Fibre Optic Excellence from KRONE

Fibre Optic Components

Fibre optic components

So-called passive optical components are necessary for flexible handling of optical fibres and for sensible transmission configurations. They permit the setting up of complex system structures, so that all the possibilities for FO transmission can be fully utilised.

FO connectors

The FO connector is one of the most important components for non-permanent connections. This component must meet with highest demands concerning positioning precision and manufacturing tolerances.

Several different connector systems are available today, which have been designed for different requirement profiles and different applications.

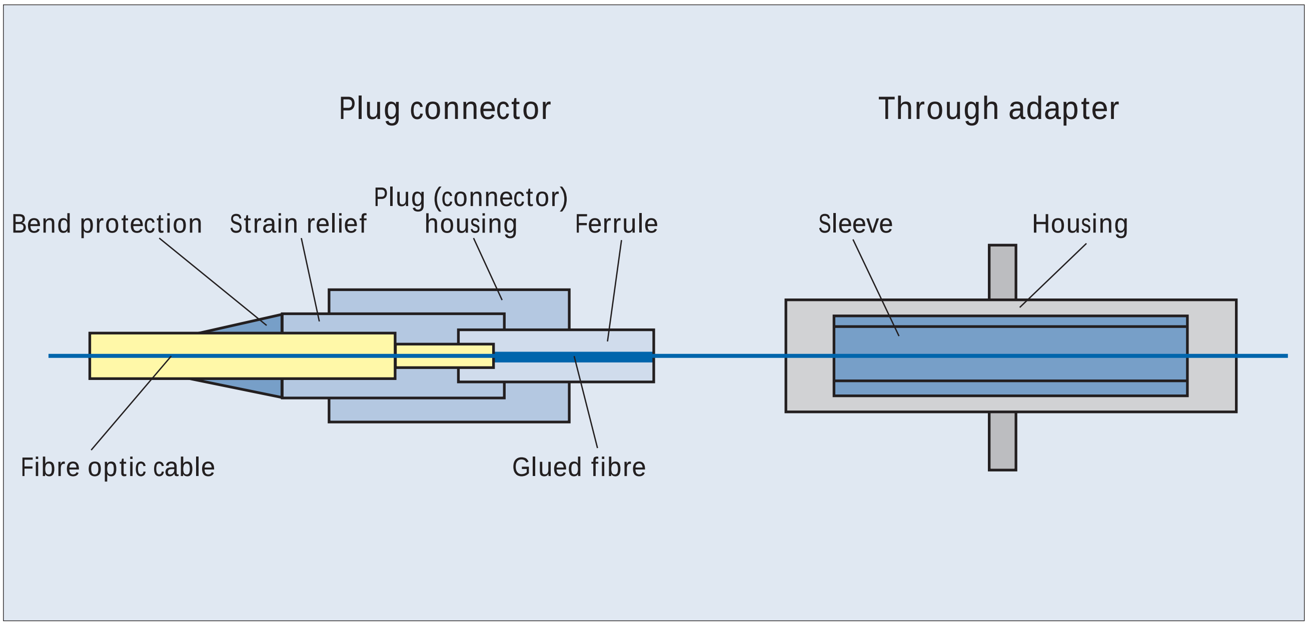
Principle of operation

An FO plug connection must ensure that two optical fibres must be aligned, in relation to each other, in a precise and reproducible manner. Most connector types are today based on the **pin-and-sleeve principle** which means that two pins (=connectors) are joined together in a sleeve (=through-adapter).

The optical fibre ends to be joined together are cemented into cylindrical pins, the so-called ferrules. The sleeve of the through-adapter ensures precise guidance of the ferrules, so that light can be transmitted between the two optical fibre cores.

The small fibre core diameters (9, 50, 62.5µm) place high demands on the tolerances of the pins and sleeves used.

The pin bore must correspond exactly to the outer diameter of the optical fibre (125µm), and must be located in the centre of the pin. The resultant eccentricity tolerances range from 0.7mµ for single-mode and 1.5µm for multi-mode optical fibres. Moreover, the outer contour of the pin should not deviate more than 1µm from the shape of an ideal cylinder. The sleeve in the through-adapter is manufactured with corresponding precision. Modern sleeves have a longitudinal slot and are pre-stressed. Pins and sleeves which must satisfy demanding network requirements are preferably made of industrial ceramic material (zirconium), whilst plastic materials or metals can be used for in-house cabling systems.



FO plug connection based on the pin-and-sleeve principle

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Insertion and return loss

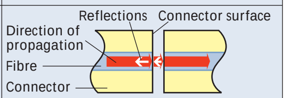
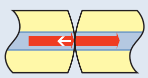
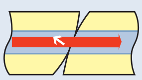
The quality of a plug connection is substantially determined by its insertion and return losses.

A plug connection is always a disruption of the signal path because coupling losses may result from emission, absorption and reflection. Losses can be caused by a number of factors, including different core diameters and refractive indices of fibres, external influences, such as air gaps between the fibres, staining of the face contact areas or imprecise alignment of the fibres in relation to each other. The quality of optical fibres has improved considerably in recent years, so that losses are today mostly due to mechanical tolerances of plug connections and the surface quality of contact areas.

- **Insertion loss**
  The insertion loss is a measure of the losses at the point of connection. It is calculated from the ratio of the light output in the fibre cores before and behind the connection. A small value means low losses, with typical values ranging between 0.1 and 0.5dB. One of the main reasons for increased insertion losses is eccentricity of the fibre core in relation to the outer diameter of the pin. In the case of a single-mode fibre with a core diameter of 10µm, an eccentricity of the fibre cores of 2µm already causes an insertion loss of 0.7dB. Different methods can be adopted for connectors for single-mode fibres in order to either directly minimise the eccentricity or reduce its influence on the insertion loss as far as possible.

- **Return loss**
  The return loss is a measure for that portion of the light which is reflected towards the light source at the point of connection. This value is expressed in dB. The higher the value, the weaker the reflections. Under certain conditions - particularly with analogue transmissions - these reflections can interfere with the laser light source and thus have to be reduced to the smallest amount possible.

Surface types

Polishing type	Return loss	Principle
Flat face with air gap between faces	14dB	
Convex polished end faces with direct contact		
PC (Physical Contact)	> 27dB	
SPC (Super Physical Contact)	> 40dB	
Angle polished with convex faces		
APC (Angle Physical Contact)	> 60dB	

Losses and reflections which occur in the plug connector are strongly dependent upon shape and surface quality of the face of the connector pins. There are generally 3 different types of face shapes for plug connectors based on the pin-and-sleeve principle:

- flat face
- convex face (physical contact - PC)
- angle physical contact (APC).

