Optical Fiber Standards and Their Applications

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Agenda

• Optical Fiber at Work
• Major Categories of Optical Fiber
• Major Attributes of Optical Fiber
• International Standards for Optical Fibers
• Bend Insensitive Fiber Standards
Since 1980s, optical fiber cable is slowly replacing copper cable as the mainstream medium of transmission in telecommunication network. From undersea submarine network, terrestrial long-haul, to metro backbone and access network, now we are already beginning to see fibers running in the last mile and even into the subscriber’s home. Fiber-to-the-Home (FTTH) has become an industrial buzzword. This is an umbrella term used for emerging access networks that use optical fiber in the first/last mile.
Major Categories of Optical Fibers

- Singlemode Fiber
- Multimode Fiber
- Specialty Fiber
- Plastic Optical Fiber
Singlemode or Multimode, Any One?

**Single-mode**
- Standard Step-Indexed
- (Match-cladding)
- Depressed Cladding

**Multimode**
- Graded index

**Refractive Index Profile**
- 50 μm
- 62.5 μm

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Types of Optical Fiber

Single-Mode Fiber
It consists of smaller core and only allows one mode (or path) for light to travel

Multimode Fiber
Its bigger core size allows multiple modes (or paths) of light to travel
Attenuation of Fiber

The attenuation is measured in dB/km

Power is measured in dBm = 10 \times \log_{10} \left( \frac{\text{Power output in mW}}{1 \text{mW}} \right)

Loss is measured in dB = \left( \frac{\text{Power output in dBm}}{\text{Power input in dBm}} \right)

Note that 3dB loss means 50% of the power is loss.
Major Attributes of Optical Fiber

• Attenuation

• Dispersion
Attenuation Curve of Optical Fiber (Attenuation versus Wavelength Curve)

Higher attenuation (or water peak) due to OH-
Present in the fiber core

Reduced or zero water peak attenuation for
G.652D and some G.655 fibers

Attenuation (dB/km)
Dispersion is one of the unique characteristics of light wave transmission in glass (e.g., optical fiber, glass prism). This is not seen in electrical transmission in copper cable.

Dispersion refers to broadening of light pulse (in time domain) over time, therefore causing pulse distortion and therefore limiting the transmission speed.
(1) Modal dispersion
- Mainly in multimode fibers

Light wave travels in different paths, thus different distances, and arriving at different times at the receiver, giving rise to modal dispersion.

Graded index in multimode fiber attempts to mitigate this effect.
Dispersion Curve for Optical Fiber

Dispersion (ps/nm.km)

Wavelength (nm)

Components of Chromatic Dispersion
• material dispersion
• wavelength dispersion

More of the different fiber standards later
International Standards for Optical fiber

**ITU-T G.651**
Multimode fiber standard

**ITU-T G.652**
Standard Singlemode fiber. 4 different categories (A, B, C, D) differ in the water peak attenuation around the 1383nm window

Equivalent standards: Telcordia GR-20, IEC 60793-2, TIA/EIA-492CAAB

**ITU-T G.653**
Zero Dispersion Shifted Fiber (ZDSF), having zero dispersion around the 1550nm window

**ITU-T G.654**
Cutoff shifted and low attenuation fiber, designed mainly for submarine applications

**ITU-T G.655**
Non-zero Dispersion Shifted Fiber (NZDSF), having low dispersion in the 1550nm and 1625nm windows, the DWDM region. Suited for longhaul and backbone applications. Categories A, B, C, D, E differ in PMD and dispersion values

**ITU-T G.656**
Medium Dispersion Fiber (MDF), designed for local access and longhaul fiber

**ITU-T G.657**
Latest standard (from 2008 Jan) for FTTH application. Designed to bend at small radius of down to 10mm radius and 7.5mm radius
Bend Insensitive Fiber Standards

- The Need for Bend-Insensitive Fiber
- The Standards for Bend-Insensitive Fibers
- To Bend or Not to Bend, that is the Question
In FTTH, fibre is “home-run” from exchanges all the way to the subscriber premises up to the Termination Point (TP) on the wall of the subscriber’s home.
Sharp bend

Wall-mounted TP box (OpenNet)

Sharp bend

Sharp bend

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• Sharp bends are unavoidable in last mile cable installation in FTTH deployment

• Patch cord connecting TP point to ONT (Optical Network Terminal) also requires ruggedized bend-insensitive capability
Can We Defy Laws of Optics?

\[ \phi_2 > \phi_c \]

Light reflected back into core
Total internal reflection occurs

Light is guided through the fibre by law of total internal reflection

Moderate loss with large diameter bends
Increased loss with tighter bends
• In enterprise network, multimode fiber is becoming more popular in the horizontal cabling in the Fiber-to-the-Zone (FTTZ) architecture

• Bandwidth is shifting from 1Gbps to 10Gbps, therefore shrinking the power loss budget
## Standards for Bend Insensitive Fiber

### Singlemode Fiber Standards

**ITU-T G.657**

**Category A**

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<thead>
<tr>
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<tbody>
<tr>
<td>10mm</td>
<td>0.75 dB/turn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.5 mm</td>
<td>-</td>
<td>0.5 dB/turn</td>
<td></td>
</tr>
<tr>
<td>5 mm</td>
<td>-</td>
<td>-</td>
<td>0.15 dB/turn</td>
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Category A emphasize on backward compatibility with ITU-T G.652.D

Loss specified at 1550nm
## ITU-T G.657

### Category B

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<td>7.5 mm</td>
<td>0.5 dB/turn</td>
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<tr>
<td>5 mm</td>
<td>-</td>
<td>0.15 dB/turn</td>
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Category B need not be backward compatibility with ITU-T G.652.D
Loss specified at 1550nm
Multimode Fiber Standards

<table>
<thead>
<tr>
<th>Bend Radius</th>
<th>IEC 60793-2-10</th>
<th>ITU-T G.651.1</th>
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<tbody>
<tr>
<td>37.5 mm</td>
<td>0.5 dB/100 turn</td>
<td>-</td>
</tr>
<tr>
<td>15 mm</td>
<td>-</td>
<td>1 dB/2 turn</td>
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Loss at 850nm

Currently there is no standard which define tighter bend radius for Multimode fibers

Bend insensitive multimode fiber, achieved by keeping most modes in the core of the fiber, may disturb the mode distribution vital in the high performance MMF such as OM3 and OM4