Synchronous Interferometric Measurement of Dispersion Applied to Customization of Supercontinuum Sources

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8 - 9 February, Wien, Austria

Overview

- FYLA
- Method. Synchronous Interferometric Measurement of Dispersion
- Application. Customization of Supercontinuum Sources
- Conclusions

FYLA

All made in Spain, to the world

As a company, FYLA is the only one in the south of Europe, and one of the few in the world, able to produce and control the supply and manufacturing of the 100% of the components and technologies required for the production of our All-fiber pulsed Lasers, from our proprietary White Lasers Series , to pulsed lasers in the range of pico and femto seconds, with a ground breaking In-Fiber laser generation technology."

SEE MORE

FYLA CENTRAL SITE

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THE COMPANY

Motivation

- Lack of Information on D values from optical fiber manufacturers
- Limitation for labs and companies:
  - accurate modelling (pulse propagation)
  - interpretation of experimental results
  - …

20/400 Ytterbium-Doped LMA Double Clad Fiber

Nufern's Large Mode Area (LMA) Ytterbium-doped double clad fiber is ideal for high power fiber lasers and amplifiers used in military, industrial, and medical applications. These fibers enable efficient, compact, diode pumped lasers that directly compete with traditional solid-state lasers. The fiber features a 20 micron diameter core and 400 micron diameter clad size with a low NA (0.08) core. With > 75% slope efficiency and compatibility with operating at > 1kW of CW output power, this fiber is ideal for use in high power single-mode industrial fiber lasers.

Typical Applications

- High power fiber lasers
- CW and pulsed amplifiers
- Military, industrial and medical

Features & Benefits

- NuCOAT™ fluoroacrylate coating — Greater fiber durability in extreme environmental operating & storage conditions
- LMA core design — Useful for generating high CW powers
- "Few" moded core design — Easy to maintain single mode LP01 beam through fiber & components
- PANDA-style stress structure for increased birefringence — Superior optical performance and uniformity
- All fiber proof tested to > 100 kpsi — Critical for ensuring long term reliability when coiling

Optical Specifications	PLMA-YDF-20/400-VIII	LMA-YDF-20/400-VIII
Operating Wavelength	1060 – 1115 nm	1060 – 1115 nm
Core NA	0.060 ± 0.010	0.060 ± 0.010
First Cladding NA (5%)	≥ 0.46	≥ 0.46
Cladding Absorption	0.50 ± 0.05 dB/m at 915 nm 1.50 dB/m near 975 nm	0.40 ± 0.05 dB/m at 915 nm 1.20 dB/m near 975 nm
Birefringence	nominal 3.5×10^{-4}	N/A
Geometrical & Mechanical Specifications		
Cladding Diameter	400.0 ± 15.0 µm	N/A
Cladding Diameter (flat-to-flat)	N/A	400.0 ± 15.0 µm
Core Diameter	20.0 ± 2.0 µm	20.0 ± 1.5 µm
Coating Diameter	550.0 ± 20.0 µm	550.0 ± 20.0 µm
Coating Material	Low Index Polymer	Low Index Polymer
Prooftest Level	≥ 100 kpsi (0.7 GN/m²)	≥ 100 kpsi (0.7 GN/m²)

ofs A Furukawa Company

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Optical Properties | Dimensions/Geometric Properties | Mechanical and Testing Data | How To Order: | Typical Applications | Options

Optical Properties	
Type	Polarization-Maintaining
Cutoff Wavelength	≤ 1290 nm
Numerical Aperture (Nominal)	0.13
Mode Field Diameter	@ 1310 nm, 9.3 ± 1.0 µm
Attenuation	@ 1310 nm, ≤ 1.2 dB/km
Beat Length	@ 1310 nm, ≤ 3.8 mm
Crosstalk	@ 1310 nm/100 m, ≤ -30 dB
Crosstalk (Typical)	@ 1310 nm/100 m, ≤ -35 dB
Operating Wavelength	1310 nm
Dimensions/Geometric Properties	
Clad Diameter	125 ± 1.0 µm
Coating/Buffer Diameter	250 ± 10 µm
Coating Type	Dual UV Acrylate
Core/Clad Offset	≤ 0.7 µm
Clad Non-Circularity	≤ 2.0%
Mechanical and Testing Data	
Operating Temperature	-40 to +85 ºC
Proof Test Level	≥ 100 kpsi 0.689 GPa