Flat face

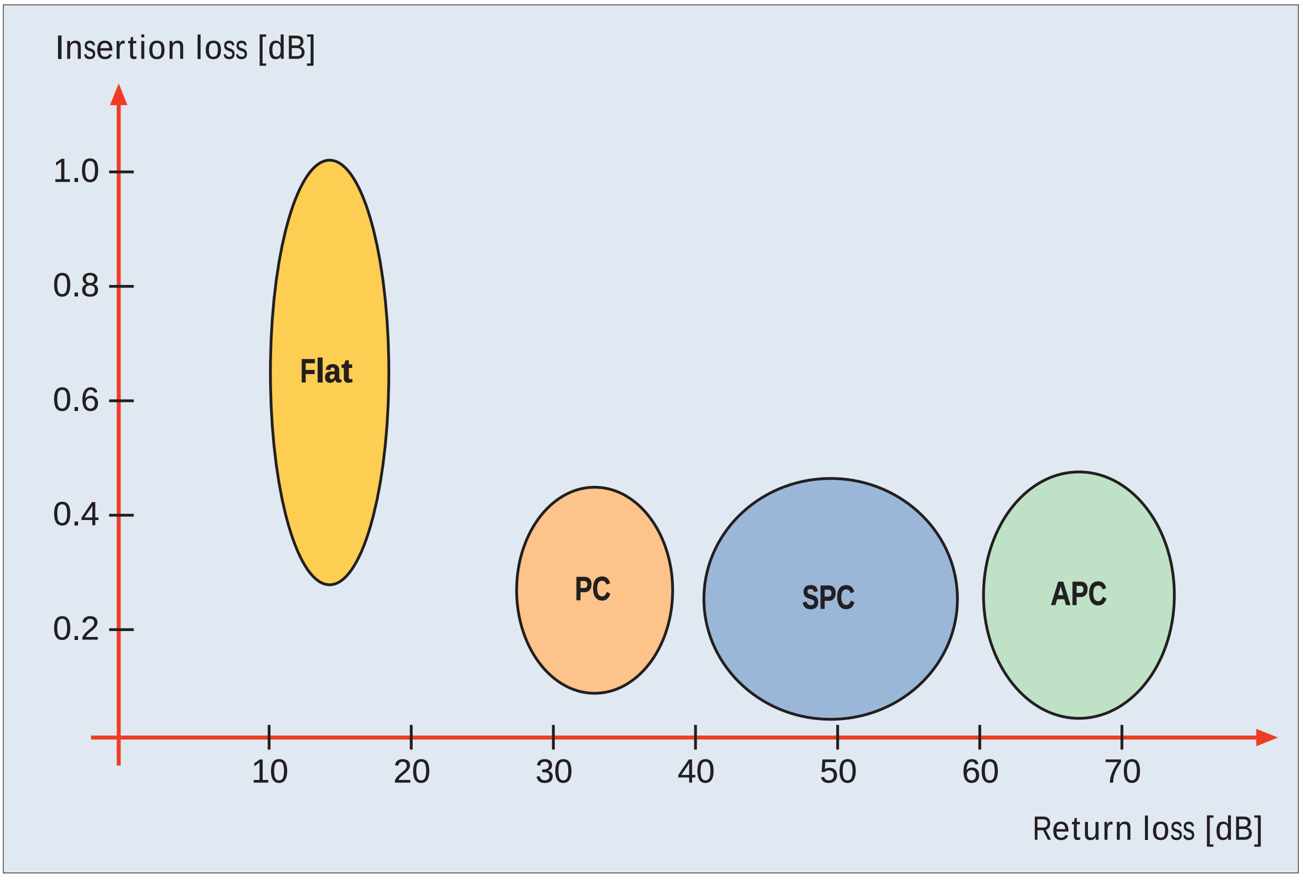
Until recently, end faces were flat and had no contact when the connection was closed. The light had to bridge the air gap in order to enter the other optical fibre. The transition from glass to air and vice versa causes approx. 4% reflections, corresponding to a reflection loss of around 14.6dB. Typical insertion loss values in plug connections with an air gap are in the order of 1dB. This is why this surface shape is hardly used now.

Physical contact

The convex shape of the faces with a physical contact (PC) ensures that no air remains between the fibre ends, so that reflections are substantially reduced. When the connection is closed, the faces of the connector pins are pressed against each other, so that the opposing fibre ends physically contact (PC). The reflections then primarily depend upon the surface quality of the fibres which come in three different grades, i.e. standard PC (PC), super PC (SPC) and ultra PC (UPC). Ultra PC versions permit reflection loss values of up to 55dB. The disadvantage of the PC face is that reflections increase strongly in the unplugged condition, because this means that there is again a transition between glass and air. The PC system is today quite common for multi-mode applications because the reflection requirements are less pronounced in this case as they are in multi-mode applications where at least the SPC type is preferred.

Angle physical contact (APC)

Return losses can be further improved by the angle physical contact configuration. The convex faces of the connector pin are slanted in relation to the fibre axis (usually at an angle of 8°). Reflections are then directed off the fibre core, no matter whether a connection has been established (transition from glass to glass) or whether the connection is unplugged (transition from glass to air).



Insertion and return loss as a function of the connector face area

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Overview of plug connector systems

As already mentioned, a large number of connectors are available today to meet the most varied demands in terms of application, handling and type of optical fibre.

Connectors preferably used for single-mode fibres:
(Multi-mode fibres are exclusively connected using the physical-contact (PC) version).

Single-mode connectors	SC	FC	DIN	E2000
typical application: **Telecom Companies** **LANs** **Measurement** **Cable TV**	 yes yes yes yes	 yes – yes yes	 yes – yes yes	 yes yes – yes
Locking mechanism	Push-Pull	Thread	Thread or Push-Pull	Push-Pull
Fibre/cable type	0.9mm lead, 3mm cable, 3mm duplex cable			
Tensile strength	100N (cable version)			
Connector: Shell **Ferrule** **Surface**	Plastic Ceramic PC, SPC, APC	Brass, stainless steel Ceramic PC, SPC, APC	Nickel silver Ceramic SPC, APC	Plastic Ceramic SPC, APC
Through-adapter: Shell **Sleeve** **Fixing**	Plastic Ceramic Screws with M2 thread or snap-in . connection	Brass Ceramic Square-flange version: Screws with M2 thread Round-flange version: Union nut	Nickel silver Ceramic 2 nuts	Plastic Ceramic Screws with M2 thread or snap-in connection
Colour code	PC, SPC: blue APC: green	APC: green bend protection	APC: green bend protection	SPC: blue APC: green
Life	up to 1000 connections			
Operating temperature	–25 to +70º C (depending on the type of cable)			
Insertion loss	< 0.5dB.			
Return loss[1]: **PC surface** **SPC surface** **APC surface**	 > 27dB > 40dB > 60dB	 > 27dB > 40dB > 60dB	 – > 40dB > 60dB	 – > 40dB > 60dB
Standards	IEC874-14 CECC 86260	IEC 874-7 CECC 86115-801	DIN 47256 CECC 86135-801 FTZ TL 6060-3001, parts 1 to 7	CECC 86275-801 and -802 FTZ TL 6060-3015

[1] Not applicable with multi-mode fibres

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Typical single-mode connectors with PC and APC surfaces

Typical multi-mode connectors

Connectors preferably or exclusively used for multi-mode fibres:

Multi-mode connectors	ST	SC-MM	Duplex-SC	FDDI
Typical application: **Telecom companies** **LANs** **Measurement** **Cable TV**	 – yes – –	 – yes – –	 – yes – –	 – yes – –
Locking mechanism	Bayonet	Push-pull	Push-pull	Push-pull
Fibre/cable type	0.9mm lead, 3mm cable, 3mm duplex cable		3mm duplex cable	4mm duplex cable (62.5µm)
Tensile strength	100N (cable version)			
Connector: Shell **Ferrule** **Surface**	Zinc diecast Ceramic, Polymer PC	Plastic Ceramic, Polymer PC	Plastic Ceramic, Polymer PC	Plastic Ceramic PC
Through-adapter: Shell **Sleeve** **Fixing**	Zinc diecast Ceramic, Phosphor bronze, Polymer Nut	Plastic Ceramic, Phosphor bronze, Polymer Screws with M2 thread or snap-in connection	Plastic Ceramic, Phosphor bronze, Polymer Screws with M2 thread or snap-in connection	Plastic Ceramic Snap-in connection
Colour code	–	blue, beige	blue, beige	black, beige
Life	up to 500 connections			
Operating temperature	–20 to +70ºC (depending on cable type)			
Insertion loss	< 0.5dB			
Standards	IEC874-10 CECC BFOC/2.5	EN 50173 ANSI/TIA/EIA-568-A		ISO/IEC 9314-3 ANSI X3.166

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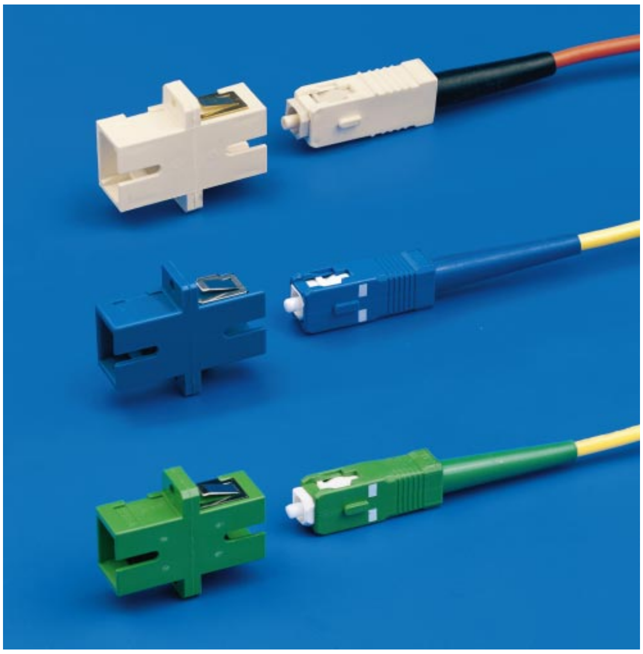
SC plug connectors



