**Optical Fibers**

**History**:

1966: Kao & Hockham (a Standard Telecomm, UK

- Proposed that optical fibers can be used for
  telecom. If the loss is $< 2$ dB/km


- Developed the fiber with loss $< 2$ dB/km
  - Removed impurities from glass

1977: First optical comm. system was installed in
  Chicago. It carried 672 voice channels over
  15 miles.

1979: Single-mode fibers were made. Fiber loss $= 0.2$
  dB/km

1980s → Efficient semiconductor lasers − Invented

1990s → Optical amp. − Namely, EDFA − Invented

- New era in opt. communication

2009 → Infini rewire in physics − Kao

Today → $96\%$ of world's long distance is
  carried over optical fiber cable

- Data is transmitted over per
  fiber over thousands of km.
  (Millions of voice & video channels)

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**Optical Fiber Structure**:

- Core is surrounded by cladding of slightly lower refractive
  index

- Cladding − Silica

  - Core → Silica + $\text{Ge}_2$ → RI decreases
  slightly
CLADDING — SILICA
CORE — SILICA + GeO₂ — R.I. OCCURS
SLIGHTLY HIGHER

n₁ = 1.46, n₂ = 1.45
CLADDING DIAMETER = 125 mm ~ SIZE OF HUMAN

ADVANTAGES OF FIBER OVER COPPER CABLE:

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<th>FIBER</th>
<th>COPPER CABLE</th>
<th>CABLE</th>
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<tr>
<td>(i) BANDWIDTH ➔ SEVERAL THZ</td>
<td>(i) BANDWIDTH ➔ MILLI THZ</td>
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<td>(ii) ATTENUATION ➔ NO. DEC/EM</td>
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<td>(iii) EMI &amp; ELECTROMAGNETIC INTERFERENCE</td>
<td>(iii) EMI NOISE FIELD SETS UP CONDUCTION CURRENT LEADING TO SIGNAL DISTORTION</td>
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EM NOISE FIELD SETS UP CONDUCTION CURRENT LEADING TO SIGNAL DISTORTION

OPTICAL FIBERS ARE USED IN ELECTRIC POWER SYSTEMS BECAUSE THEY ARE IMMUNE TO EMI.

HIGH ELECTRIC FIELD = KU or MV

BASIC OPTICAL REVIEW

REFLECTION:
CAN OF REFLECTION:
\[ \theta_i = \theta_f \]

Maxwell's Eq. can be used to prove:

Fermat's Principle: There are many possible paths for light to go from A to B after passing through the mirror. Out of these infinite paths, light chooses a path for which the transit time is minimum.

In free space, the distance traversed by light wave
\[ z = c t \quad \text{Time of Flight} \]

Shortest path = shortest time

\[ O' - \text{image of} \quad O \quad \Rightarrow \quad OM' = O'M' \]
\[ CO = CA' \]
\[ CO = CA' \quad \text{and so on} \]
\[ AC_1B = AC_1B' \quad \text{and} \quad AC_O = AB' \]

Suppose \( AC'O \) is a straight line. \( \Rightarrow \) \( AC_1B \) is the shortest path.

According to Fermat, light chooses \( AC'O \).

\[ \angle A = \angle A' \]
\[ \theta_i + \theta_f + 2\alpha = 180^\circ \]
\[ \theta_f + \alpha = 90^\circ \]
\[ \alpha = 90^\circ - \theta_f \]

\[ \theta_i + \theta_f + 2(90^\circ - \theta_f) = 180^\circ \]
\[ \theta_f + \theta_f + 180^\circ - 2\theta_f = 180^\circ \]
\[ \theta_i = \theta_f \]