super NTT-FC/PC
3U=Ultra NTT-FC/PC
3A=Angled NTT-FC/PC
SC=SC
SCA=Angled SC
LC=LC
X=No Connector
See table 6 of the *Standard Tables*
http://www.ozoptics.com/ALLNEW_PDF/DTS0079.pdf
for other connector types

Frequently Asked Questions (FAQs):

Q: What wavelength ranges are available?
A: OZ Optics offers a variety of WDMs working from 400nm to 1650nm. Custom designs are available for combining and splitting most combinations of wavelengths in this region.

Q: Can I use different fibers on each port?
A: Yes, OZ Optics WDM design offers the flexibility of having different fiber types on each of the ports.

Q: Can I use high power with these WDMs?
A: Yes, OZ Optics standard design can handle up to 200mW, for higher power applications a custom design can be done to handle up to 2W.

Q: What is the standard package size? Can I get a smaller package?
A: The standard packages for WDMs use a 0.8 or 1.6 inch cube design. These packages are ideal for low cost proto-type applications. For OEM applications OZ Optics will work with you to design a package that meets your size requirements.
Q: Do you offer WDM's that can combine more than two wavelengths?
A: Yes. Systems that combine 3 and 4 different wavelengths have also been made.

Application Notes:

Wavelength Division Multiplexers (WDM) are used to combine and split (multiplex and demultiplex) signals in different systems ranging from telecommunications to imaging systems. The basic principle of WDM is based on thin film filters that transmit light in a certain spectral range and reflect light in another spectral range. Figure 2 on page 2 demonstrates the basic principle of splitting and combining two different wavelengths.

The WDM plate is designed to transmit and reflect 2 thereby "multiplexing" the two inputs into the common port. Due to the inherent bi-directional nature of the filter, this component will also work in the opposite direction in order to "de-multiplex" the two wavelengths.

Data Sheet

Cisco Prisma II Optical Switch Modules

Description

If you're looking for optical path redundancy and using the Cisco Prisma II best-in-class architecture, the Prisma II Optical Switch (OPSW) is the right choice. The high-density OPSW (Figure 1) is a 1 x 2 switch designed to fit directly into a Prisma XD chassis or, with a host module adaptor, a standard Prisma II chassis.

Figure 1. Optical Switch Module

The optical switch module in the Prisma II XD chassis module form factor features Subscriber Connector/Angle-Polished Physical Contact (SC/APC) connectors for input and output optical connections. For use in the full-height Prisma II chassis, a host module adaptor is available.

Features

- High-density design that allows up to 16 OPSWs in a Prisma II XD chassis or up to 24 in a standard Prisma II chassis with redundant power supplies
- Energy-efficient design with low power consumption per module
- Optical switches allow for network primary/secondary redundancy
- Multiple setup and control options include:
  - Local control through a Local Craft Interface (LCI)
  - Local monitoring through an Intelligent Communications Interface Module (ICIM)
  - Remote monitoring through a ROSA status monitoring and control element manager
- OPSW modules have multiple modes of operation and user-settable trigger values

Table 1 gives specifications of the OPSW.

Table 1. OPSW Specifications

Optical	Units	Value	Notes
Nominal Optical Wavelength	nm	1550 (□20)	
Input Optical Power Range	dBm	-10 to +14	1
Insertion Loss	dB	≤ 2.0	2
Inputs	-	Primary (1) Secondary (1)	
Output	-	Common	
Cross-Talk	dB	≥ 55	
Return Loss	dB	≥ 50	3
Optical Interfaces		SC/APC (3)	
Electrical			
Sense and Switch Time (from Primary to Secondary state)	ms	□ 50	
Power Consumption @ 24 VDC (maximum)	W	3	
Switching Threshold	dB	-10 to +14 (user changeable)	
Restore Threshold	dB	0.5 to 9.5	
Wait Time before Restoration	seconds	0 to 600 in 1-second increments	
Environmental			
Operating Temp Range **Full Specs** **Storage**	°C °F °C °F %	-20 to +65 -4 to +149 -40 to +85 -40 to +185 0 to 95	
Humidity Range			4
Mechanical	in.	8.8 x 3.48 x 1.03	
Length x Height x Width	cm	22.35 x 8.84 x 2.62	

Notes:

1. Optical input power of -3.0 dBm or greater is required to maintain the full user-settable threshold range. When the optical input power is less than -3.0 dBm, there is a 1-for-1 reduction in threshold range.
2. Insertion loss of module with 0.25-dB loss per mated connector pair for a total connector loss of 0.5 dB. Actual connection loss may be less or more depending on mating connector compatibility.
3. With APC connectors.
4. Noncondensing external to the Prisma II or XD chassis.