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SM FIBER

125µm diameter SM specialty fibers

	SM450	SM600	SM750	SM800(5.6/125)	SM980(3.7/125)	SM980(4.5/125)	SM980(5.8/125)
Operating Wavelength (nm)	488 - 633	633 - 780	780 - 830	830 - 980	980	980 - 1550	
Cut-Off Wavelength (nm)	350 - 450	500 - 600	610 - 750	660 - 800	870 -970		
Numerical Aperture	0.10 - 0.14				0.21 - 0.23	0.17 - 0.19	0.13 - 0.15
Mode Field Diameter (µm)	2.8 - 4.1 @488nm	3.6 - 5.3 @633nm	4.5 - 6.5 @780nm	4.7 - 6.9 @830nm	3.4 - 4.0 @980nm	4.2 - 4.9 @980nm	5.3 - 6.4 @980nm
Attenuation (dB/km)	≤50 @488nm	≤15 @633nm	≤5.0 @780nm	≤5.0 @830nm	≤2.0 @980nm		
Proof Test (%)	1, 2 or 3 (100, 200 or 300 kpsi)						
Cladding Diameter (µm)	125 ± 1						
Core Cladding Concentricity (µm)	≤0.75	≤1.0			≤0.50		
Coating Diameter (µm)	245 ± 7						
Coating Type	Dual Acrylate						
Operating Temperature (ºC)	-55 to +85						

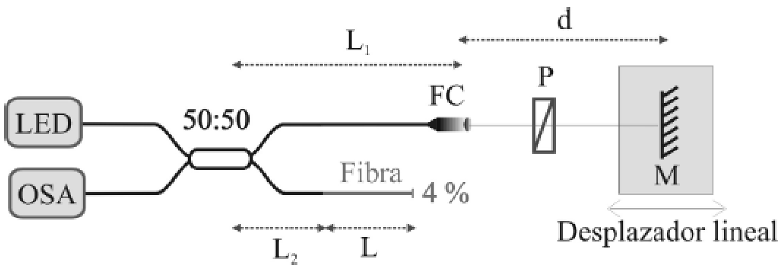
Current Methods

- Phase Differential Measurement of RF signals conveyed by coherent lasers
  - Spectral Resolution very high. Spectral Bandwidth very limited (eg by EOM bandwidth)
- Optical Interferometric Measurements
  - Spectral Bandwidth is (potentially) very high. Noisy, long and tedious measurements. Spectral Resolution is Low.

Ultimate Goal

- Commercial System of Dispersion Measurement
- Full VIS-IR Band
- Universal (any optical fiber/photonic device)
- Automated
- Very Fast (minutes range)

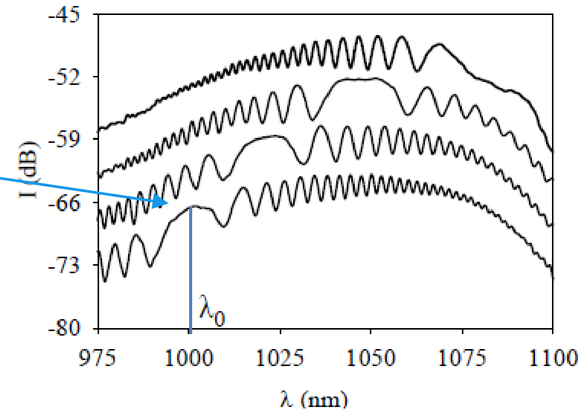
Method: Full VIS-IR Interferometric Measurement of Dispersion



$$I = (E_1 + E_2)(E_1 + E_2)^* = I_1 + I_2 + 2\sqrt{I_1 I_2} \cdot \cos(\phi_2(\omega) - \phi_1(\omega))$$

