



**LE VERRE FLUORÉ**  
INFRARED SOLUTIONS

# CATALOG 2021

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## Our company

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Le Verre Fluoré was established in 1977 as a spin-off of the discovery of **fluoride glasses** by Poulain brothers at Rennes University in 1974.

**40 years of continuous R&D effort** lead to outstanding pioneering achievements:

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In addition to the definition of the classical ZBLAN glass (1979), LVF also produced the first fluoroindate glass fibers (1992), the first single mode fluoride fibers, the first laser fibers, and the first polarization maintaining fibers.

For fiber laser and amplifier application, **double clad fibers** have been developed, with specific D-shaped cores in order to optimize their efficiency. A variety of **rare earth doped fibers** have been manufactured, allowing numerous laser applications thanks to dozens of active transitions both in **visible** and **mid-infrared**.

LVF proposes **robust, reliable and low cost** solutions for industrial applications (spectroscopy, lasers, measurements). Our fluoride fibers are also the most transparent of the market.

LVF can design and manufacture **custom fibers** and fiber **patch cables**, including all your requirements (geometry, numerical aperture, rare earth content, cutoff wavelength...).

We also provide any kind of **bulk glasses** (parallelepipeds, tubes, rods, ribbons, prisms...) and a large variety of **fiber components** (end caps, splices, hermetic feedthroughs, flow cells...), as well as **fiber modules** or mid-infrared **supercontinuum** sources.

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We can comply your needs with custom infrared solutions.

# Our products

Our **fluoride fibers** can be divided in **three main categories**:

**ZFG** (Zirconium  $\text{ZrF}_4$  Fluoride Glass) = fluorozirconate fibers  
Exhibit a high transparency from **0.3 up to 4.5  $\mu\text{m}$**

**IFG** (Indium  $\text{InF}_3$  Fluoride Glass) = fluoroindate fibers  
Exhibit a high transparency from **0.3 up to 5.5  $\mu\text{m}$**

**AFG** (Aluminium  $\text{AlF}_3$  Fluoride Glass) = fluoroaluminate fibers,  
generally used for **end capping** solutions.



PASSIVE FIBERS



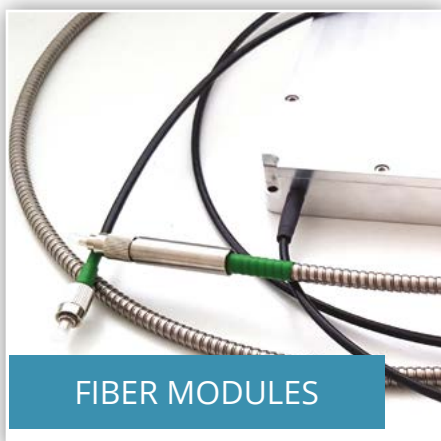
ACTIVE FIBERS



BULK FLUORIDE GLASSES



FIBER COMPONENTS



FIBER MODULES

Le Verre Fluoré provides **the most transparent fluoride fibers** of the market.

# Your applications



## INDUSTRY



Fluoride glass is a key technology for many mid-infrared industrial applications.

### Process control

#### Mid-IR spectroscopy

Many molecules used in industry exhibit spectral absorption in the 2-5.5  $\mu\text{m}$  range. LVF offers a large portfolio of solutions to transmit mid-IR light in industrial environment.

#### Wet paint thickness sensor

LVF has developed and patented a complete solution to measure in real-time paint thickness for coil coating and metallic packaging: Targazh.

#### Mid-IR ellipsometry, mid-IR OCT

Leukos and LVF are associated to propose robust, efficient and cost-effective mid-infrared supercontinuum laser sources: Electro-MIR.

### Material processing

#### Glass cutting

2.8  $\mu\text{m}$  is the most relevant wavelength to cut glass. A 100 W CW laser emitting @2.8  $\mu\text{m}$  is under development.

#### Plastic cutting

3.5  $\mu\text{m}$  is a very relevant wavelength to cut plastic. 5 W CW laser already allows plastic cutting.

#### QCL/ICL pigtail

Thanks to its low Fresnel losses (4% typical, 1% with AR coating) and its high transmission up to 5.5  $\mu\text{m}$ , InF3 fibers are the natural solution for QCL/ICL pigtail.



## RESEARCH



Thanks to its outstanding properties, fluoride glass allows innovative laser developments from UV to mid-infrared.

### Fluoride glass fiber lasers

LVF has hundreds of rare-earth doped fibers in stock and can design and manufacture custom fibers for lasers & amplifiers.

### Mid-IR spectroscopy and optical measurements

LVF proposes patch cables and bundles for optical set-up.

### Mid-IR supercontinuum

Thanks to their performances, LVF non linear single mode fibers allow very flat and broadband output spectrum.

### Fluorescence

LVF manufactures custom rare earth doped fluoride glass bulks for fluorescence studies.



# Your applications



## MEDICAL



Fluoride glass technology allows very efficient transmission and laser emission from UV to mid-infrared. Thanks to the many rare-earth available transitions, LVF commercializes also a wide range of fluorescent solid-state dyes.

### Er:YAG laser fiber delivery

LVF offers high power end caps that handles several hundreds of mJ per pulse of Er:YAG laser. High power fiber patch cable for Er:YAG laser delivery will be commercialized in 2021.

### 2.8 $\mu\text{m}$ fiber laser

2.8  $\mu\text{m}$  fiber lasers (10 W CW) for dentistry, surgery, dermatology are commercialized since 2019 by LumIR Lasers, a spin-off of COPL and LVF.