Ordering Information

The part number for the OPSW is shown in Table 2. Please consult with your Account Representative, Customer Service Representative, or Systems Engineer to determine the best configuration for your particular application.

Table 2. Part Number for OPSW

Description	Part Number
Optical Switch	4037229

Americas Headquarters
Cisco Systems, Inc.
San Jose, CA

Asia Pacific Headquarters
Cisco Systems (USA) Pte. Ltd.
Singapore

Europe Headquarters
Cisco Systems International BV Amsterdam,
The Netherlands

Cisco has more than 200 offices worldwide. Addresses, phone numbers, and fax numbers are listed on the Cisco Website at **www.cisco.com/go/offices.**

Printed in USA C78-733547-00 12/14

Calculations :

1. (i) My city to Your city

Insertion loss = loss of (switch + WDM)

Amplifier Gain = 17

$0.18x + 1 + 2 = 17$

$0.18x = 14$

$x = 77km$

Potential site for amplifier (A1) = 72km

$\therefore$ Excess gain $= 0.18 \times 72 + 1 + 2 + 4.8 - 20$

$20 - 15.96$

$= 4.04 dB$

Next amplifier (A2)

$0.18x + 9.8 \times 1 = 20$

$x = 40$

Potential site for Amplifier A2 = 96km

Excess : $- 0.18 \times 24 - 9.8 + 20$

$= 9.92 dB$

Next amplifier at 124 km

Placing DCM at 122 km

$9.8 + 0.18 \times (124 - 96) = 14.84 dB$ ↳ loss

Excess $= 20 + 5.82 = 25.82 - 14.84$

$= 15.08 dB$

After A_2, placing another DCM

loss $= 46 \times 0.18 + 1 + 3 = 12.28$

Summary :

Component name	Gain (+) / loss (-) dB
A1	17
A2	20
A3	20
DCM 1	-9.8
WDM	-1
DWDM	-1
OADM	-3
Switch	-2
DCM 2	-3

Excess = 15.08 − 12.28 ≈ 2.8 dB

$20 + 20 + 20 - 57.2$

$= 0.28$

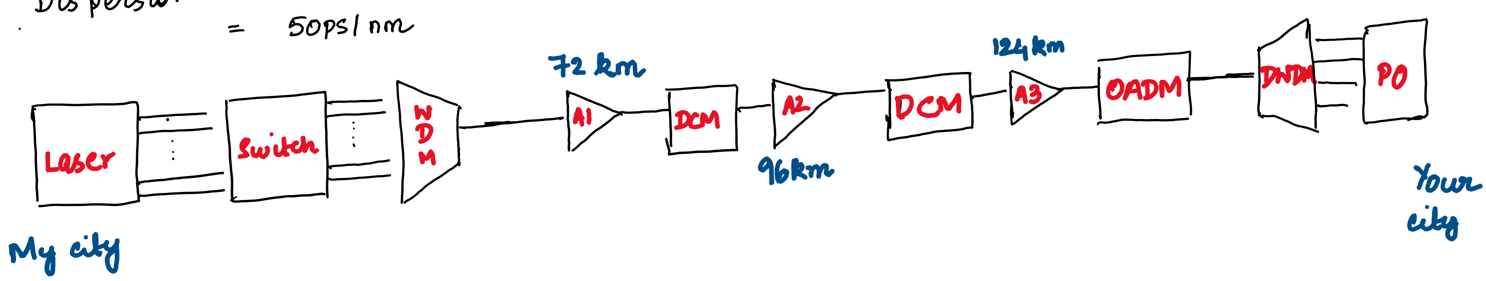
$P_{in} = \dfrac{2\,mW}{10^{0.28}} = 1.049\,mW$ (meets the requirement)

$$SNR = \frac{(1.049\times10^{-3})^2\,(0.75)^2}{8.49\times10^{-12} + 7.55\times10^{-13}}$$

