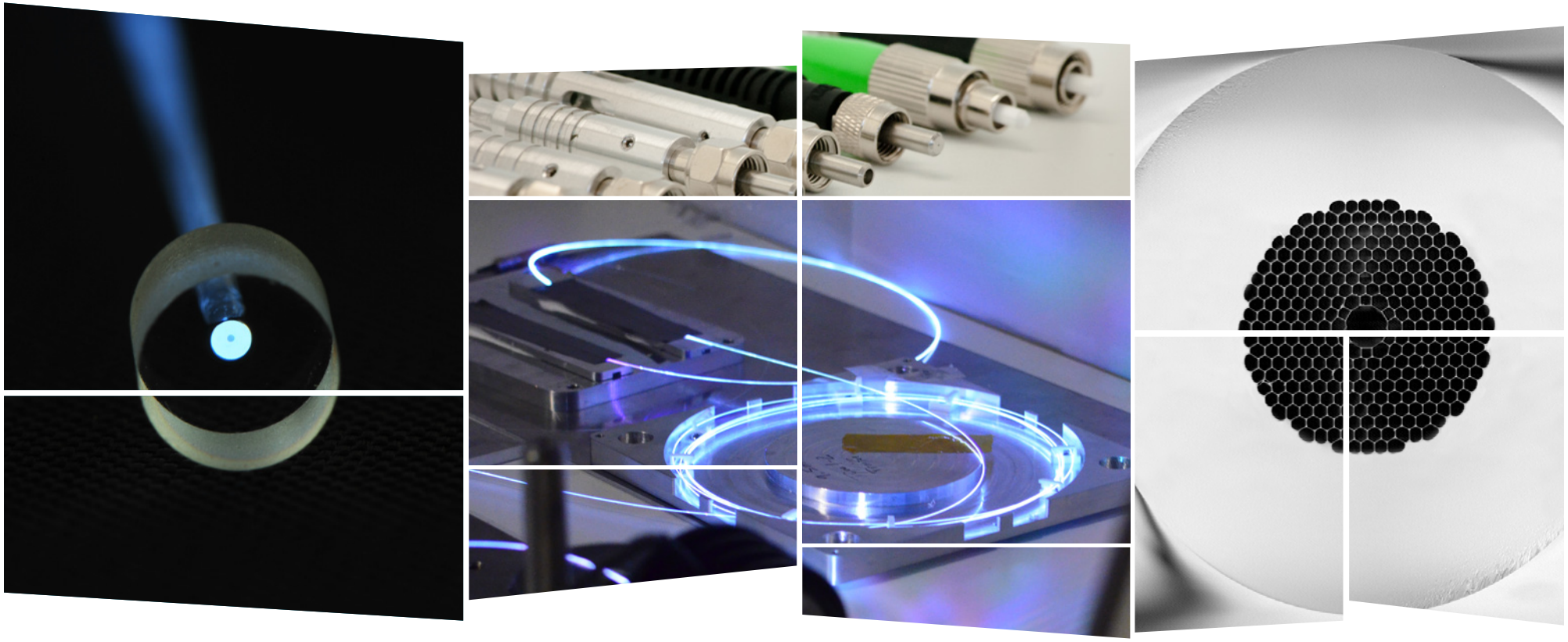
ALPhA NOV

Optics & Lasers Technology Center



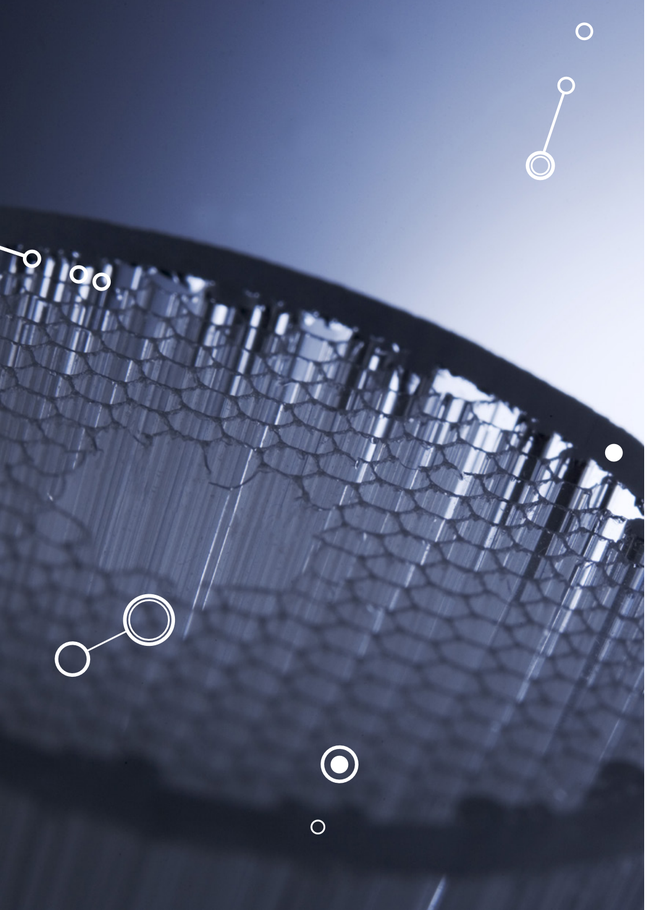
Photonic Crystal Fiber Interfacing

In partnership with NKT Photonics the power of light

With strong expertise in designing fiber lasers and fused fiber components, ALPhANOV, the Technology Center in Optics and Lasers, entered a partnership with NKT Photonics for supplying end-treatment solutions to Photonics Crystal Fibers (PCF). Such fiber preparation includes PCF connectors, sealed and cleaved PCF, end-capped PCF and PCF with mode-adaptors. ALPhANOV addresses the whole PCF product line of NKT Photonics, ranging from active double-clad large mode area fibers, such as the DC-200/40-PZ-Yb and rod-type fibers to passive PCF such as hollow-core fibers and nonlinear PCF.

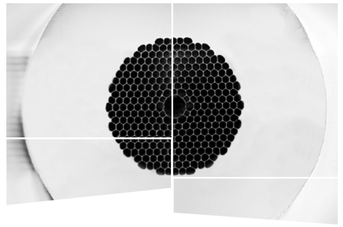
One of ALPhANOV's main missions is to help companies develop innovative products based on optics and lasers. Introducing PCF often gives a real advantage in terms of performance, compactness and reliability. Through this partnership with NKT Photonics, ALPhANOV can share its expertise with PCF users and helps them reach innovative and efficient solutions faster.

