Chapter 8
Fiber Cable Connectorization and Testing

- Splicing (接合)
- Connectors (连接器)
- Installation Hardware
- Design of Local-Area-Network（局域网设计）
- Test and Measurement (测试与测量）

8.1 Splicing (接合)

◆ Connection Losses

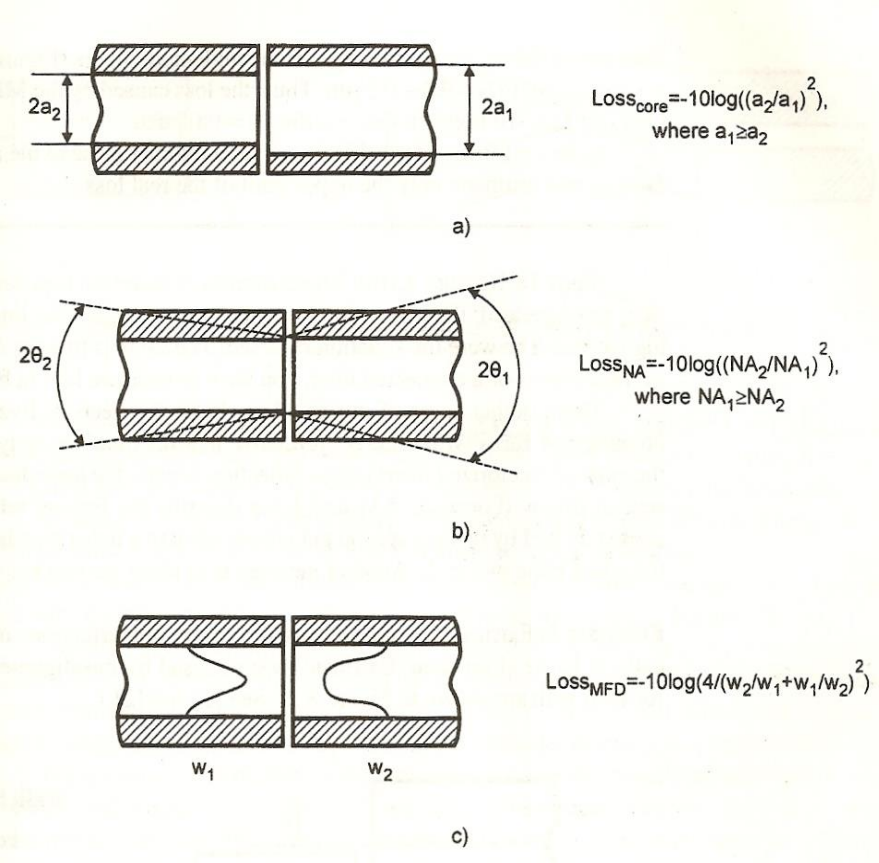
- ***Intrinsic losses*** （固有损耗）

a) Core-diameter,

b) NA,

c) MFD mismatch,

d) Fresnel Reflection

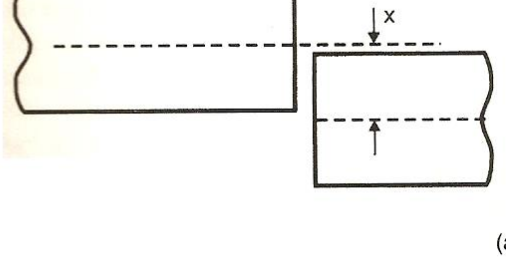


- ***Extrinsic losses (外来损耗)***

a) Lateral, angular, end separation misalignment;

b) Improperly cleave fiber ends, foreign particles;

c) Fiber curl and a lack of concentricity



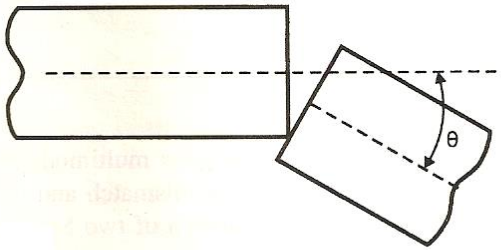
(a)

