SMA 905 fiber connectors: multimode

SMA MAIN BODY
SMA style connectors are most commonly used with multimode fibers. The ferrule design on the SMA connector makes it an ideal choice for large core fibers. Thorlabs stocks a complete selection of SMA connector sizes to accommodate our full line of large core fibers: see pages 418-425.

ST® fiber connector: single mode, ceramic

This ST® style single mode connector features a ceramic ferrule with a pre-radiused tip (R20mm) to minimize back reflections. Packaged with a strain relief boot for Ø3mm tubing.

ST® fiber connectors: multimode

These ST® style connectors are designed for multimode applications. The stainless ferrule connectors can be customized to accept fiber diameters up to Ø1mm.

FC fiber connector: single mode ceramic

This FC style single mode connector features a pre-radiused (R20mm) ceramic ferrule; the pre-radiused tip minimizes back reflections. Packaged with a strain relief boot for Ø3mm tubing.

FC fiber connector: multimode

This FC style connector is designed for multimode applications.
FC fiber connector: adjustable key/pm fibers

These FC style connectors are designed for Polarization Maintaining (PM) Fiber. The key is continuously adjustable, allowing precise alignment with the axis of the PM fiber.

(NO CRIMP TOOL REQUIRED)

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<tr>
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<td>FC Connector, Rotatable Key 900µm Boot</td>
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LC fiber connector

The LC connector was developed to meet the need for small and easier to use fiber optic connectors. The LC connector reduces space required on panels by 50%.

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LC is a registered trademark of Lucent Technology

SC fiber connectors: single mode & multimode

These SC style connectors feature a pre-radiused (R20mm) ceramic ferrule; the pre-radiused tip minimizes back reflections.

(CRIMP TOOL REQUIRED, SEE BELOW)

<table>
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FC/APC angle connector

The FC/APC connector has an 8° pre-angled ceramic ferrule that simplifies the production of angled polishes. This connector has a low 0.25dB connector-to-connector loss. The angled finish will typically result in a <0.1dB return loss.

(CRIMP TOOL REQUIRED, SEE BELOW)

<table>
<thead>
<tr>
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<td>€0.48</td>
<td>¥65</td>
<td>900µm Strain Relief Boot</td>
<td></td>
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Connector crimp tool

One tool for crimps on SMA, FC, SC and ST connectors. Sold as a single unit.

<table>
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<th>€</th>
<th>¥</th>
<th>USE</th>
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<td>£80.99</td>
<td>€113.03</td>
<td>¥15,150</td>
<td>Crimp Tool Handle with Crimp Die</td>
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Source to Fiber Coupling: \[ N_c = \frac{P_t}{P_s} \text{ - power into fiber} \]

1. Factors affecting loss: a) Uninterrupted illumination loss
   b) NA loss

2. Characterization of radiant patterns from LEDs and LDs
   a) Lambertian source: \[ I = I_0 \cos \theta \]
   \[ \theta = 0^\circ \]
   \[ I = \frac{dI}{d\Omega} \text{ - power over solid angle} \]

   b) Edge Emitting LED or LD: \[ I = I_e \cos^2 \theta \]

   Beam Profiles:
   1. LED: \( \pm 60^\circ \times 530^\circ \)
   2. LD: \( \pm 5^\circ \times 525^\circ \)

   Fundamental emission property of a source is its Radiance

   Radiance (Brightness): \[ L(\theta) = \frac{d^2 I(\theta)}{d\omega \, dA \, \cos \theta} \]

   Power per Increment of Solid Angle per Projected Area (measured in Source): Brightness Theorem:
   - The Radiance of an Image on the Fiber Core Cannot Exceed That of the Source.
   - Focusing from a Large Area Source to a Smaller Fiber Does Not Help.

   We integrate the radiance to determine the amount of power collected by a fiber from a source.
**FIGURE 5-2**
Radiance patterns for a lambertian source and the lateral output of a highly directional laser diode. Both sources have $B_0$ normalized to unity.

**FIGURE 5-3**
Schematic diagram of an optical source coupled to an optical fiber. Light outside the acceptance angle is lost.
For a general source (Lambertian or non-Lambertian)

\[
P_{\text{collected}} = \int_{A_s} \int_{w_r} \frac{L(A_s, w_r)}{4\pi} \, dA_s \, dw_r
\]

(integrate collection region of fiber over area of source)

For any small source area (pt source approximation)

Assume Lambertian source - Power delivered from the source

\[
I = L \theta \cos \theta = I_0 \cos \theta \quad \text{where} \quad I = \frac{dI}{d\Omega}
\]

Alternatively, \( L = L_0 \cos \theta \)

\[
\text{Power collected by fiber within area of the ring}
\]

\[
dA_F = 2\pi (r \sin \theta) r \, d\theta
\]

\[
dW_{\text{collected}} = \frac{dA_F}{r^2} = \frac{2\pi \sin \theta \, d\theta}{r^2}
\]

For increment of source area \( dA_s \) with Lambertian source \( L \theta \cos \theta \)

\[
dP_{\text{collected}} = dA_s \, L_0 \int_0^{\theta_{\text{max}}} 2\pi \sin \theta \cos \theta \, d\theta
\]

Note: \( \int_0^{\theta_{\text{max}}} \sin^2 \theta = \frac{1}{2} \sin^2 \theta \bigg|_0^{\theta_{\text{max}}} \)

\[
\theta_{\text{max}} = \frac{\pi}{2} \quad \text{for a hemisphere i.e. total power}
\]

\[
dP = dA_s \, \pi \, L_0
\]

\[
\text{TOTAL power emitted from source element } dA_s
\]
Total Power From Source:

Obtained After Integration:

\[ P_s = \frac{\pi}{2} \rho_s^2 \frac{\pi L_o}{d} = \frac{\pi^2 \rho_s^2 L_o}{d} \]

For a fiber with \( NA = \sin \theta_{\text{max}} \) \( d \rho = dA_s \frac{\pi L_o NA^2}{d} \)

\( \theta_{\text{max}} \): Max acceptance angle

For source with \( \rho_s \) \( \pi \rho_s^2 \)

- If \( r_s < \rho_s \) (smaller than fiber radius), \( P_{\text{Fiber}} = \frac{\pi^2 \rho_s^2 L_o NA^2}{d} \)

- If \( r_s > \rho_s \) (larger than fiber radius), \( P_{\text{Fiber}} = \frac{\pi^2 \rho_s^2 L_o NA^2}{d} \left( \frac{r_s}{\rho_s} \right)^2 = \frac{\pi^2 \rho_s^2 L_o NA^2}{d} \)}
Example:
\[ V_c = 35 \text{ cm} \]

LED Source Power \( = 150 \text{ W/}m^2 \cdot \text{sr} = A \times 111 \text{ Radiance} \ (L_0) \)

Can detect (1) \( a_1 = 50 \mu \text{m} \) with \( NA = 0, 20 \) \{ source radius \( > \) fiber core radius \}

(2) \( a_2 = 25 \mu \text{m} \)

\[ P_1 = P_{src} (NA)^2 = \bar{u}^2 r_1^2 L_0 (NA)^2 = 0.725 \text{ mW} \]
\[ P_2 = \left( \frac{a_2}{r_1} \right)^2 P_1 (NA)^2 = \left( \frac{25}{50} \right)^2 P_1 (NA)^2 = 0.37 \text{ mW} \]

**Graded Index Fiber:** \( V_2 < a \)

\[ P_0 = 2 \pi^2 L_0 \int_0^{r_2} [(m^2(r) - m_2^2)^2] r \, dr \]

Index Profile: \( m(r) = m_1 \left[ 1 - 2 \Delta \left( \frac{r}{a_1} \right)^2 \right]^{1/2} \quad r < a \)

\[ m_2 = m_1 [1 - 2 \Delta]^{1/2} \quad r > a \]

\[ \theta_c = \sin^{-1} \left( \frac{1 - \left( \frac{m_2}{m_1} \right)^2}{r_2^2} \right) \quad \text{critical angle varies over the profile} \]

\[ P_0 = \frac{2}{\pi} \left( \frac{a_2^2 r_2^2 L_0}{2} m_1^2 \Delta \left[ 1 - 2 \frac{r_2}{a_1^2} \left( \frac{r_2}{a_2} \right)^2 \right] \right) \]

Note:
\[ NA(r) = \begin{cases} 
(m^2(r) - m_2^2)^{1/2} & r \leq a \\
0 & r > a
\end{cases} \]

With the Axial Numerical Aperture
\[ NA_0 = \left[ m_1^2 - m_2^2 \right]^{1/2} = \left( m_1^2 - m_2^2 \right)^{1/2} \sim m_1 \sqrt{\Delta} \]

\[ \Delta = \frac{m_1 - m_2}{m_1} \]
\[ \Delta = \frac{m_1^2 - m_2^2}{2m_1^2} \]
Graded Index Fiber

Fiber Collecting Angle

\[ \Theta_c(r) = \sin^{-1}\left\{ 1 - \left( \frac{m_r^2}{m_0^2} \right)^{\frac{1}{2}} \right\} \]

where \( m_r = m_1 \left[ 1 - 2\Delta\left( \frac{r}{a} \right)^{\alpha} \right]^{\frac{1}{2}} \)

For Graded Index

\[ m_r = m_2 \]

where \( m_2 = m_1 \left[ 1 - 2\Delta \right]^{\frac{1}{2}} \)

\[ NA(r) = \left[ m_r^2 - m_2^2 \right]^{\frac{1}{2}} = \frac{NA(0)}{\sqrt{1 - \left( \frac{r}{a} \right)^{2\alpha}}} \quad j \quad r < a \]

\[ = 0 \quad j \quad r > a \]

with \( NA(0) = \left[ m_0^2 (0) - m_2^2 \right]^{\frac{1}{2}} = \left[ m_0^2 \right]^{\frac{1}{2}} = m_0 \sqrt{\Delta} \)

with \( \Delta = \frac{m_0^2 - m_2^2}{m_1^2} \)

Substitute into Collecting Power Relation

\[ P_c = 2 \pi \int_0^a \left[ m_r^2 - m_2^2 \right] r \, dr \quad \text{with} \quad r < a \]

Using \( m(r) \) from above

\[ P_c = 2 \left[ \pi \int_0^a \left[ 1 - \frac{2}{\alpha+2} \left( \frac{r}{a} \right)^{\alpha} \right] \right] m_r^2 \Delta \left[ 1 - \frac{2}{\alpha+2} \left( \frac{r}{a} \right)^{\alpha} \right] \]

\[ \text{Source Power} \left( P_s \right) \]

\[ P_c = 2 P_s m_r^2 \Delta \left[ 1 - \frac{2}{\alpha+2} \left( \frac{r}{a} \right)^{\alpha} \right] \quad \text{Power Coupled to the Graded Index Fiber} \]

For \( \alpha = 2 \)

\[ P_c = P_s m_r^2 \Delta \left[ 1 - \frac{1}{2} \left( \frac{r}{a} \right)^2 \right] \]