Contents



PHOTONIC CRYSTAL FIBERS

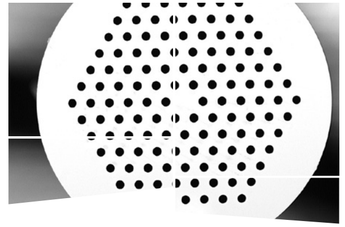
HOLLOW-CORE FIBERS



Hollow-core photonic bandgap fibers use a micro-structured cladding region with air holes to guide light in a hollow core. The photonic bandgap guiding mechanism is fundamentally different from the traditional total internal reflection guiding principle.
This new technology provides the basis for high power delivery without nonlinear effects or material damage.

Fiber example: HC-440; HC-532; HC-580; HC-800; HC-1060; HC-1550; HC-19-1550; HC-2000

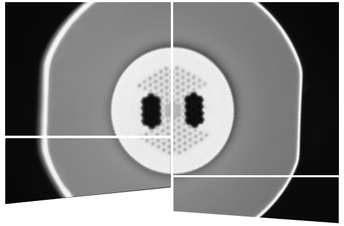
LARGE MODE AREA FIBERS



The selection of Large Mode Area Crystal fibers covers a range of fibers for diffraction limited high power delivery, and provide single mode operation in a large wavelength range - endlessly single mode operation. The very large mode area enables high power levels without nonlinear effects or material damage.