MMGI Fiber

$$Loss_{lat} = -10\log[1 - 8 \cdot x/(3 \cdot \pi \cdot a)]$$

SM Fiber

$$Loss_{lat} = -10\log[\exp(-x/w_0)^2]$$



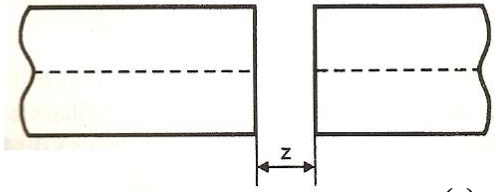
(b)

MMGI Fiber

$$Loss_{lat} = -10\log[1 - 8 \cdot n\sin(\theta)/(3 \cdot \pi \cdot NA)]$$

SM Fiber

$$Loss_{lat} = -10\log[\exp(-T^2)]$$



(c)

MMGI Fiber

$$Loss_{lat} = -10\log[1 - z \cdot NA/(2 \cdot a \cdot n)]$$

SM Fiber

$$Loss_{lat} = -10\log[\exp(1/(S^2 + 1)]$$

- **Reflection losses** （反射损耗)

a) $R = P_{refl}/P_{in} = ((n_1-n_2)/(n_1+n_2))^2$ when $\phi_i = 0$

RL (dB) = -10 log(R)

b) Assume the gap is filled with air, and fiber $n_1 = 1.46$,

R = 3.5%, RL = 14.56dB

-> *Fresnel loss*: the insertion loss caused by reflection

$Loss_{Fresnel} = -10 \log(1 - R)$

c) No reflection loss for fusion splicing

d) Typical reflection loss for mechanical splices is about 50dB (*Index matching material or physical contact*)

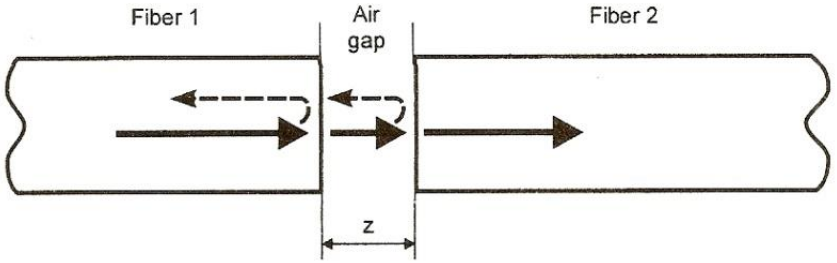


Figure 8.4 Reflection loss.

Splicing Procedure

- ***End preparation***

-> Stripping : Cable jacket -> Strength member -> Buffer tube ->
Coating -> “Bare” fiber

-> Cleave: <1°

- ***Mechanical splicing （机械对接）***

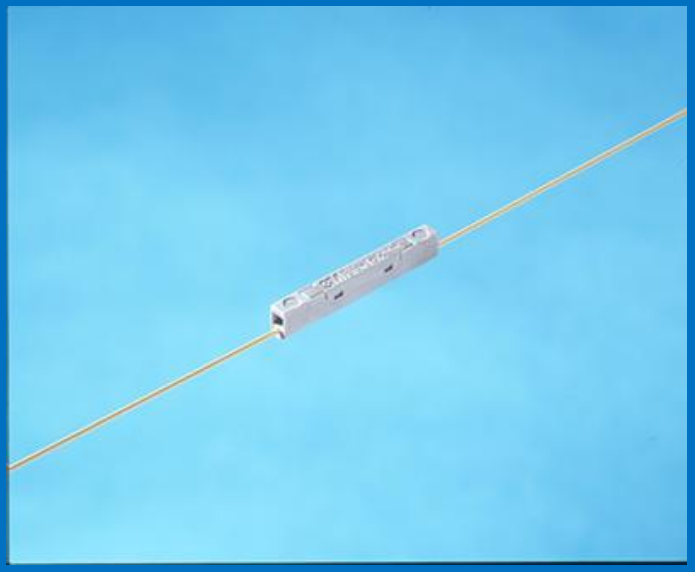
Insertion loss: 0.2 - 0.1dB

-> Reflection loss: 45 to 55dB.

-> The heart of the device is an alignment guide.

-> Cost is relatively high

for quick repair or small number of splices.