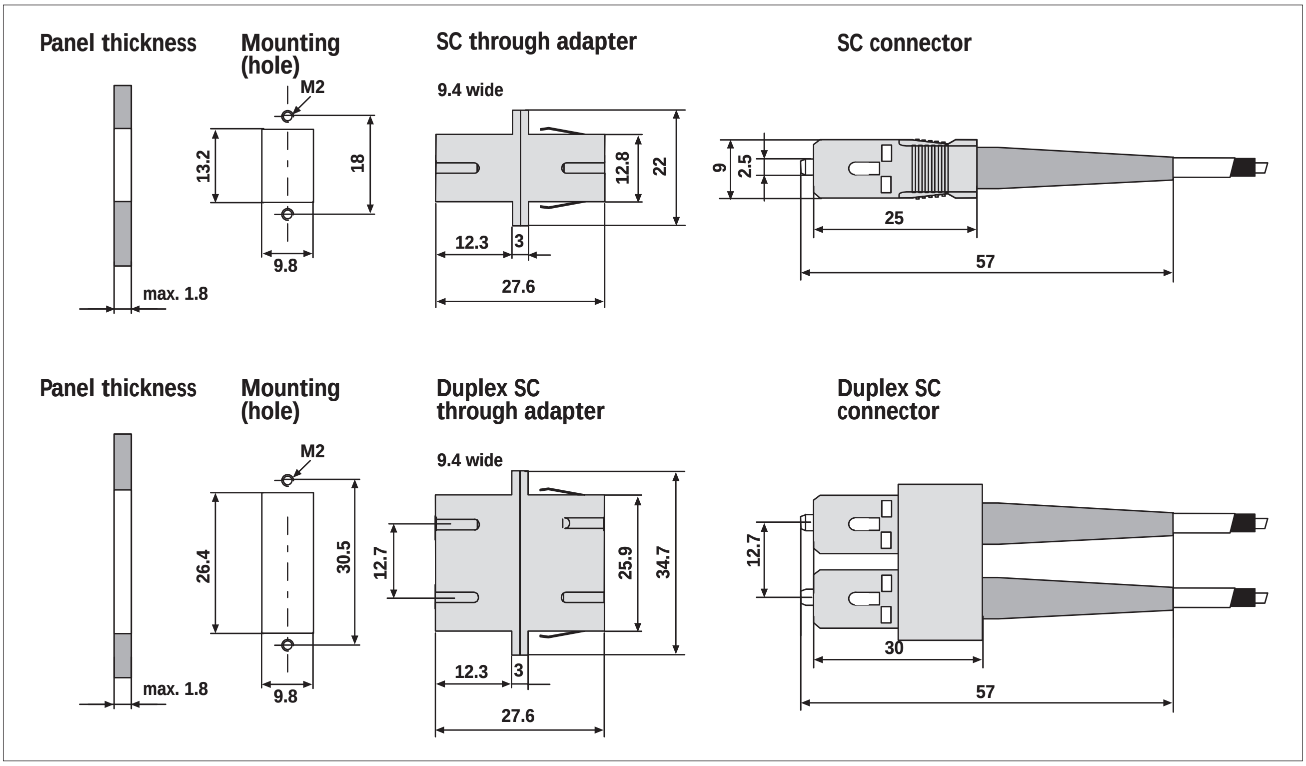
The SC plug connector was developed by Nippon Telephone and Telegraph (NTT). Originally designed as a subscriber connector (SC), it is today increasingly used world-wide in the Telekom and LAN areas, for measuring applications and in cable TV networks.

SC connectors are primarily used for single-mode fibres. The PC and SPC surface versions have a blue shell, whilst a green shell represents the APC type.

Connectors for multi-mode fibres come with a beige or blue shell. These versions can also be designed as duplex plug connectors.

The connector comes with a push-pull mechanism which permits a high connection density and easy handling.

The through-adapter can be installed in the enclosure wall using 2 screws with an M2 thread or directly by means of a snap-in clamp.



SC plug connector

Fibre Optic Components

FC plug connectors

The fibre connector (FC) was developed by Nippon Telephone and Telegraph (NTT) for fibre optic networks. It is world-wide the most frequently used fibre optic plug connector for Telecom applications.

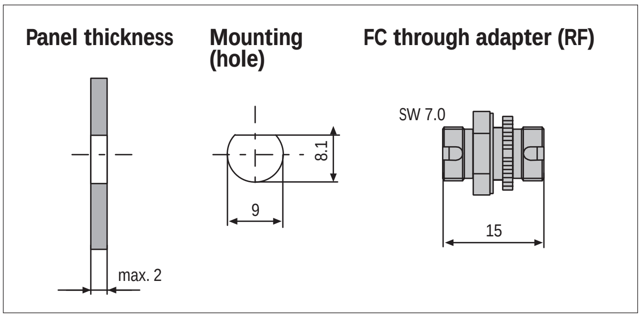
FC connectors are primarily used for single-mode fibres. The APC surface version comes with a green bend protection sleeve.

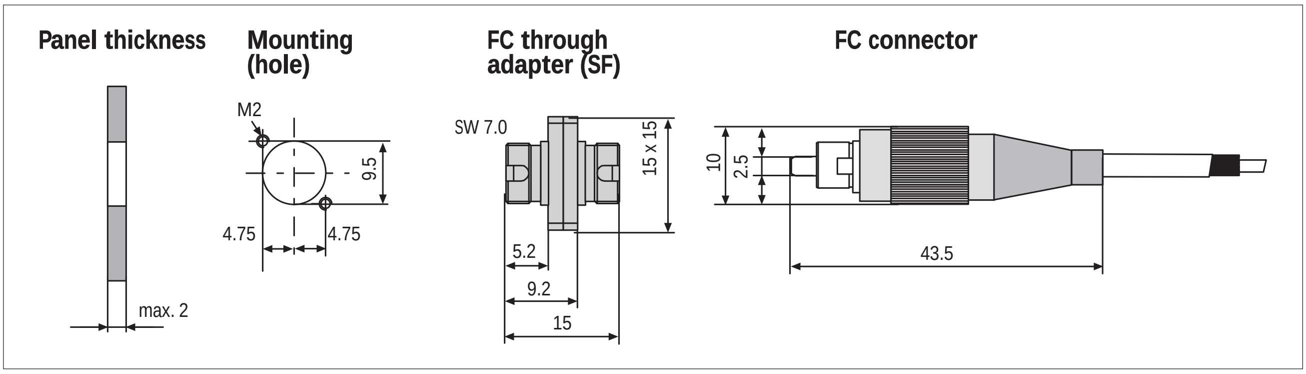
The coupler is locked by a screw and a union nut.

The through-adapter is available in two versions:

- The square-flange (SF) version is fixed by 2 screws with an M2 thread.
- The round-flange (RF) version is secured by a nut in a hole for convenient installation in distribution panels.

FC plug connector



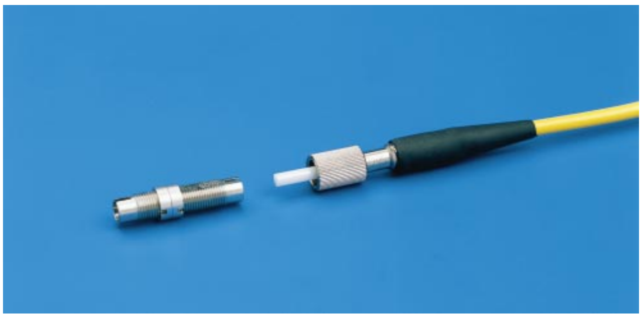


FC plug connector

DIN plug connectors

DIN plug connectors are almost exclusively used in Germany and in networks from Deutsche Telekom AG. These connectors are available as hand plugs and as special device plugs for use in plug-in systems. As Deutsche Telekom AG is increasingly using SC-type connectors, the importance of DIN connectors will reduce in the future.

Nonetheless, this plug connector does have its advantages thanks to its screw locking mechanism, its small overall dimensions and its high quality.