Fiber example: LMA-5; LMA-10; LMA-10-UV; LMA-15; LMA-25; LMA-PM-5; LMA-PM-10; LMA-PM-15

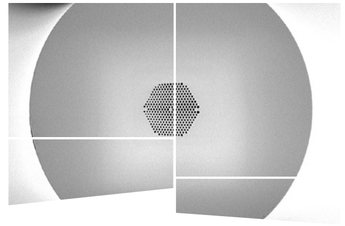
YTTERBIUM DOPED DOUBLE CLAD FIBERS



The ytterbium doped double clad fibers offer the largest single-mode cores enabling amplification to unprecedented power levels while preserving very good mode quality and stability.

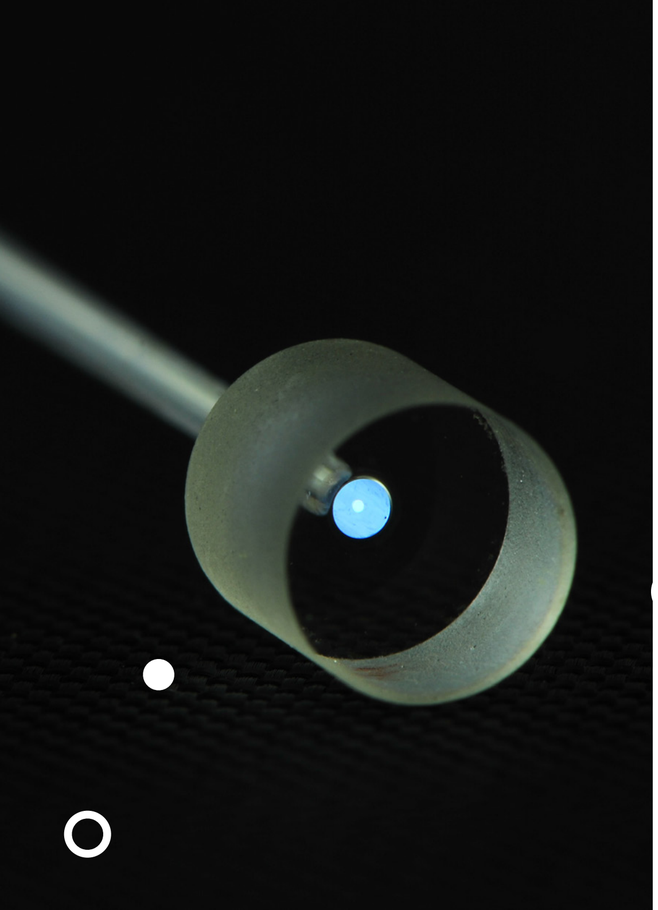
Fiber example: DC-135-14-PM-Yb; DC-200/40-PZ-Yb

NONLINEAR FIBER



Optimized for supercontinuum generation and nonlinear wavelength conversion, nonlinear photonic crystal fibers offer a unique combination of tailored dispersion profile and very high nonlinear coefficient.

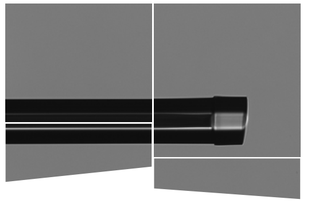
Fiber example: NL-PM-750; SC-5.0-1040 (PM)



END-CAPPING

SMALL END-CAPS

- For all PCF fibers
- Pure silica
- Different diameters and lengths available
- On-demand polished angle



A small end-cap can be used either to protect the fiber micro-structure from dust and humidity or to decrease the beam fluency at the input or output interface without modification of the N.A.