- **Fusion splicing (熔接)**

-> Insertion loss: 0.01 dB to 0.15dB

-> Passive alignment

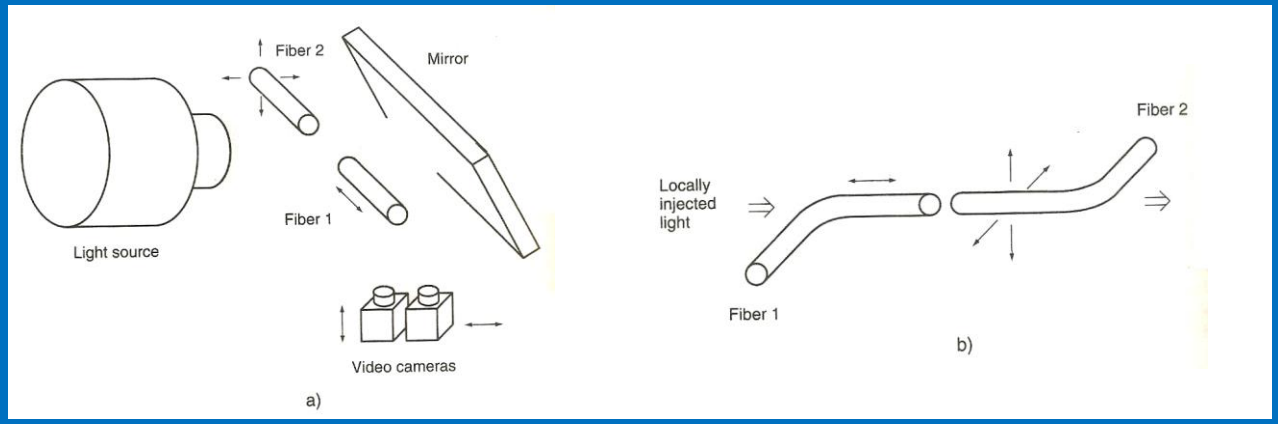
0.03 –0.07 dB (Auto); 0.15 dB (Manually)

-> PAS (Profile-alignment system 轮廓对准系统) -> (a)

-> LID (Local injection and detection 本地注入与检测)

-> PAT (Power-alignment technology 功率对准系统) -> *(b)*

0.01 –0.02 dB



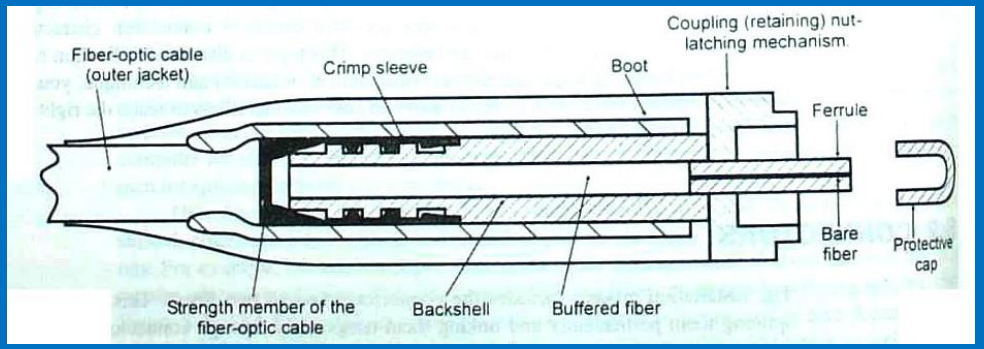
Video for fusion splicing

8.2 Connectors （连接器）

- In fiber optic communications systems, the most common point of failure is at the connector.
- About 30% of the installation cost is for labor associated with connectorization.
- Connectors are vital components of the system both from performance and economic standpoint.

◆ Basic structure

-> Ferrule (插芯), Coupling Nut (闭锁螺母), Boot (尾套)， Backshell (后壳), Crimp Sleeve (压接套筒), Strength member (加强件), Outer Jacket (外护层)



Eccentricity of Ferrule:

< 0.7um for SM Fiber;

< 2um for MM fiber.