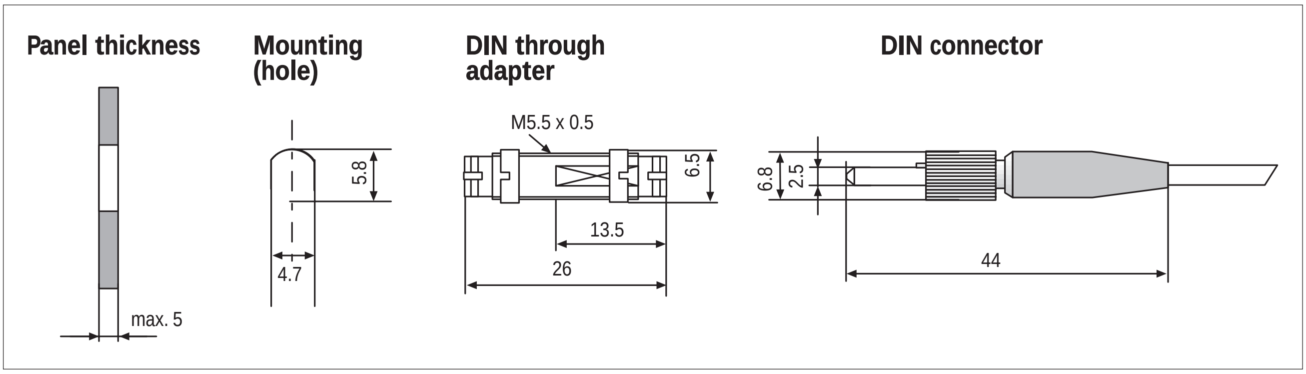


DIN plug connector

Fibre Optic Components

DIN plug connectors are primarily used for SPC and APC-type single-mode fibres. The APC version comes with a green bend protection.

The connector is secured on the through adapter by a screw and a union nut. The through adapter is suitable for both SPC and APC connectors. It is secured on the enclosure wall by two nuts.



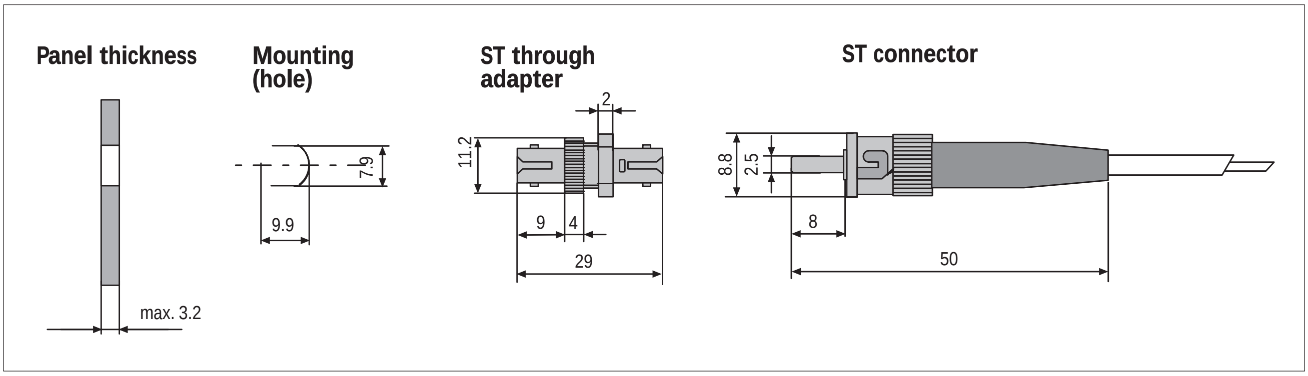
DIN plug connector

ST plug connectors

The straight tail (ST) connector was developed by AT&T. It is the type most frequently used in LANs, and is internationally standardised as a multi-mode connector. In the USA, however, the Bell Operating Companies also use it as an SM connector.

A bayonet mechanism secures the connector on the through adapter.

The through adapter is fixed in a hole by a nut.



ST plug connector

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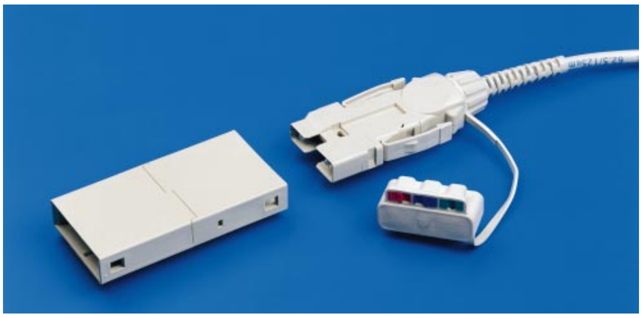
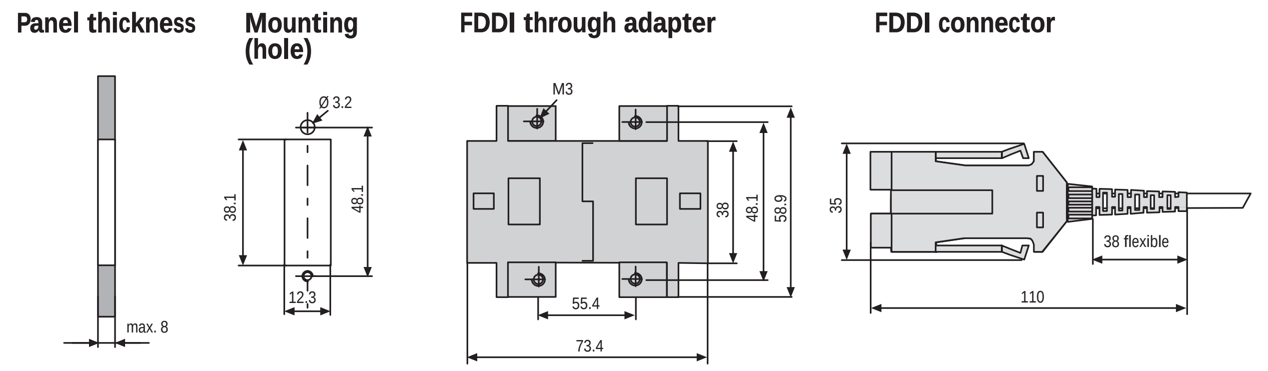
FDDI plug connectors

The FDDI (Fibre Distributed Data Interface) is a dual token ring standardised by the US standards institute ANSI. A 62.5/125µm graded-index fibre is specified as the transmission medium, permitting a maximum range of 2km between ring stations at a data rate of 100Mbit/s in conjunction with 1310nm LEDs.

The duplex-type media interface connector (MIC) connects neighbouring FDDI stations.



FDDI-MIC plug connector



FDDI-MIC plug connector

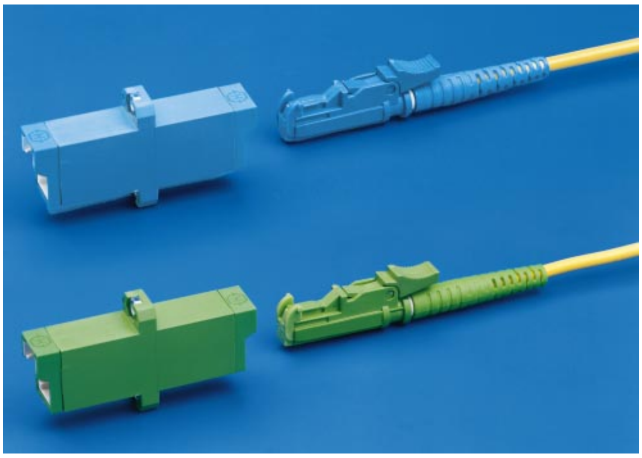
E2000 plug connectors

The E2000 plug connector was developed by the company Diamond. Its special features include integrated dust covers and/or laser protection covers, as well as mechanical and colour coding possibilities for connectors and through-adapters.

Thanks to the push-pull locking system, the connection density is as high as that of SC connectors.

E2000 plug connectors are primarily used for single-mode fibres. The SPC surface type comes with a blue, the APC version with a green shell.

The through-adapter can be installed in the enclosure wall using 2 screws with an M2 thread or directly by means of a snap-in clamp.