S-end-cap

- End-cap diameter: 125 µm
- End-cap length: ≤100 µm
- Polished angle: 0°
- Material: Pure silica

M-end-cap

- End-cap diameter: from 125 µm to 400 µm
- End-cap length: ≤400 µm
- Polished angle: 0°
- Material: Pure silica

L-end-cap

- End-cap diameter: from 400 µm to 1.5 mm
- End-cap length: ≤1.5 mm
- Polished angle: 0°
- Material: Pure silica

Options available on-demand for all end-caps

- Custom polished angle (up to 12°)
- Custom length
- AR coating

Special End-Capping development upon request

5X5 MM END-CAPS

for high-energy laser beams

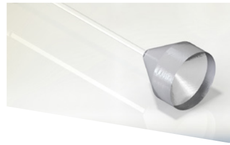
- For LMA or DC fiber
- Conical geometry
- Pure silica
- 0° or 5° polished angle with AR coating

These end-caps are used for high-energy systems. Their unique geometry allows for a strong bond with the fiber, providing the possibility to attach them easily in a mount.

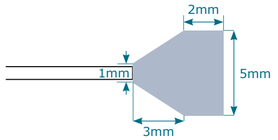
Specifications

- End-cap diameter: 5 mm
- End-cap length: 5 mm
- Polished angle: 5° or 0° with AR@800-1300 nm
- Material: Pure silica

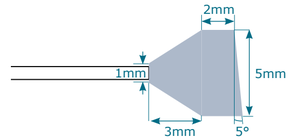
(Other AR coating on-demand)



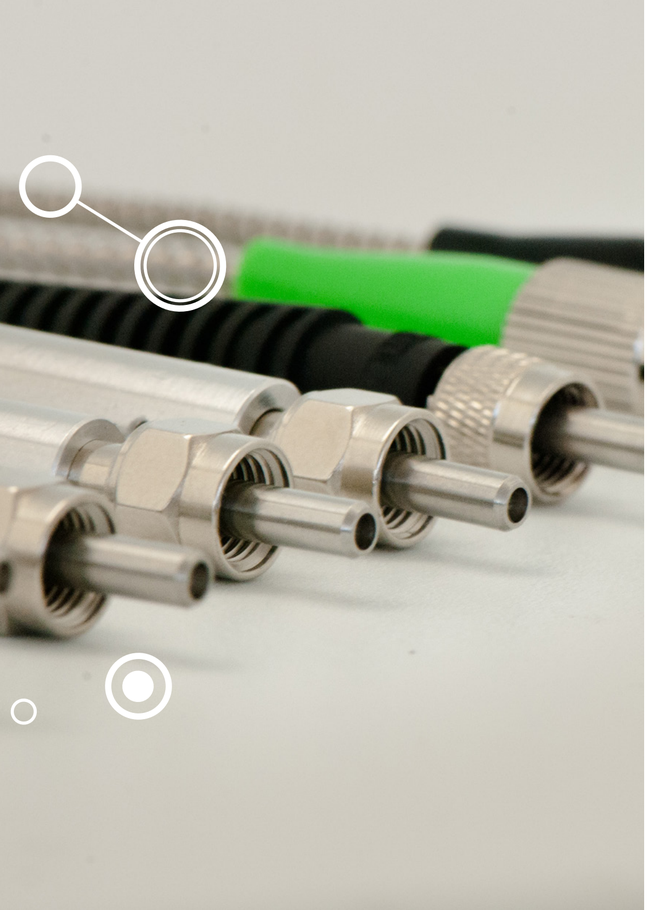
Dimensions



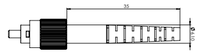
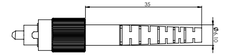
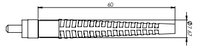
Conical end-cap polished at 0° with 800 nm - 1300 nm AR coating

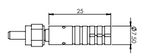
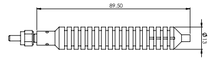
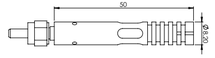