Major Characteristics

-> Insertion loss （插入损耗）:

Average loss 0.25 dB (0.1-1 dB), Max loss 0.5 dB (0.3-1.5dB)

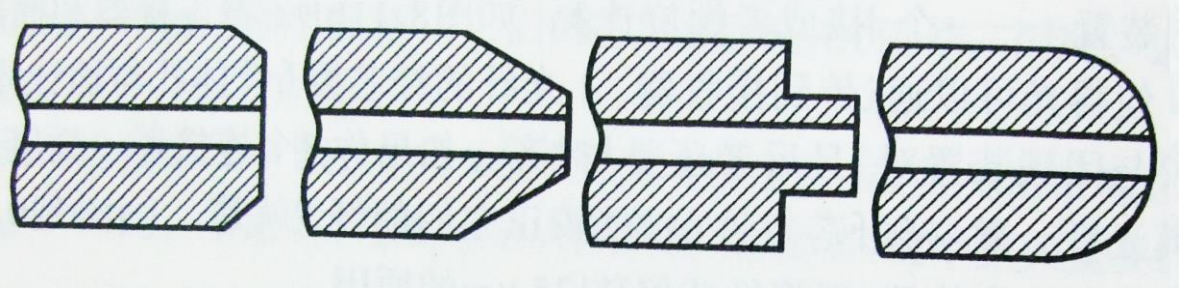
-> Return loss （回波损耗）:

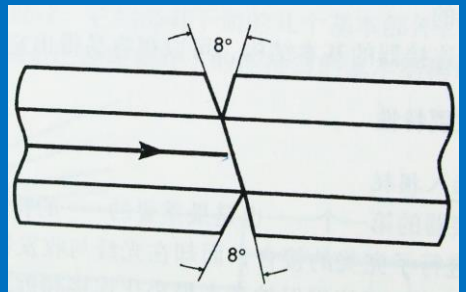
Ferrule endfaces with different profiles, angled

PC (physical contact): 40dB ~ 55dB

UPC (ultra-polishing connectors) : 60dB

APC (angled physical contact): 75dB





◆ Connectors Styles

- ***FC Connectors***

(Fixed Connection 固定连接器)

-> Cylindrical metal coupling nut with keyed sleeves

2.5 mm ceramic ferrule

-> For long-haul and LAN

- ***SC Connectors***

(Subscriber Connector用户连接器)

-> Square, push-pull latching

- ***ST Connectors***

(Straight Tip 直通式连接器)

-> Twist-lock bayonet coupling

-> For long-haul and LAN

8.3 Installation Hardware

- …
- …

8.4 Design of Local-Area Network

- Metropolitan Area Network (MAN)
- Local Area Network (LAN)
- Two types of fiber, TIA/EIA 568A
  (1) 62.5/125 μm graded-index MM; (2) SM

◆ Link Consideration

-> A fiber link: collection of splice, connectors, AWG, filters, Switches, Add on/Drop off etc.

-> Add the loss of every components together.

-> Initial Power and receiver sensitivity.

-> Always keep reasonable power margins.

- **Power Budget （功率预算）**

-> Cable loss

-> Splicing loss

-> Connector loss

-> Transmitter power

-> Receiver sensitivity

-> Power margin (功率裕度)

Example:

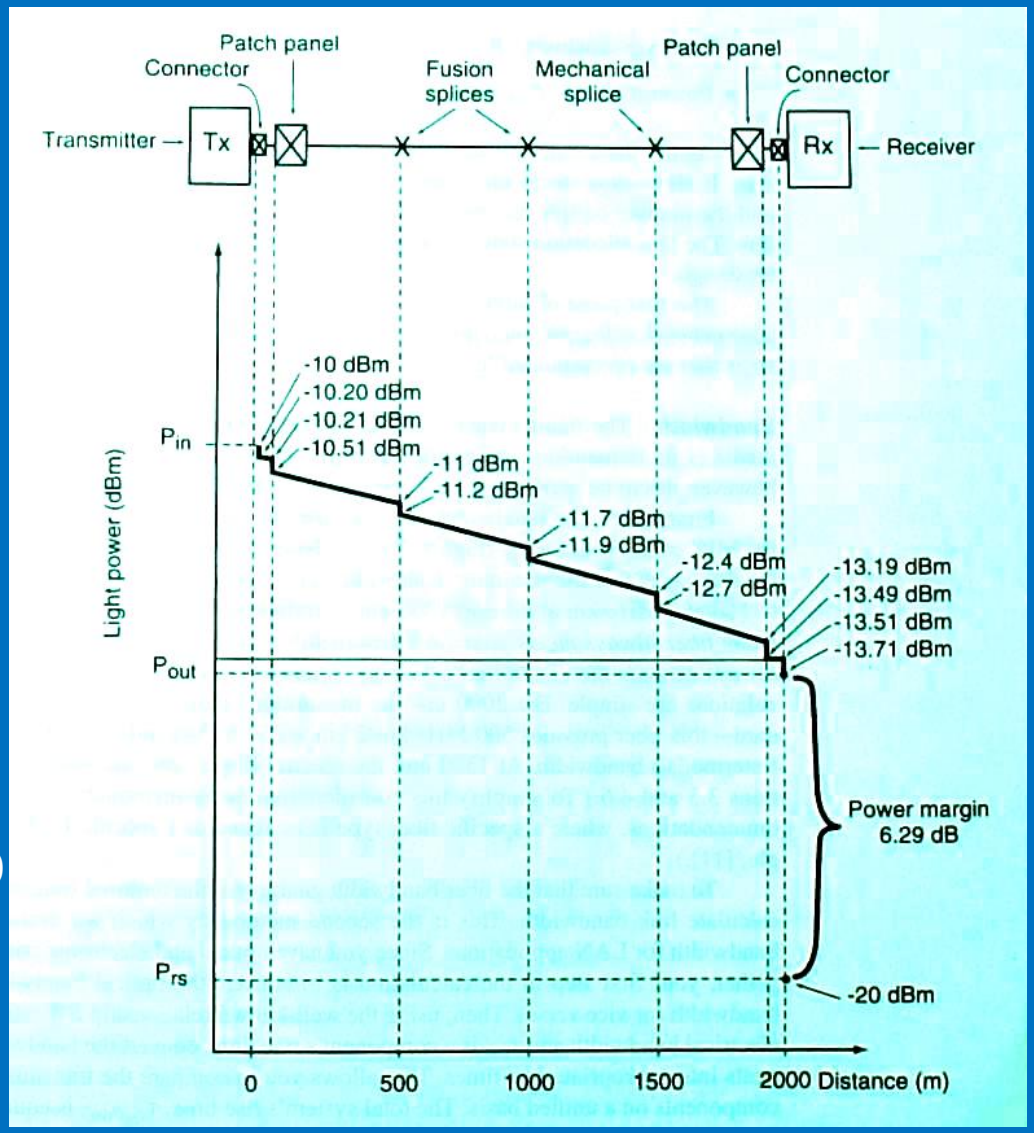
Power lunched into fiber: -10dBm

- 2.01 dB (cable loss 1.0dB/km ⑨2.01km)
- 0.4 dB (fusion loss 0.2dB ⑨2)
- 0.3 dB (mechanical splice)
- 0.6 dB (PC connector loss 0.3dB ⑨2)
- 0.4 dB (connector coupling loss 0.2dB ⑨2)

= -13.71 dBm

Power margin = -13.71 dBm – (-20dBm)

= 6.29 dB



- ***Bandwidth （带宽）***

-> Electrical bandwidth （电频宽）:

$$BW = 0.35/\tau_{rise}$$

-> Rise-time budget equation :

$$\tau_{syst-rise} = \sqrt{(\tau_{fib-rise}^{\ 2} + \tau_{ltw-rise}^{\ 2})}$$

Example:

A local data link is to be installed having the following characteristics: maximum bit rate 16 Mbit/s, installation length 2000 m, operating wavelength 850 nm, rise time of the lightwave equipment 4 ns, LED spectrum width 20 nm. Will MM 62.5/125 um fiber support the required bit rate?

Solution: The required maximum rise time of the fiber:

$$\tau_{\text{sys-rise}} = 0.35/BW = 0.35/16 \text{ MHz} = 22 \text{ ns}$$

$$\tau_{\text{fib-rise}} = \sqrt{(\tau_{syst-rise}^{\ 2} - \tau_{ltw-rise}^{\ 2})} = 21.6 \text{ ns}$$