SNR = 48.4 dB (meets the requirement)

Dispersion = $(18\times170) - (2010 + 1000)$

= 50 ps/nm



Your city to my city

Amplifier A1

$0.18x + 2 + 1 = 20$

$0.18x = 17$

$x \simeq 94.4$

Potential site for A_1 = 77 km

loss = $0.18\times46 + 3 = 11.28$

excess gain = $20 - 11.28 = 8.72$ dB

Amplifier A2

$0.18x + 9.8 = 20$

$x \simeq 56$ km

Potential site for A_2 = 125 km

$0.18\times48 + 9.8 = 18.44$ dB − loss

Summary

component	gain (+) / loss (−) dB
A1	15
A2	20
A3	10
A4	20
DCM1	9.8
DCM2	3.4
DCM3	3.4
Switch	2
WDM	1
DWDM	3

$$\text{Excess gain} = 20 - 18.44 + 8.72$$
$$= 10.72\,dB$$

Amplifier A3

$$0.18x + 4.8 + 4 = 20$$
$$x = 62.2$$

Potential site for A3 = 170km

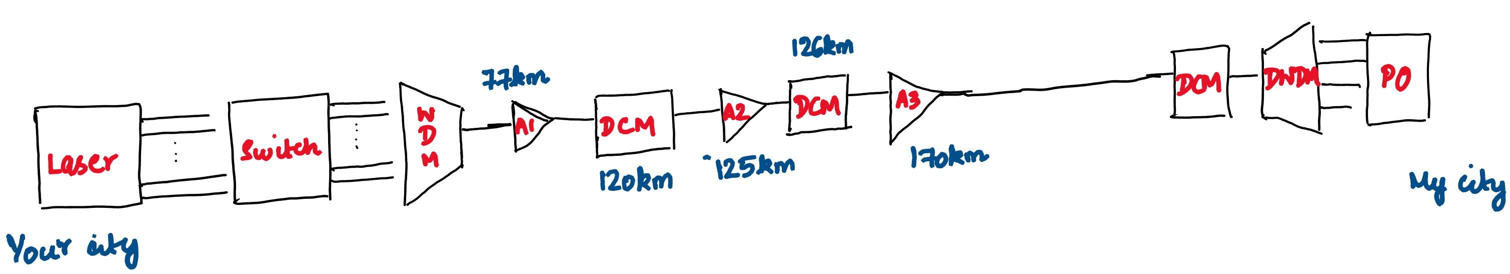
$$\text{loss} = 0.18 \times 45 + 4 + 4.8$$
$$= 16.96\ dB$$

$$\text{excess gain} = 20 + 4.56 - 16.96$$
$$= 7.6$$

$$\text{Received power} = \frac{2}{10^{(15+20+20+7.6-11.28-19.16-16.96)/10}}$$

$$= 0.06\,mW$$ (meets the requirement)

$$SNR = \frac{(0.07\times10^{-3})^2(0.75)^2}{8.19\times10^{-13} + 5.4\times10^{-13}} = 33.1\,dB$$ (meets the requirement)



$$\text{Dispersion} = (18\times170) - (2010 + 1000)$$
$$= 3060 - 3010$$
$$= 50\,ps/nm$$

$$r_{spm} = 4\times10^{-20}\times1 \,/\, 1550\times10^{-9} \times 2\times10^{-2}$$

$\leq$ 1 rad/mW (meets the requirement)

3. (i) Her city to Your city

Amplifier A1

$0.18x + 1 + 2 = 20$

$x = 94\,km$

Potential site for A1 = 83km

$0.18 \times 83 + 1 + 2 = 17.94$

loss $= 0.18 \times 83 + 1 + 2 = 17.94$

excess gain $= 20 - 17.94$

$= 2.06\,dB$

Amplifier A2

$0.18x + 9.8 = 15$

$x = 19\,km$

Potential site for A_2 = 102km

loss $= 0.18 \times 19 + 9.8 = 13.22\,dB$

excess gain $= 15 - 13.22$

$= 2.06\,dB$

Placing DCM at 100km

gain $= 15 - 13.22 + 2.06 = 3.84\,dB$

Amplifier A_3

$0.18x + 3.4 + 3 + 1 = 15$

$x = 48$

Potential site = 150 km

loss $= 0.18 \times 48 + 3.4 + 3 + 1 = 16.04\,dB$

Summary:

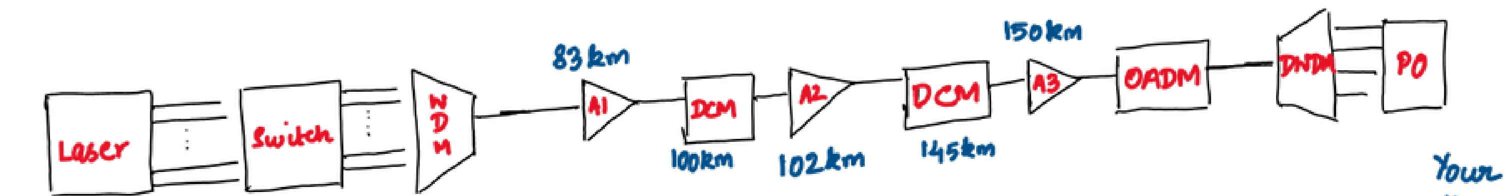
Component	Gain (+) / Loss (-) dB
A1	20
A2	15
A3	15
DCM 2	-3.84
Switch	-2
WDM	- ~~2~~ 1
OADM	-3
DWDM	-1
DCM	-9.8

excess = $15 + 3.84 - 16.04$

$= 2.8\,dB$

$$P_{in} = \frac{2m}{10^{(20+15-15-17.94-13.22-16.04)/10}} = 0.714\,mW \text{ (meets the requirement)}$$

$$SNR = \frac{(0.714 \times 10^{-3})^2 (0.75)^2}{8.19 \times 10^{-13} + 5.4 \times 10^{-13}} = 53.24\,dB \text{ (meets the requirement)}$$



Dispersion = $(18 \times 170) - (2010 + 1000)$

$= 3060 - 3010 = 50\,ps/nm$

ii) Your city to her city

Amplifier A1

$0.18x + 2 + 1 = 20$

$0.18x = 17$

$x \approx 93$

Potential site for A1 = 83

loss = $0.18 \times 83 + 3 = 17.94$

excess gain = ~~2.06~~ $20 - 17.94$

$=$ ~~20~~ $2.06\,dB$

DCM is placed 107km having value of 9.8 insertion loss

Amplifier A_2:

$0.18x + 9.8 = 15$

$0.18x = 5.2$

$x \approx 28\,km$

Potential site for A_2 = 108km

Summary

component	gain (+) | Loss (-) dB
A1	20
Switch	-2
WDM	-1
DCM1	-9.8
DCM 2	-3.4
A2	20
A3	10
DWDM	1

$\text{Loss} = (0.18)(\cancel{25}) + 9.8 = 14.3\,\text{dB}$

$\text{Excess gain} = 20 + 2.06 - 14.3$

$= 7.76\,\text{dB}$

Amplifier A3 :

Placing DCM (D2) at 121 km

A3 is placed at 122 km having gain of 10dB

$\text{Total gain} = 10 + 7.76 - (0.18 \times 14) - 3.4 - 4$

$= 17.76 - 5.92$

$= \cancel{17}.84\,\text{dB}$

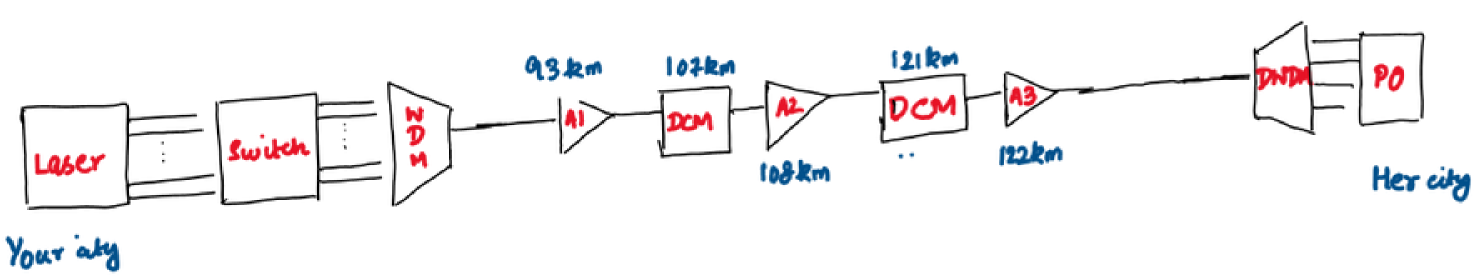
$$\text{Power at receiver} = \frac{2\,\text{mW}}{10^{(20+15+10-5.92-14.93-\cancel{\ldots}\,9.92)/10}}$$