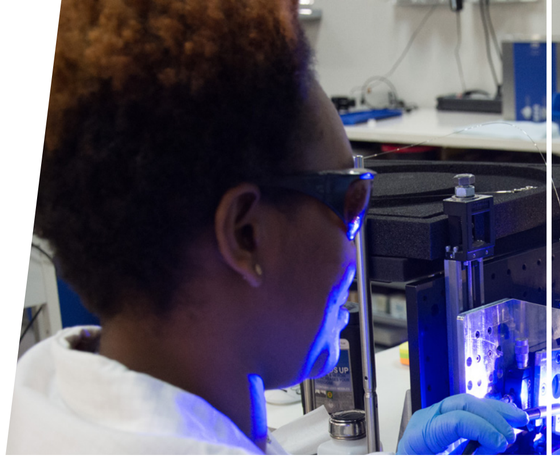
Conical end-cap polished at 5°

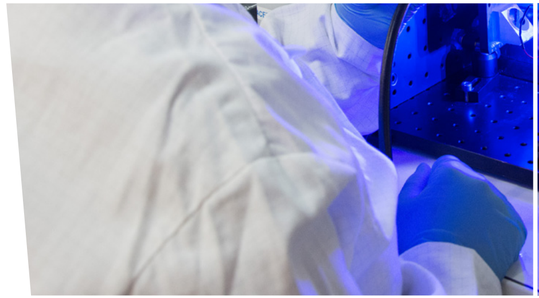


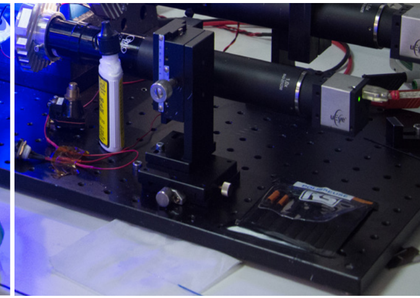
PCF CONNECTORS

	FC/PC connectors	FC/APC connectors	SMA connectors
Specifications			
Standard end-cap diameter	Fiber clad diameter	Fiber clad diameter	Fiber clad diameter
Standard end-cap length	<100 µm	<100 µm	<100 µm
Power limitations	500 mW injection loss	500 mW injection loss	500 mW injection loss
Ferrule type	Ceramic	Ceramic	Metallic
Ferrule diameter	2.5 mm	2.5 mm	3.2 mm
Polished angle	0°	8°	0-12°
Options			
On-demand end-cap length	From 20 µm - 400 µm	From 20 µm - 400 µm	From 20 µm - 400 µm
On-demand end-cap diameter	From fiber size to 400 µm	From fiber size to 400 µm	From fiber size to 400 µm
PM alignment	Fast or slow axis	Fast or slow axis	Fast or slow axis
Dimensions			

	SMA-1 connectors	SMA-2 connectors	SMA-6 connectors	SMA-AF connectors
Specifications				
Standard end-cap diameter	Fiber clad diameter	Fiber clad diameter	Fiber clad diameter	Fiber clad diameter
Standard end-cap length	<100 µm	<100 µm	<100 µm	<100 µm
Power limitations	1 W injection loss	2 W injection loss	6 W injection loss	200 W pump limit
Ferrule type	Metallic	Metallic	Metallic	Metallic
Ferrule diameter	3.2 mm	3.2 mm	3.2 mm	3.2 mm
Polished angle	0-12° +/-1	0-12° +/-1	0-12° +/-1	0-12° +/-1
Options				
On-demand end-cap length	From 20 µm - 1.5 mm	From 20 µm - 1.5 mm	From 20 µm - 1.5 mm	From 20 µm - 1.5 mm
On-demand end-cap diameter	From fiber size to 1.5 mm	From fiber size to 1.5 mm	From fiber size to 1.5 mm	From fiber size to 1.5 mm
PM alignment	Fast or slow axis	Fast or slow axis	Fast or slow axis	Fast or slow axis
Dimensions				
				







Specific connectorization on demand

INDUSTRIAL PCF CABLES

ALPhANOV can meet demanding requests to carry Photonic Crystal Fibers at an industrial level.