$$I_\omega \propto \cos(\Delta\phi(\omega))$$

$$\frac{\partial}{\partial \omega}\Delta\phi(\omega) = 0$$

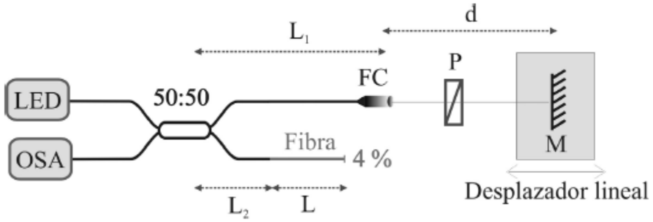


$$\tau_c \cdot (L_2 - L_1) - \frac{d}{c} = \tau \cdot L$$

$$\left.\frac{\partial \beta_c}{\partial \omega}\right|_{\lambda_0}(L_2 - L_1) - \frac{d}{c} = \left.\frac{\partial \beta}{\partial \omega}\right|_{\lambda_0} L$$

$$D_c \cdot (L_2 - L_1) - \frac{1}{c}\frac{\partial d_0}{\partial \lambda} = D \cdot L$$

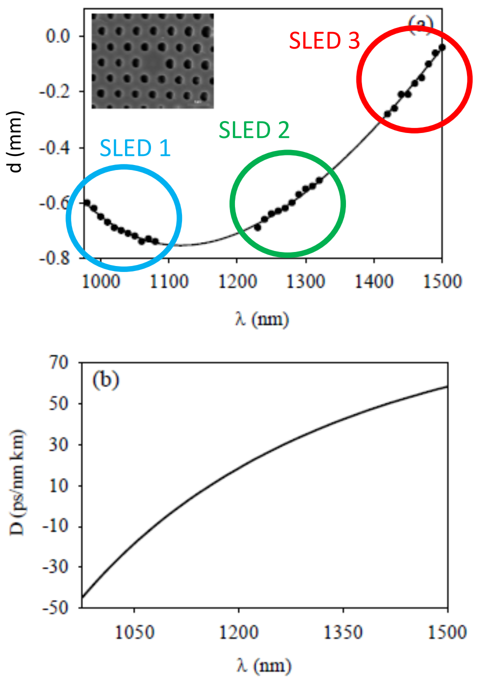
Method: Full VIS-IR Interferometric Measurement of Dispersion



$$D_c \cdot (L_2 - L_1) - \frac{1}{c}\frac{\partial d_0}{\partial \lambda} = D \cdot L$$

- Experimental Curve
  d = d (λ_0)

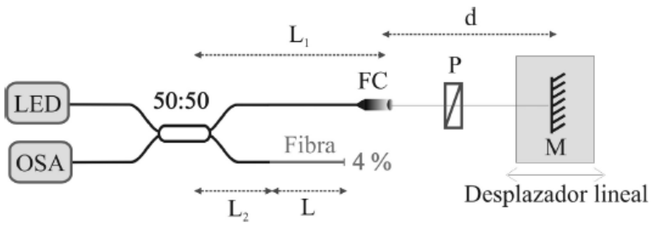
- Dispersion Curve

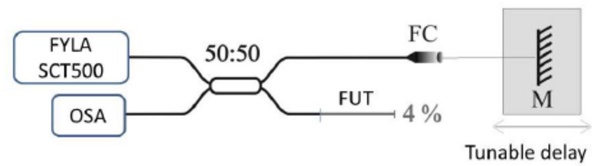


Drawbacks

- WHITE LAMP: ALIGNMENT
- LEDS: MULTIPLE SOURCES.
- LOW SPECTRAL POWER DENSITY
- LOW VISIBILITY OF FRINGES
- NOISE
- LOW SPECTRAL RESOLUTION
- TEDIOUS
- LONG TIME CONSUMING