E2000 plug connector

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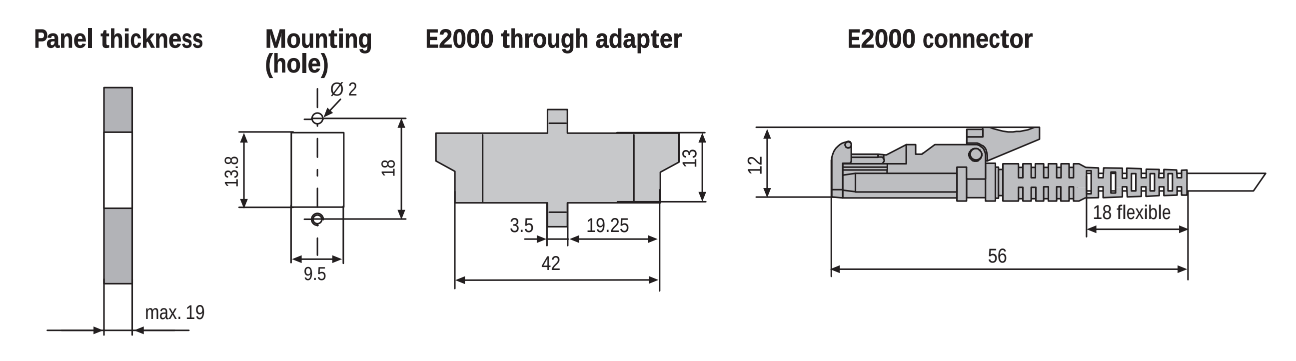
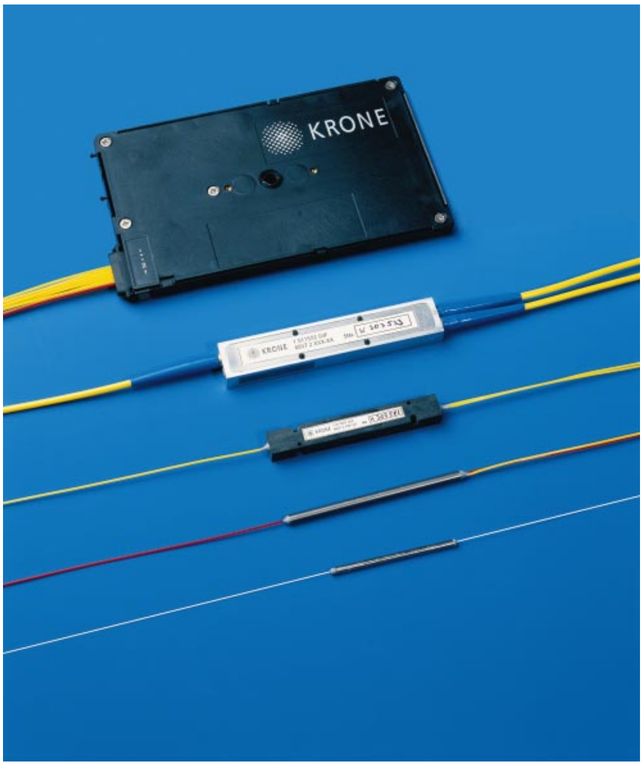


E2000 plug connector

FO couplers



Coupler modules and couplers in different sizes

FO couplers are used to distribute and merge optical signals.

FO couplers serve as passive distribution and collection points for optical information (telephone, cable TV, etc.) transmitted through public and private fibre optic networks. Further applications for FO couplers include measuring systems, measuring instruments and sensor equipment.

Since 1993, KRONE has been producing fused FO couplers for single-mode fibres in Berlin. Participation in the OPAL projects of Deutsche Telekom AG in 1993 and 1994 has made KRONE Europe's largest manufacturer of fused couplers.

KRONE couplers feature the following characteristics:

- low insertion and excess losses, i.e. extremely low losses in FO networks
- high return loss, i.e. no interference due to reflection affecting the transmitters in analogue systems
- narrow-band or broad-band spectral behaviour
- high thermal and mechanical stability
- any coupling ratio can be implemented (1/99 ... 50/50%)
- the optimum solution for any application in terms of optical and mechanical properties
- manufacturing according to customer specifications is possible.

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Technology

KRONE couplers are manufactured by the so-called FBT (fused biconical taper) process which generates coupling zones by simultaneous fusing and drawing/tapering of optical fibres.

The base material is a single-mode fibre with a protective plastic coating (primary coating, 250µm). A simple coupler with two inputs and two outputs is produced by first removing a short length of this primary coating in the middle of two optical fibres. These points are thoroughly cleaned, aligned parallel and secured in place. Due to the subsequent fusing and drawing process, light can pass from the core of one fibre into the core of the other. This means that the two fibres constitute a pure glass connection without any interruption by cement or filters, for example.

The fusing and drawing process is controlled by sophisticated measuring equipment which synchronously monitors the drawing process which can be stopped at any point, so that the degree of transmission of the input power into the second fibre and hence the coupling ratio can be controlled. An even distribution of the optical power to the outputs with the lowest losses possible is normally required. Couplers of this type are called symmetrical because 50% of the input power is available at each output of a 1x2 coupler.

Certain applications, however, may require a different, asymmetrical pattern. It is, for instance, possible in measuring systems to tap 5% of the power in order to set up a control loop for the optical transmitter. This can also be achieved with a fused coupler by stopping its drawing process when the desired 5/95% coupling ratio has been reached.

Following the drawing process, the coupler is fixed on a quartz substrate by means of special cement, inserted into an invar tube and then once again fixed by means of an elastomer which also serves as a strain relief for the fibres.

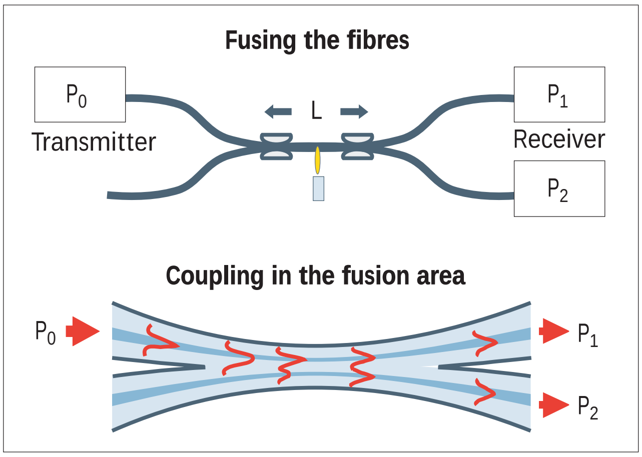
After sealing, the coupler has two input and two output fibres (= 2x2 coupler). The reflection-free termination of the second input fibre results in a coupler with a 1x2 configuration.

The FTB process can also be used to produce attenuation modules, wavelength multiplexers and the KRONOLITH coupler with an nx3 or nx4 configuration obtained by fusing three or four fibres.

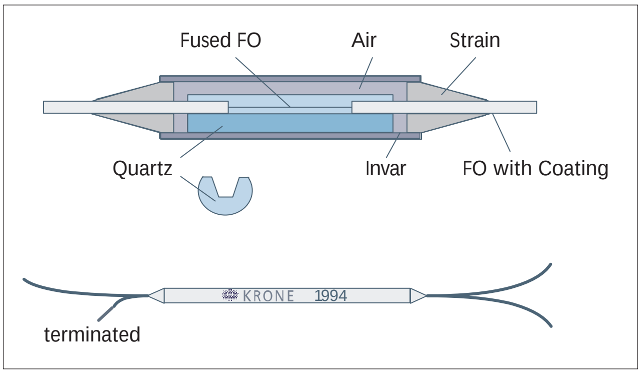
Each coupler is identified by its serial number, so that manufacturing parameters, workplace and material of each coupler can be traced back at any time. Each component is subjected to a burn-in test and a temperature shock test in order to ensure its long-time stability.

The mechanical and climatic requirements of the following standards and specifications are met:
- EN 81000 (corresponds to CECC 81000)
- TL 6060-3006 (Deutsche Telekom AG)
- Bellcore TR-NWT-001209

Test reports can be supplied on request.



Production and operating principles: fusing the fibres (top) and coupling in the fusion area (bottom).

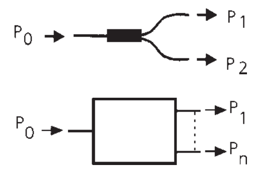
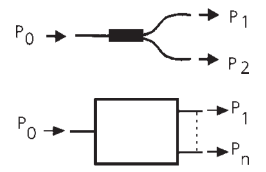
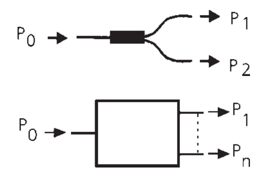
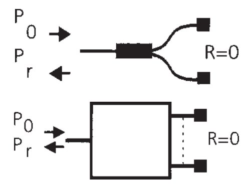
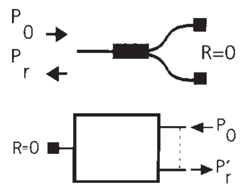
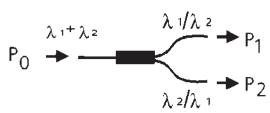


Schematic structure of a fused coupler

KRONE

Characteristic values

Definition of the characteristic values for couplers (K), coupler modules (KM) and wavelength multiplexers (WDM):