TUBING

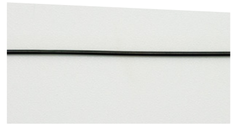
to protect your fibers

- Available for all kinds of fibers
- Different materials available
- Waterproofness (optionial)

Different kinds of jackets can be proposed in option to protect your fibers depending on the power.

Hytrel 900 µm jacket

The Hytrel 900 µm jacket is the smaller jacket available for PCF fiber. It can only be used for low power, typically below 1 W average power injected.



3 mm PVC jacket

The 3 mm PVC jacket is used to protect the fiber up to 3 W average power injected.

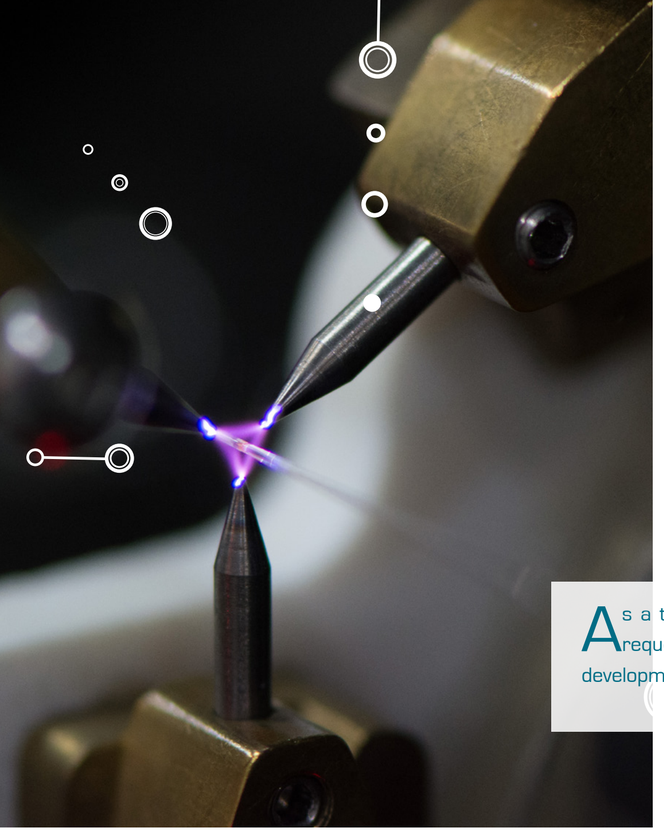
Steel jackets

Adapted for high-power, steel jackets are available for all connectors. These jackets are implemented as depicted in the figure below.

Specific Tubing on demand

EXAMPLE OF REALIZATION

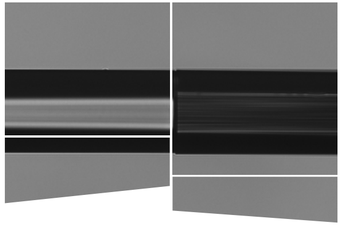
Industrial HC-1550 patch-cable, using LC connectors and waterproof sheathing.



SPECIAL TERMINATION

As a technology center, ALPhANOV is able to address special requests on PCF interfacing through feasibility studies or developments.

SPLICES



- All kinds of PCF fibers
- PCF-to-PCF or PCF-to-standard fiber
- PM alignment

Different kinds of splices can be proposed: PCF-to-PCF splices or PCF-to-Standard fiber.

Best effort splices

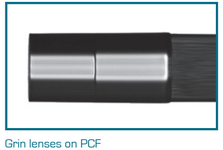
Each splice is different and ALPhANOV cannot guarantee a specific loss. Nevertheless this kind of splicing job is done on a best effort.

Optimized splices

ALPhANOV offers you the possibility to optimize any kind of splice. Losses are not guaranteed, but through a short feasibility study, we are able to develop a specific process to minimize them.

Examples : Splice of 40/200 fiber to Kagome fiber with < 0.7 dB loss.