Method: Full VIS-IR Interferometric Measurement of Dispersion





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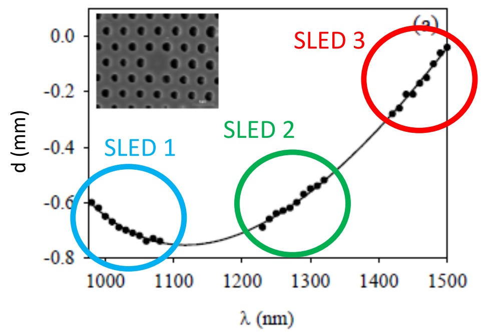
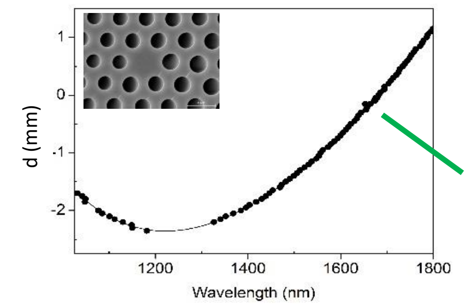
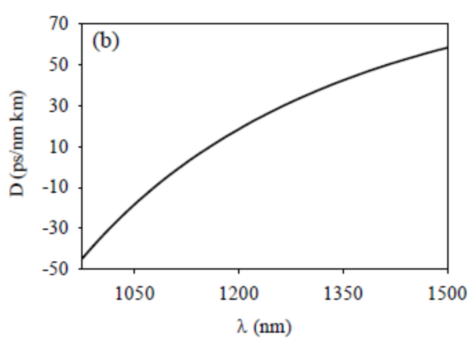


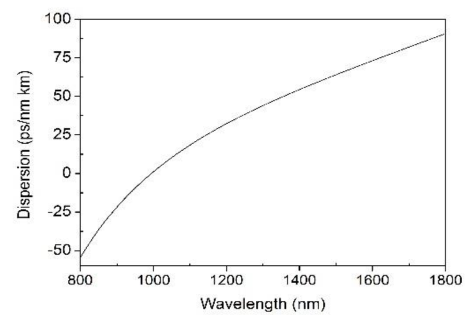


Advantages

- SINGLE FIBER COUPLED SOURCE
- HIGH SPECTRAL POWER DENSITY
- SYNCHRONIZED INTERFERENCES
- HIGH VISIBILITY OF FRINGES
- HIGH RESOLUTION
- LOW TIME CONSUMING
- LIABLE OF AUTOMATION

- Dispersion Curve





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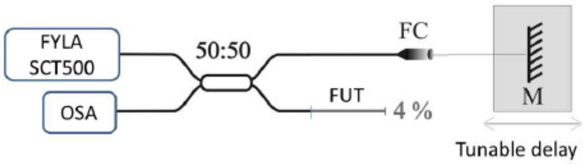