$$= \frac{2\,\text{mW}}{4.14}$$

$= 0.48\,\text{mW}$ (meets the requirement)

$$\text{SNR} = \frac{(0.48 \times 10^{-3})^2 \times (0.75)^2}{(8.19 \times 10^{-13} + 5.4 \times 10^{-13})}$$

$= 49.79\,\text{dB}$ (meets the requirement)



$\text{Dispersion} = (18 \times 170) - (2010 + 1000)$

$= 3060 - 3010$

$= 50\,\text{ps/nm}$

$r_{spm} = 4 \times 10^{-1} \times 1 \,/\, 1550 \times 10^{-9} \times 2 \times 10^{-2}$

$\simeq 1\,\text{rad/mW}$ (meets the requirement)

2. (i) His city to Your city

Amplifier A_1

$0.18 \times x + 2 + 1 = 20$

$x = 94$ km

A_1 is placed at 94 km

Loss $= 94 \times 0.18 + 2 + 1 = 19.92$ dB

Excess gain $= 20 - 19.92$

$= 0.08$ dB

Amplifier A_2

$0.18x + 9.8 = 20$

$x = 57$ km

Amplifier is placed at 127 km

loss $= 0.18 \times (127 - 94) + 9.8$

$= 15.74$ dB

Excess $= 20 + 0.08 - 15.74$

$= 4.34$ dB

Amplifier A_3

$0.18 \times x + 8.4 = 15$

$x = 31$ km

Amplifier is placed at 158 km

loss $= (0.18 \times 31) + 8.4 = 13.98$ dB

Summary :

Component	Gain (+) / Loss (−) dB
A1	20
A2	20
A3	15
A4	15
DCM2	−8.4
DCM1	−9.8
Switch	− 8
WDM	− 2
OADM	3
DWDM	1

Excess = 15 + 4.34 − 13.98
= 5.36 dB

Amplifier A4

$0.18x + 3 + 1 = 15$

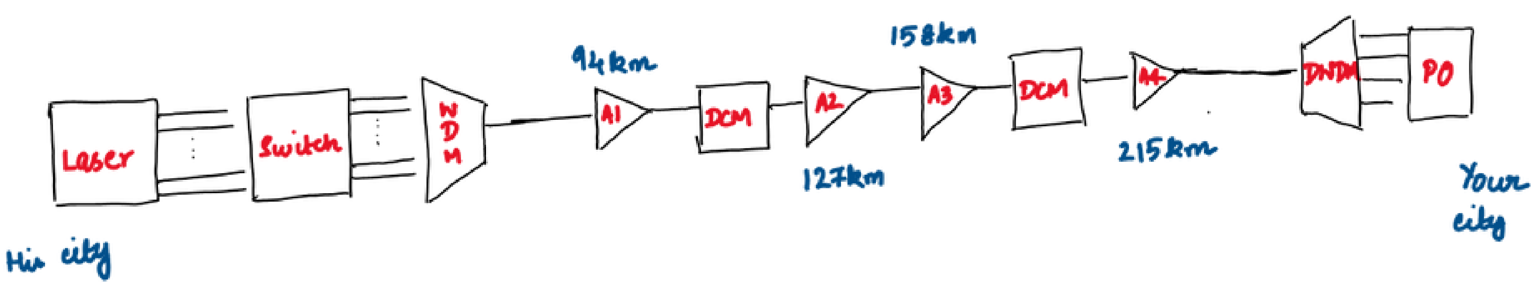
$x = 57$ km

Amplifier is placed at 215 km

$0.18 \times 57 + 3 + 1 = 14.26$ dB

Excess = 15 + 5.36 − 14.26 = 6.1 dB

At 100th km, DCM is placed having insertion loss of 8.4 dB



$$P_{in} = \frac{2\,mW}{10^{(20+20+15+15-19.92+15.74-13.98-14.26)/10}} = \frac{2\,mW}{10^{0.61}}$$