LENSES

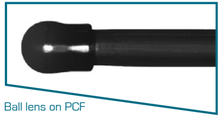


Grin lenses on PCF

GRIN lenses

ALPhANOV has developed a process to splice and control Grin Lenses for micro-structured fibers. The behavior of the lens can be simulated ; the focal length and the beam waist can be controlled.

Example: Spot size of 20 µm at a distance of 150 µm starting from a non-linear fiber.



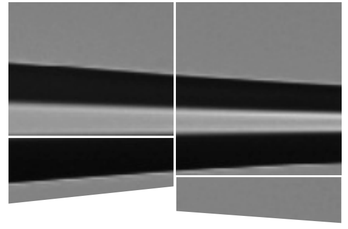
Ball lens on PCF

Ball lenses

Example: By splicing a ball lens at the end of a Kagome fiber with 15 µm core size, we obtained a spot size of 7 µm at a focal distance of 500 µm.

MODE FIELD ADAPTER & TAPERS

MODE FIELD ADAPTATION



- For fiber with different MFD
- Up to 40 µm fiber core size
- PM alignment

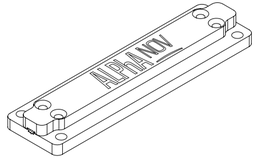
The mode field adapter (MFA) is a component that reduces connection loss between fibers with different mode field diameters. The most extreme MFA from our standard product range connects 6 µm and 40 µm core fibers.

Benefit of MFA component:

- Optimized signal transmission
- Improved stability
- Improved efficiency in fiber lasers

Principle of a MFA

Dimensions



TAPERING

ALPhANOV's expertise allows us to taper micro-structured fibers without collapsing the air holes, in order to maintain the ratio of the structure inside the fiber during the tapering process.

Example: Tapering of a ROD fiber: reduction of the outer diameter of a ROD fiber from 1 mm to 600 µm without any loss.

HIGH-POWER SPECIAL FIBER AMPLIFIER

For active microstructured fibers

ALPhANOV offers solutions to build fully monolithic high performance fiber amplifiers based on active micro-structured fibers.

Pump specification

Number of pump fibers	2 or 6
Pump fibers core diameter	105 µm N.A. 0.15 or 0.22
Max pump power	50 W per port
Typical pump loss	<0.5 dB

Signal specification

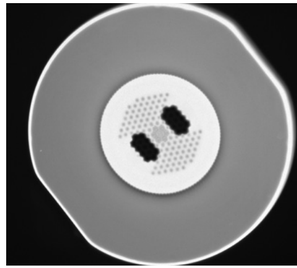
Fiber type available	PM980, PLMA10, PLMA15
Typical insertion loss	< 1.5 dB
Regime	Pulsed or CW

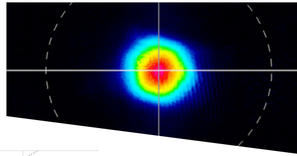
Output specification

Fiber type	Ytterbium doped DC fiber
Typical efficiency	> 70 %

Options

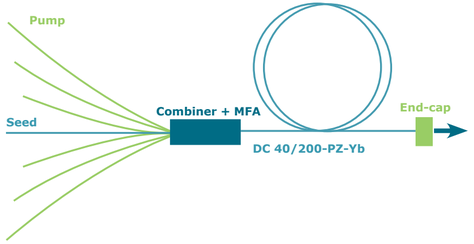
- Collimation/isolation module
- Electronics
- Possibility of contra-propagative waves with micro-optics

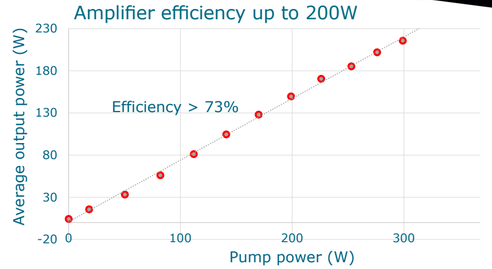




Example

- Fiber type: DC 40/200 fiber (other active fiber on request)
- Input fibers: 15 µm core
- Input signal: ~2 W; 40 MHz; 100 ps
- Output signal: up to 200 W