Insertion Loss	Loss between the input and output in question	K KM WDM	$-10 \log (P_i/P_0)$ (i = 1…n)	[dB]	
Coupling Ratio	Ratio (in percent) of the optical power at the outputs	K KM	$[P_i/\Sigma P_i] \times 100$	[%]	
Excess Loss	Power loss in the coupler	K KM	$-10 \log [\Sigma\, P_i/P_0]$	[dB]	
Return Loss	Ratio of launched to reflected power at an input or output, respectively	K KM WDM	$-10 \log (P_r/P_0)$	[dB]	
Directivity	Percentage of the launched power reflected to the parallel fibre on the same side	K KM WDM	$-10 \log (P_r/P_0)$	[dB]	
Isolation	Power ratio of the unwanted and required wavelengths at the output in question. The isolation depends on the two working wavelength ranges..	WDM	$-10 \log [P_{1\lambda1}/P_{2\lambda1}]$ $-10 \log [P_{2\lambda2}/P_{1\lambda2}]$	[dB] [dB]	

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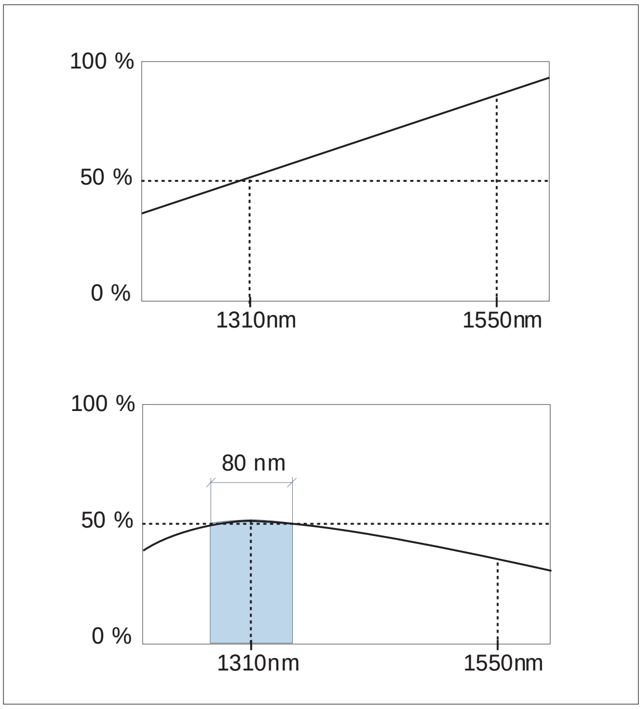
Couplers

Couplers with different transmission and coupling characteristics can be produced by manipulating the drawing process and by special pre-treatment.

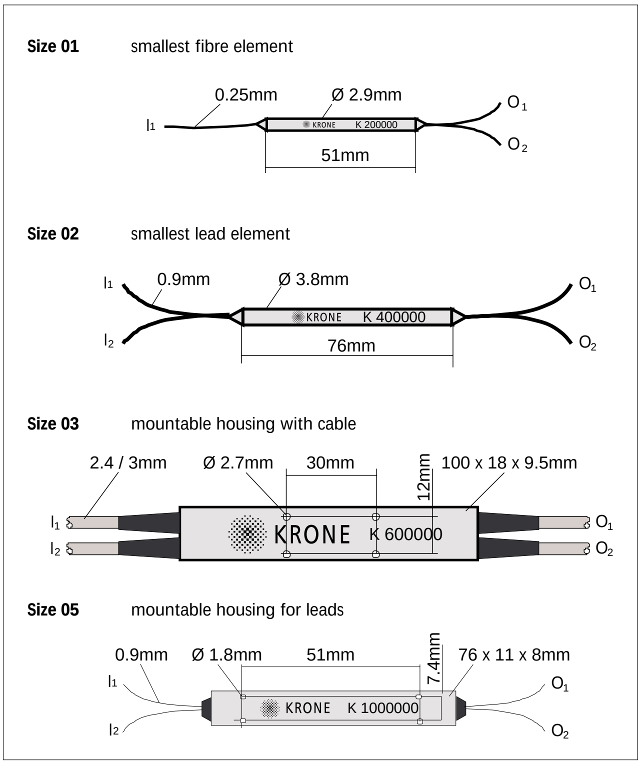
There are three different types of fused couplers:

- **Standard couplers**
Standard couplers (SSC = standard single-mode couplers) are used to distribute power and to merge light of one nominal wavelength, e.g. 1310nm.
- **Single-window couplers**
Single-window couplers (WFC = wavelength flattened couplers) are optimised for given wavelength ranges and thus ensure a constant coupling ratio over a wide bandwidth, e.g. 1550 ± 40nm.
- **Dual-window couplers**
Dual-window couplers (WIC = wavelength independent couplers) ensure a constant coupling ratio in the second and third optical windows (1310 ± 40nm and 1550 ± 40nm).

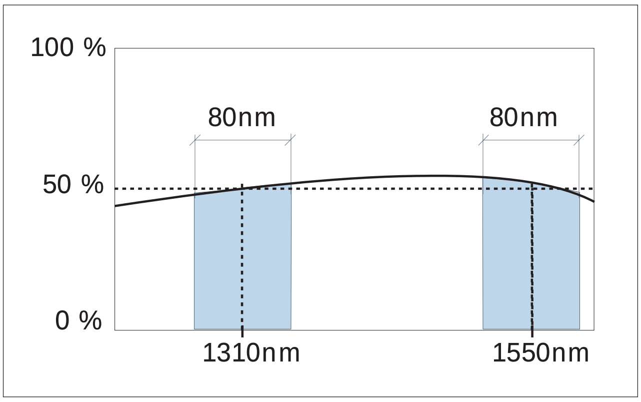
The couplers are available in different sizes. All the sizes are available as 1x2 or 2x2 versions. The standard fibre length totals at least 2m. Fibre type: SMF-28 (9/125µm).



Wavelength dependence of the coupling behaviour



Coupler sizes



Dual window couplers

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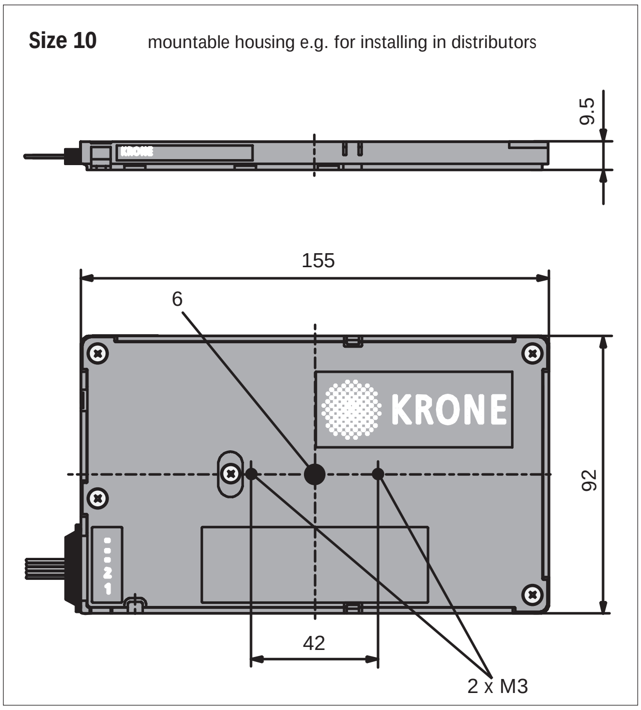
Coupler modules



Coupler module size

Coupler modules are designed for installation in various types of racks and distributors.

Couplers with a 1x2 configuration are cascaded via splices in an enclosure, so that so-called coupler modules with up to 16 output fibres can be set up. The power launched at the input end is normally equally distributed to all the output fibres.