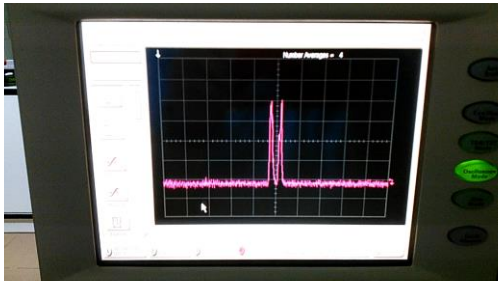

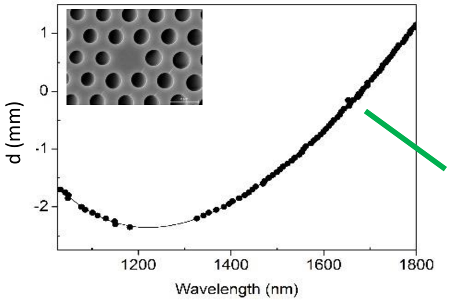

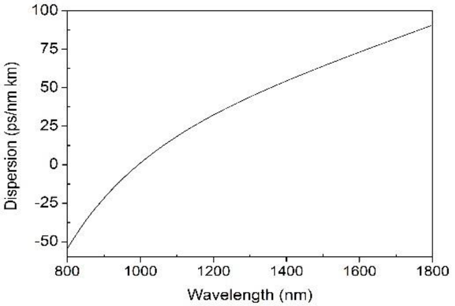

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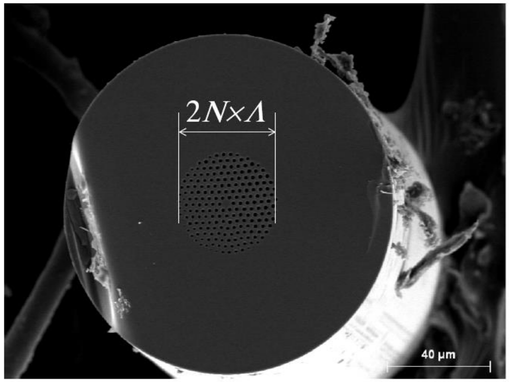
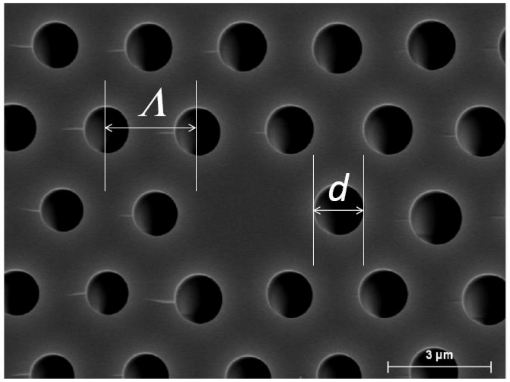
Fine Tuned Manufacturing of PCF to Customized SC Spectrum for OCT application



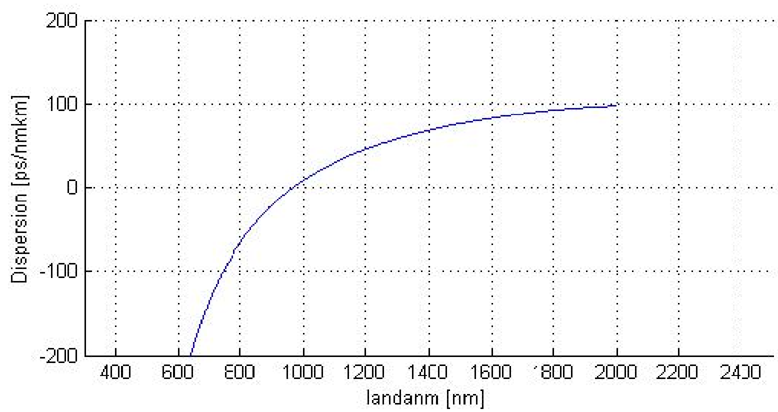


Requirements

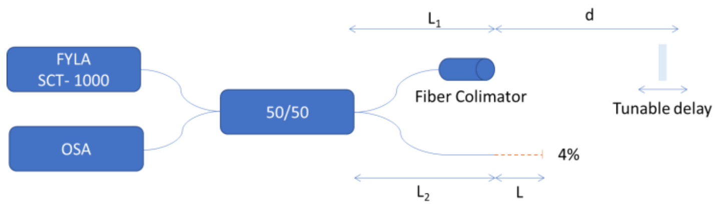
- Low cutoff wavelength (3dB) = **560 ± 10 nm**
- High cutoff wavelength (3dB) **= 850 ± 50 nm**
- Spectral Power Density > **200 µW/nm** in range [560,850] nm