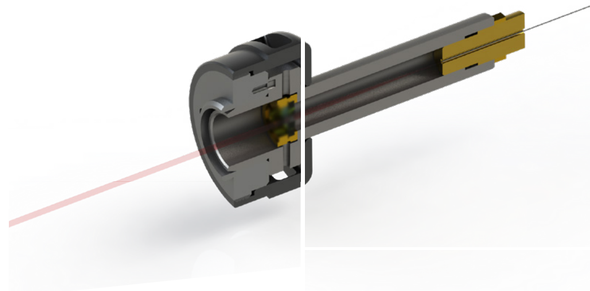
HIGH-POWER FEMTOSECOND PULSES FIBER DELIVERY CABLE

Based on hollow-core fibers

Our PowerPAC connector offers a highly precise connector for single-mode hollow-core fibers (*). It includes a collimator, which can withstand more than 100 Watts of injected power. It is particularly suitable for beam delivery based on hollow-core fibers, for instance in the femtosecond regime.

Features:

- 100 W-class in femtosecond regime
- Plug-and-play (high repeatability)
- Passive cooling (active cooling on-demand)



Optical specifications assuming input laser beam with M2=1.1:

Wavelength	1000 - 1100 nm
Max. power input (1)	100 W
Maximum loss (1)	20 W
Collimated beam diameter (2)	2 mm
Divergence	< 0.5 mrad
Injection loss	< 10 %
Optical return loss	> 40 dB
Pointing precision (3;4)	+/-0.1 mrad
Beam location precision (3;4)	< 0.3 mm (of the collimator center)

(1) Considering 80% coupling efficiency in the femtosecond regime
(2) MFD measured at $1/e^2$
(3) Depends on the fiber
(4) Considering 10% loss of the coupling ratio
(*) This connector is also possible for other large core single-mode PCF (Kagome, LMA PCF,...)

Specific high-power, high-precision connector developments on-demand

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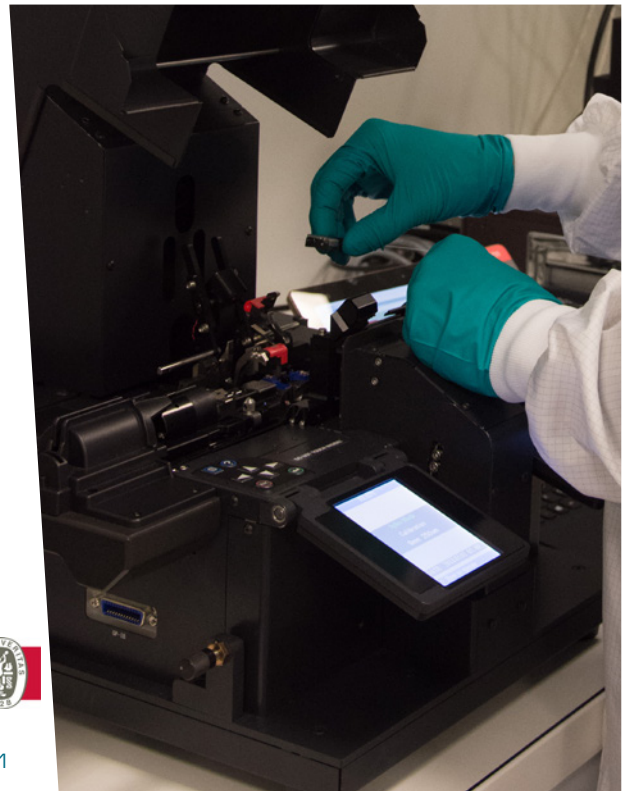

In partnership with NKT Photonics the power of light

Photos : ALPhANOV, NKT photonics - version 07/2021