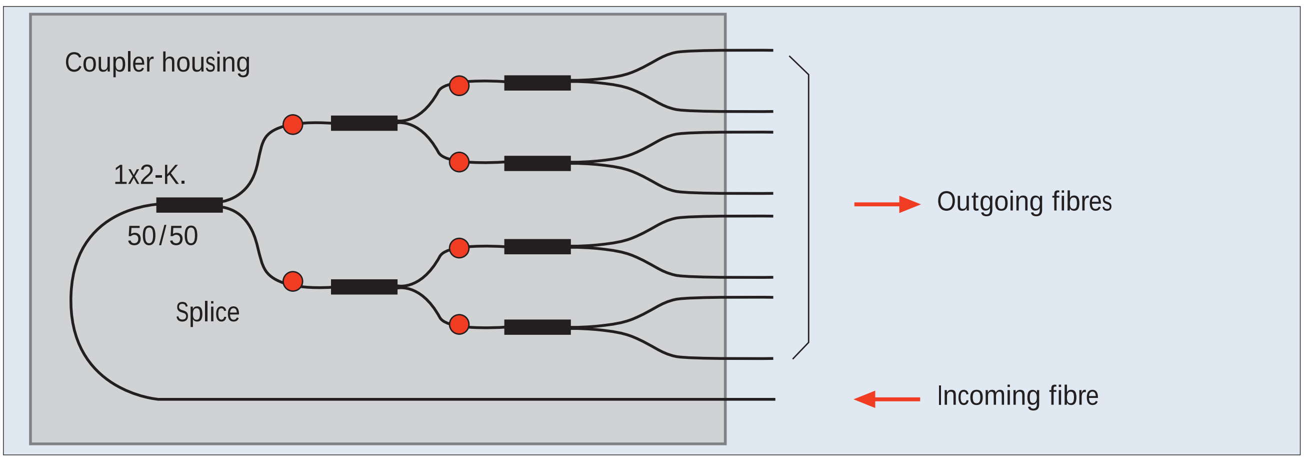
Three different type of coupler modules exist in analogy to couplers:

- **Standard coupler modules**
  Standard coupler modules are used to distribute power and to merge light of one nominal wavelength, e.g. 1310nm.
- **Single-window coupler modules**
  Single-window couplers are optimised for individual wavelength ranges and thus ensure a constant loss pattern over a wide spectral bandwidth in the second or third optical window.
- **Dual-window coupler modules**
  Dual-window couplers ensure a constant coupling ratio in the second and third optical windows (1260 to 1360nm and 1480 to 1580nm).

Coupler modules are available in the nx2 to nx16 configurations (n = 1 or 2). The standard size offered is size 10. This design corresponds to the technical delivery standard TL 6060-3006 from Deutsche Telekom AG.

The standard fibre length totals at least 2m. The fibre type used is SMF-28 (9/125µm). Different wire and cable pigtails are available.

Other sizes (e.g. 19" plug-in units) are available on request.



Design principles of a coupler module

Application example

Determination of the power distribution and internal design of the coupler module as a function of transmission ranges.

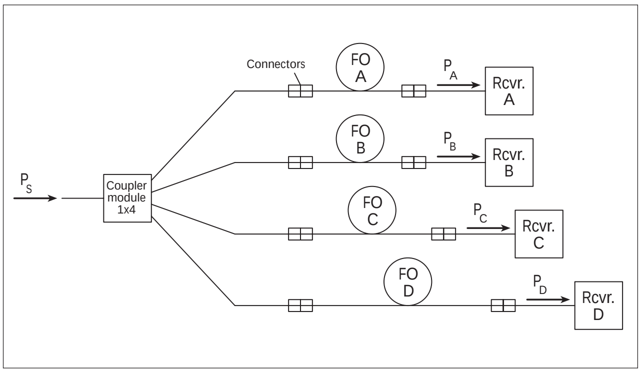
A cable TV network is to be set up using a given transmission system. In order to compensate for the different distances from the receivers, an asymmetrically distributing coupler module has to be used, so that each receiver receives approximately the same power.

This permits optimal utilisation of system performance, because - in contrast to symmetrical modules - different line losses are not compensated by attenuation modules and/or because the receivers do not need to be tuned to the different power levels.

The following design parameters have to be considered:

- A transmission wavelength of 1310 ± 40nm has to be used, and the transmission power of P_s = 0dBm has to be distributed to 4 receiver units. This means that a single-window coupler module for the second optical window has to be used with a 1x4 configuration.

Route A, 1km	D_{FA}	=	0.4dB
Route B, 1km	D_{FB}	=	0.4dB
Route C, 4.2km	D_{FC}	=	1.7dB
Route D, 6.5km	D_{FD}	=	2.6dB
Connector loss	D_S	=	0.5dB

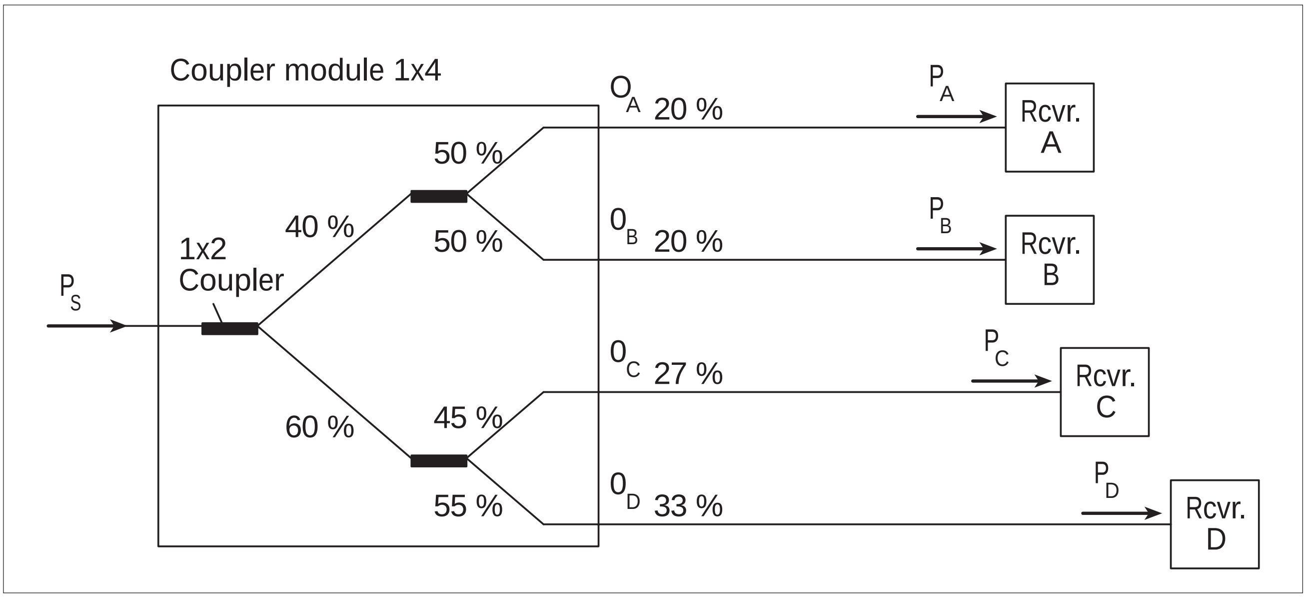


System configuration

The route sections behind the coupler module are subject to the losses D_A to D_D. This means that the input power at the coupler module outputs O_A to O_D must be distributed as follows:

- D_A = $D_S + D_{FA} + D_S$ = 1.4dB ' O_A = 20%
- D_B = $D_S + D_{FB} + D_S$ = 1.4dB ' O_B = 20%
- D_C = $D_S + D_{FC} + D_S$ = 2.7dB ' O_C = 27%
- D_D = $D_S + D_{FD} + D_S$ = 3.6dB ' O_D = 33%

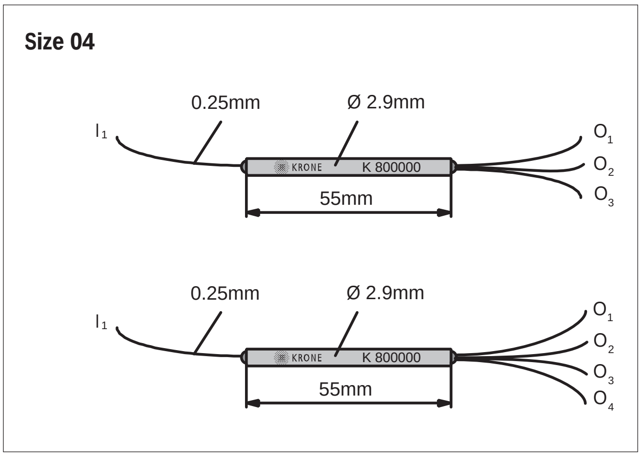
This leads to the following coupler module design (the power levels P_A to P_D arriving at the receivers are then in the order of -8.4dBm).



Coupler module design

Fibre Optic Components

KRONOLITH®



KRONLITH is a coupler with more than two fused fibres. It is available in the nx3 and nx4 configurations.