Fiber rise time:

$$\tau_{fib-rise} = \sqrt{(\tau_{\mathrm{mod}-rise}^{\ 2} + \tau_{chrom-rise}^{\ 2})}$$

$$\tau_{\mathrm{mod}-rise} = \Delta t_{\mathrm{mod}\,al}$$

For 2000 m installation length, for Fig. 3.18, bandwidth-length product is 160 MHz. km:

$$BW_{\mathrm{mod}\,al} = 160\ \mathrm{MHz}\cdot\mathrm{km}/2\ \mathrm{km} = 80\ \mathrm{MHz}$$

$$BW_{el-\mathrm{mod}\,al} = 0.707 BW_{\mathrm{mod}\,al} = 56.6\ \mathrm{MHz}$$

$$\tau_{\mathrm{mod}-rise} = 0.35 / BW_{el-\mathrm{mod}\,al} = 6.2\ \mathrm{ns}$$

$$\tau_{chrom-rise} = \Delta t_{chrom} = D(\lambda) L \Delta\lambda$$

$$= 0.21\ \mathrm{ns/km/nm} \times 2\ \mathrm{km} \times 20\ \mathrm{nm} = 8.4\ \mathrm{ns}$$ (Fig. 3.19)

$$\tau_{fib-rise} = \sqrt{(\tau_{\mathrm{mod}-rise}^{\ 2} + \tau_{chrom-rise}^{\ 2})}$$

$$= \sqrt{6.2^2 + 8.4^2} = 10.4\ \mathrm{ns} < 21.6\ \mathrm{ns}$$

Local Area Network

- ***Network topologies***

-> Point-to-point

-> Star and hierarchical star

-> Ring

-> Bus

-> Logical ring

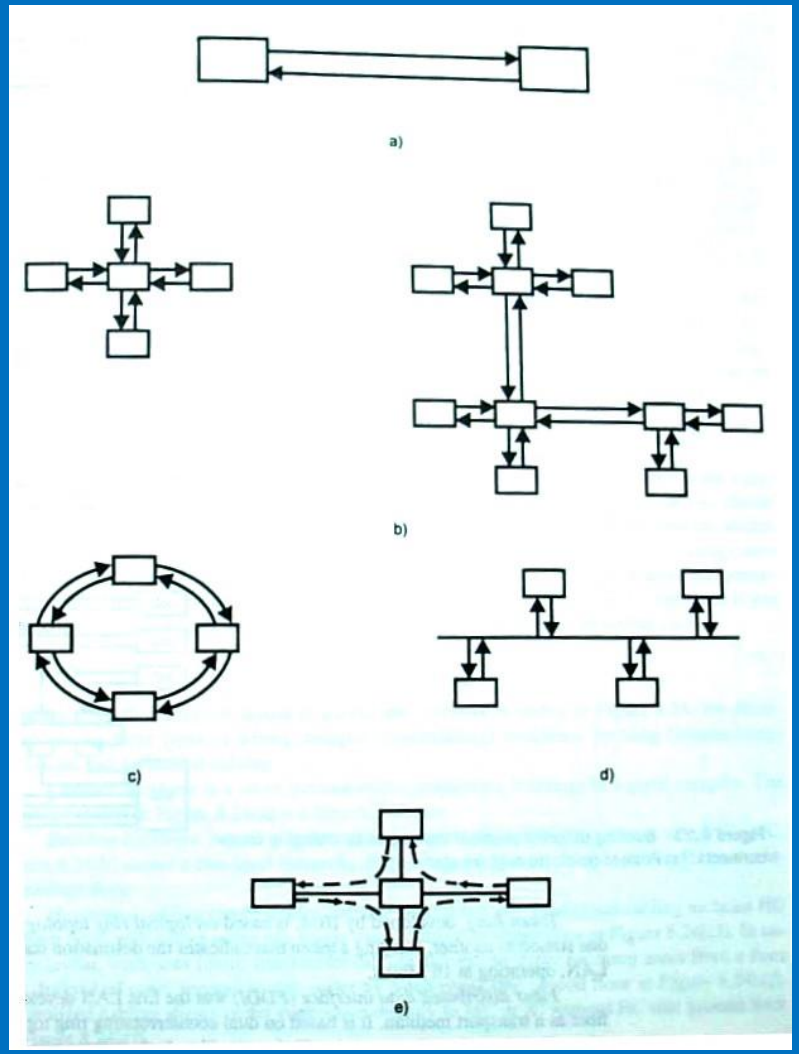
- ***LAN standards***

-> Ethernet

-> Token ring

-> Synchronous optical network (SONET)

-> Asynchronous transfer mode (ATM)



8.5 Testing, Troubleshooting and Measurement

- *Never Look at the Fiber End !*
- *Never Look into the Output Hole of the Light Source !*

◆ Test Equipments

- ***Microscope (Optical fiberscope** 光纤观察镜)*

- ***Optical Fiber Identifier*** ***（光纤识别仪）***

-> Inject 1310 or 1550 nm Tone into the desired fiber at the head-end.