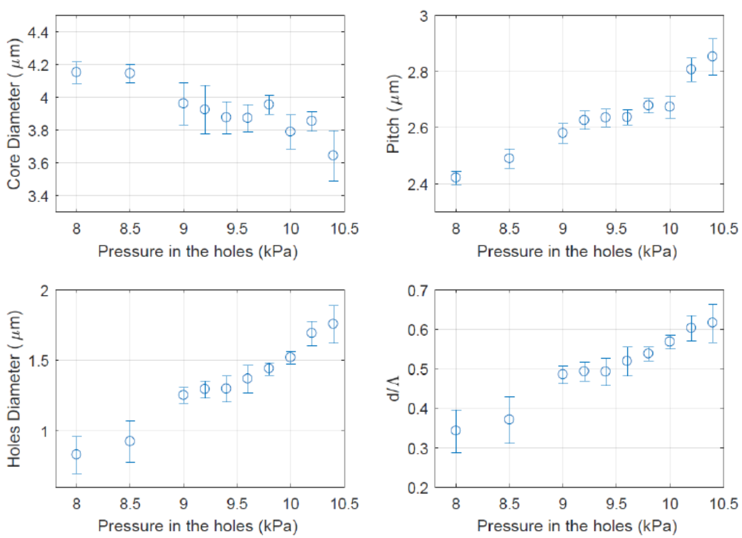
Goal Dispersion Curve

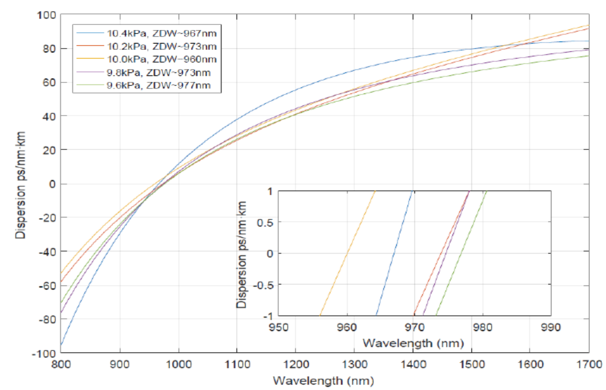
(ZDW = 967 ± 10 nm)

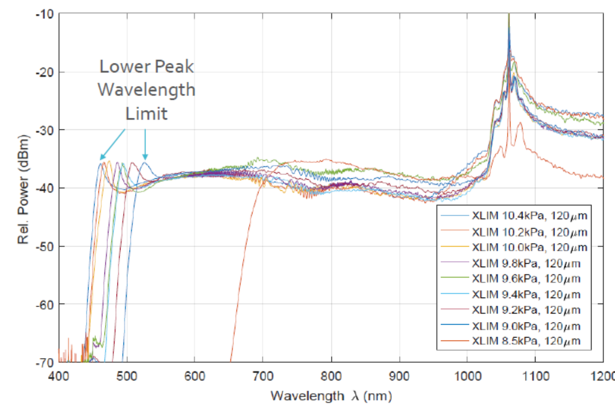


1. First approximation. 4 rings PCF



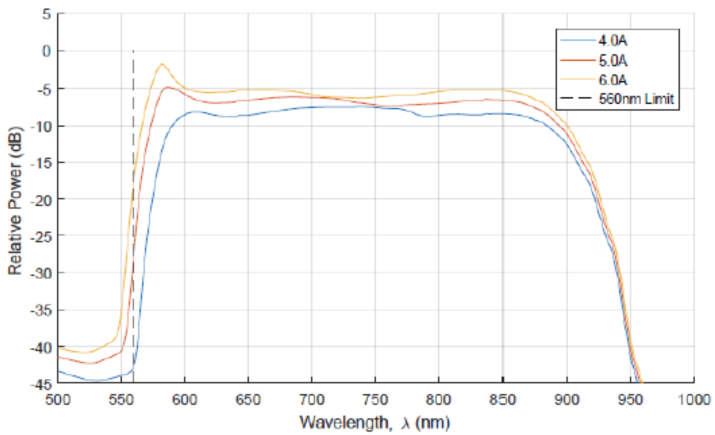






2. Fine Tuning. 7 rings PCF

Name	Material	Pressure (kPa)	Core Diameter (λm)	Hole Diameter (λm)
XLIM5	F300 silica	10.0	3.87	0.94



Requirements OK

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- SPD > **200 μW/nm** in range [560,850] nm

Outcome XLIM-FYLA Collaboration (Boosted by COST Action)

- Collaboration contract FYLA-XLIM 2017-2018
- Granted EU EUREKA Project 2018-2010
- Accepted Contribution to SPIE Photonics Europe 2018
- Several running joint experiments

EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Conclusions

- Synchronous Interferometric Method to Measure Chromatic Dispersion in Optical Fibers
- Enhanced performance vs conventional methods: spectral resolution, bandwidth, simplicity, time of measurement.
- Towards universal commercial product
- Successful application to PCF manufacturing for customized SC source.

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Questions