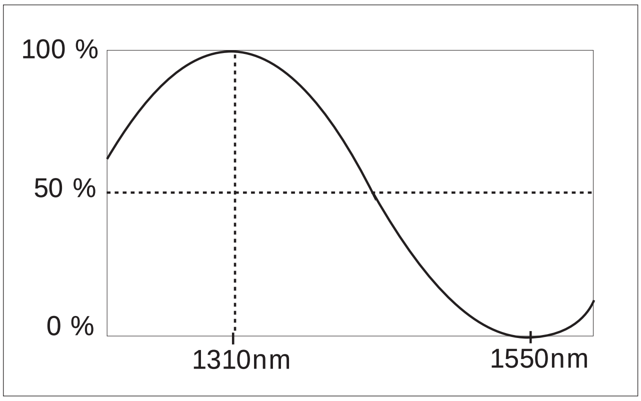
Three different types of KRONLITH couplers are available:

- **Standard KRONLITH**
  Standard KRONLITH modules are used to distribute power and to merge light of one nominal wavelength, e.g. 1310nm.
- **Single-window KRONLITH**
  Single-window KRONLITH modules are optimised for given wavelength ranges and thus ensure a constant coupling ratio over a wide spectral bandwidth, e.g. 1550 ± 40nm.
- **Dual-window KRONLITH**
  Dual-window KRONLITH modules ensure a constant coupling ratio in the second and third optical windows (1310 ± 40 and 1550 ± 40nm).

KRONLITH modules are available as size 04 types. The standard fibre length totals at least 2m. Fibre type: SMF-28 (9/125µm).

Other sizes are available on request.

Wavelength multiplexers



Wavelength dependence of a WDM

Wavelength multiplexers and demultiplexers (WDM) merge and separate optical signals with different wavelengths. They are passive optical components and can work in the unidirectional and bi-directional modes.

KRONE WDMs feature the following properties:

- multiplexing and demultiplexing of 1330 and 1550nm,
- low insertion and extra losses, i.e. minimum losses within the fibre optic network
- high return loss, i.e. non reflection interference affecting transmitters in analogue systems
- high isolation, i.e. low crosstalk
- high thermal and mechanical stability
- optimum solution for any application in terms of optical and mechanical properties
- manufacturing according to customer specifications is possible.

Two different WDM types are available:

- Standard WDMs merge and separate the two wavelength ranges of 1300 ± 20nm and 1550 ± 20nm.
- Broadband WDMs (WFC = wavelength flattened couplers) merge and separate the two wavelength ranges of 1300 ± 40nm and 1550 ± 40nm.

WDMs are available in different sizes. The standard versions of all types are supplied in the 1x2 configuration.

The standard fibre length totals at least 2m.

Fibre type: SMF-28 (9/125µm).

Fibre Optic Excellence from KRONE

Fibre Optic Components

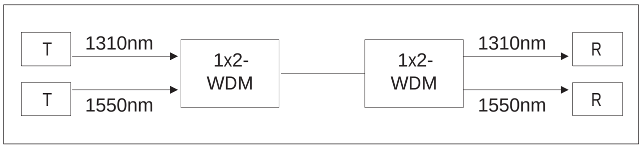
WDM application example

Wavelength multiplexers (WDMs) can be used to increase the transmission capacity of optical networks. These fibre optic components help save new fibre optic cables and the substantial costs of laying new cables.

The following system principles are possible:

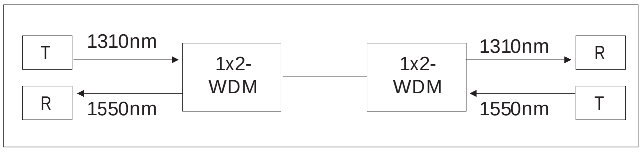
- **Unidirectional transmission:**
  In the case of unidirectional transmission, the signals of two transmitters with different wavelengths are merged (multiplexed) by a WDM at the beginning of the transmission route. Here it is important that the WDM has the smallest insertion loss possible in order to avoid line losses.

  The signals are separated (demultiplexed) at the end of the route by another WDM, so that the two wavelengths can be allocated to their proper receiver. In this case, the isolation between the two wavelengths must be very high in order to avoid crosstalk phenomena.



- **Bi-directional transmission:**
  Bi-directional transmission systems permit the independent, bi-directional transmission with different wavelengths through a common optical fibre.

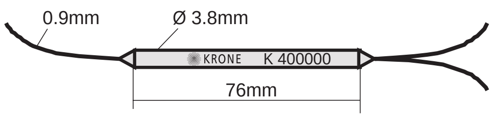
  Thanks to the high isolation values of KRONE's WDMs, the laser diodes are sufficiently protected against the light of the laser emitting its light in the opposite direction.



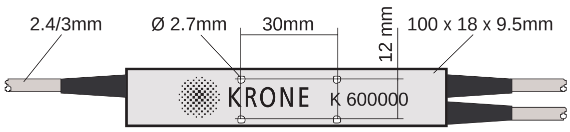
Wavelength (de)multiplexers are available in different sizes. The standard versions of all types are supplied with a 1x2 port configuration.

WDM types

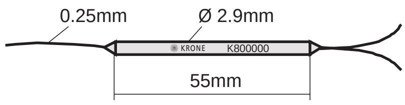
Size 02 Smallest element for leads



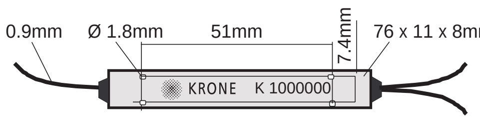
Size 03 Mountable housing with cables



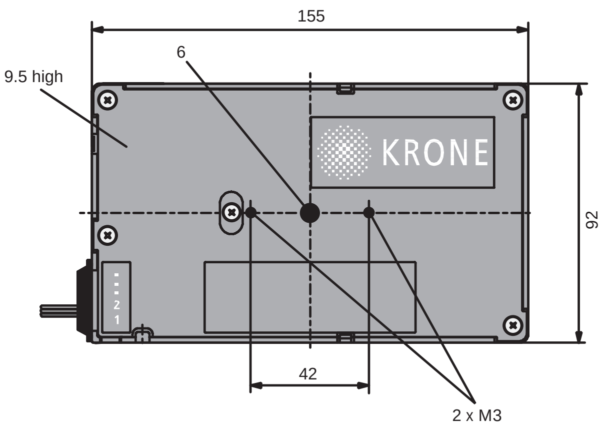
Size 04 Smallest element for fibres



Size 05 Mountable housing for leads



Size 10 Mountable housing e.g. for installation in a distributor



Fibre Optic Excellence from KRONE

Fibre Optic Components

Attenuation modules

Optical attenuation modules reduce optical power, this is necessary in many measuring set-ups. Certain transmission systems also require the fibre optic attenuation to be adapted to the system dynamic because too low a signal level can cause bit errors during data transmission and, because over-modulation of the receiver also leads to errors. Attenuation modules are passive components suitable for bi-directional operation.

Two different types of attenuation modules are available:

- **Single-window attenuation modules (ATS)**
  Single-window attenuation modules (ATSs) are optimised for given wavelength ranges and thus ensure a constant attenuation over a wide bandwidth, e.g. 1550 ± 40nm.
- **Dual-window attenuation modules (ATD)**
  Dual-window attenuation modules (ATDs) ensure a constant attenuation in the second and third optical windows (1310 ± 40 and 1550 ± 40nm).

Attenuation module application

One of the functions of attenuation modules in optical systems is to adapt the different power levels, resulting from different route lengths, to the maximum receiving levels specified for the optical receivers, in order to avoid overmodulation at the receiver end.

The following design parameters have to be considered:

- A transmission wavelength of 1310 ± 40nm has to be used, i.e. a single-window attenuation module for the 2nd optical window must be used.
- Max. receiving level P_{Emax} = -10dBm
- Min. receiving level P_{Emin} = -38dBm (BER 10^{-10})
- Transmission level P_S = -4dBm
- Distance, 10km D_F = 4dB (0.4dB/km)
- Connector loss D_S = 0.5dB

The following power levels arriving at the receiver result from the distance and the connector losses:

- $P_E = P_S - D_S - D_F - D_S$
  $= -4 - 0.5 - 4 - 0.5 = -9\text{dBm}$

Rating of the attenuation module:

- $D_{DGIMin} = |P_{EMax}| - |P_E| = 10 - 9 = 1\text{dB}$
- $D_{DGIMax} = |P_{EMin}| - |P_E| = 38 - 9 = 29\text{dB}$

In order to retain a sufficient attenuation reserve and avoid over-modulation, an attenuation module with a nominal value of between 3 and 10dB should be used.

Sizes for attenuation modules

Attenuation modules are available in different sizes. The standard fibre length totals at least 2m. Fibre type: SMF-28 (9/125µm).