= 0.49 mW (meets the requirement)

$$SNR = \frac{(0.49 \times 10^{-3})^2 (0.75)^2}{1.092 \times 10^{-12} + 3.528 \times 10^{-13}} = 49.70\text{ dB}$$ (meets the requirement)

Dispersion = (18 × 170) − (2010 + 2010)
= −960 ps/nm

(II) Your city to His city =
=

(A1) Amplifier at x

$0.18x + 2 + 1 = 20$

Summary :

Component	Gain (+) / Loss (−) dB
	20
	20

$0.18x + 2 + 1 = 20$

$x = 94\,km$

Potential site for A1 = 88km

$0.18 \times 88 + 2 + 1 = 18.84$ (loss)

Excess gain $= 20 - 18.84$

$= 1.16\,dB$

Component	Gain (+) / Loss (−) dB
A1	20
A2	20
A3	12
Switch	−2
DCM1	−9.8
DCM 2	−8.4
WDM	−1
DWDM	−1

Amplifier site A2

$0.18x + 9.8 = 15.74$

$x = 33\,km$

Potential site for A2 = 121km

$0.18 \times 33 + 9.8 = 15.74$ (loss)

excess gain $= 20 + 1.16 - 15.74$

$= 5.42\,dB$

Amplifier A3 site

$0.18x + 8.4 = 14.52$

$x = 34$

Potential site for A3 = 155km

$0.18 \times 34 + 8.4 = 14.52\,dB$ (loss)

excess $= 12 + 5.42 - 14.52$

$= 2.9\,dB$

Amplifier A4 site

$0.18x = 0.14\,dB$

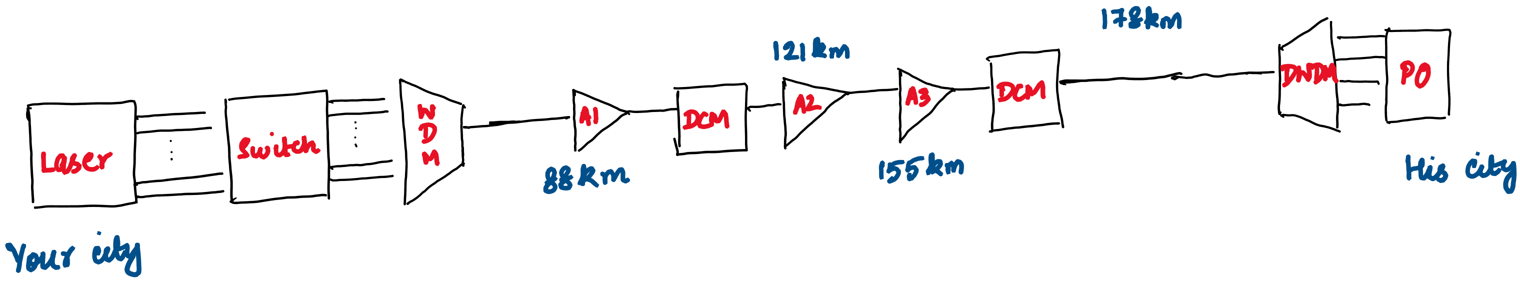
$x = 23$

Potential site for A4 = 178km

$$\text{Excess} = 10.766 - 7.66$$
$$= 3.1\,dB$$

$$P_{in} = \frac{2\,mW}{2.04} = 0.98\,mW \quad \text{(meets the requirement)}$$

$$SNR = \frac{(CP_{in} \times 0.75)^2}{\frac{4kT\Delta f F_n}{R} + 2qI\Delta f} = 37.76\,dB \quad \text{(meets the requirement)}$$



$$\text{Dispersion} = (18 \times 170) - (2010 + 2010)$$
$$= 3060 - 4020$$
$$= -960\,ps/nm$$

$$\gamma_{spm} = 4 \times 10^{-20} \times 1 \,/\, 1550 \times 10^{-9} \times 2 \times 10^{-2}$$
$$\simeq 1\,rad/mW \quad \text{(meets the requirement)}$$