- ***Visual fault locator*** ***(可视故障定位仪)***

-> 670 nm visible red laser.

-> 1 mW (0 dBm)

-> CW or 2Hz

- ***Optical calibrated light source*** ***（校准光源）***

-> LED, LD

-> 660 nm for plastic fiber

-> 850 and 1300 nm for MM

-> 1310 and 1550 nm for SM

- ***Power Meter*** ***(功率计)***

-> Detectors: Silicon, InGaAs, Germanium,

-> 660-1550 nm

-> NIST (National Institute of Standards and Technology)

-> Absolute accuracy

-> Resolution

- ***Singlemode Variable Attenuator***
  （可变衰减器）

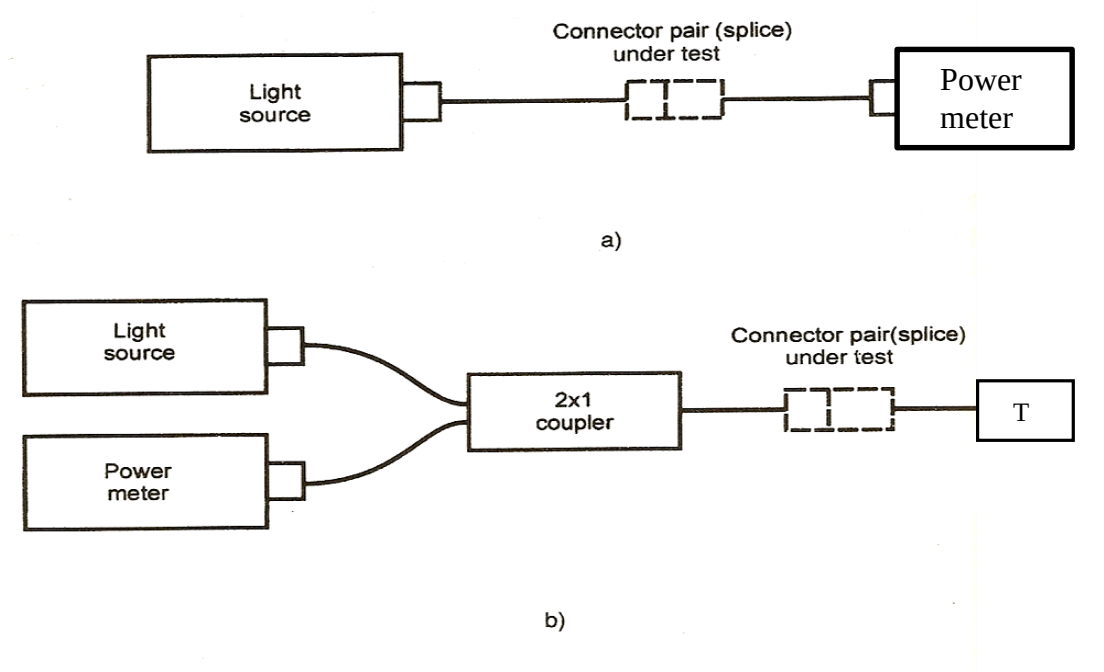
-> 1310 and 1550 nm single-mode
-> 60 dB dynamic range
-> Better than 60 dB isolation available
-> FC, SC, or ST Style Outputs
-> Low insertion loss

- ***Optical Time-Domain Reflectometer***
  （OTDR 光时域反射仪）

-> Optical radar (Send a light pulse down the fiber and measure the time delay)
-> Fault-location
-> Connection loss and reflectance
-> Splice verification

Test & Measurement

- *Bandwidth*
- *Bit-error-rate test (BERT)*
- *Insertion Loss -> (a)*
- *Return Loss -> (b)*



Homework

- 8.22, 8.23

Reference:

1. G. Keiser, Optical Fiber Communications, McGraw Hill, 2000.

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