### Mid-IR diagnosis

Mid-IR supercontinuum, backscatter probes and cables are key components for mid-IR diagnosis.

### Solid-state fluorescent dyes

LVF offers rare earth doped glass fluorescent dyes for yellow, red, green fluorescence...



## ASTRONOMY



Since 1987, LVF is the reference company for astronomy developments operating in K-band (1.9  $\mu\text{m}$  – 2.4  $\mu\text{m}$ ). For more than 35 years, cutting edge solutions and mid infrared fibers have been developed to comply needs of the most innovative astronomical projects.

### Telescope coupling

Ultra low-loss, low birefringence, low dispersion single mode ZBLAN fiber in K-band (1.9  $\mu\text{m}$  – 2.4  $\mu\text{m}$ ).

### Mode scrambling

Octagonal core multimode fiber for mode scrambling in K-band.

### Polarization rotator

Fluoride fiber subsystem to align interferometer arms polarizations in order to optimize its contrast.

### Differential delay line

Low birefringence and homogeneous fiber segments in terms of dispersion to equilibrate optical paths.

### Fused X fiber coupler

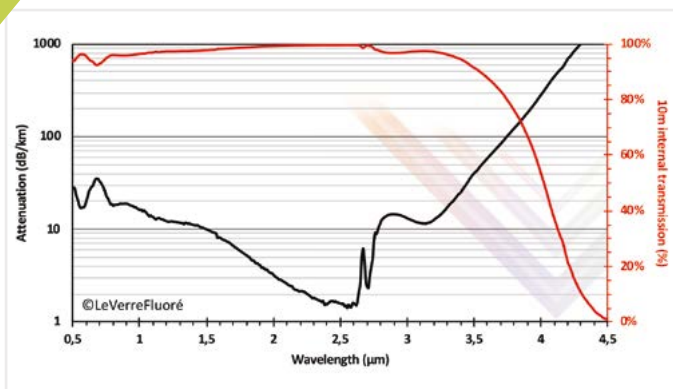
centered @ 2.2  $\mu\text{m}$ .

Projects involving Le Verre Fluoré Mid IR fiber technology include: AVIRIS, FLUOR, OHANA, GRAVITY, SPIRou, SPIP, EXOMARS.

**Consult our website to learn more**



## Discover our range of standard ZFG multimode fibers

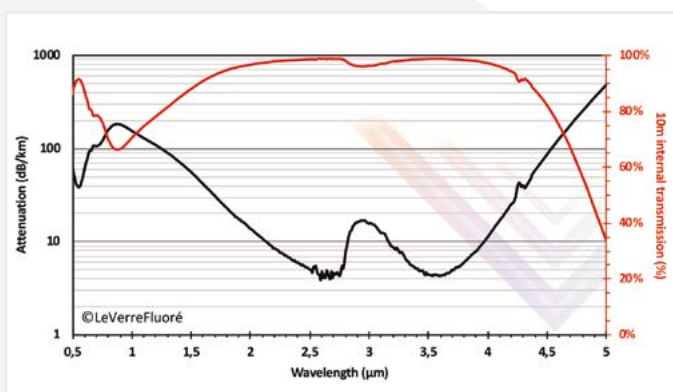


### Specifications

Operating wavelength	0.3 – 4.5 μm
Typical optical loss @ 2.5μm	< 10 dB/km
Fresnel loss (backwards reflection)	4% per face (air)
Coating material	UV curable acrylate
Operating temperature	– 180 to 150 °C

Standard fiber	Core/ clad diameter	Numerical aperture	Short term bend radius	Long term bend radius	Price/m
ZFG MM (0.15) 90/150	90/150 μm	0.15	≥ 15 mm	≥ 45 mm	25 €
ZFG MM (0.20) 100/160	100/160 μm	0.20	≥ 15 mm	≥ 45 mm	55 €
ZFG MM (0.20) 200/260	200/260 μm	0.20	≥ 25 mm	≥ 75 mm	80 €
ZFG MM (0.20) 300/360	300/360 μm	0.20	≥ 35 mm	≥ 100 mm	160 €
ZFG MM (0.20) 400/460	400/460 μm	0.20	≥ 45 mm	≥ 120 mm	240 €
ZFG MM (0.20) 600/680	600/680 μm	0.20	≥ 70 mm	≥ 150 mm	480 €

## Discover our range of standard IFG multimode fibers

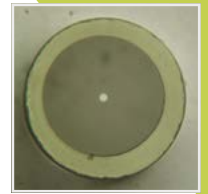


### Specifications

Operating wavelength	0.3 – 5.5 μm
Typical optical loss @ 3.5μm	< 10 dB/km
Fresnel loss (backwards reflection)	4% per face (air)
Coating material	UV curable acrylate
Operating temperature	– 180 to 150 °C

Standard fiber	Core/ clad diameter	Numerical aperture	Short term bend radius	Long term bend radius	Price/m
IFG MM (NA) 100/160	100/160 μm	0.20/0.30	≥ 15 mm	≥ 45 mm	90 €
IFG MM (NA) 200/260	200/260 μm	0.20/0.30	≥ 25 mm	≥ 75 mm	140 €
IFG MM (NA) 300/360	300/360 μm	0.20/0.30	≥ 40 mm	≥ 100 mm	315 €
IFG MM (NA) 400/460	400/460 μm	0.20/0.30	≥ 55 mm	≥ 120 mm	560 €
IFG MM (NA) 600/680	600/680 μm	0.20/0.30	≥ 90 mm	≥ 150 mm	1120 €

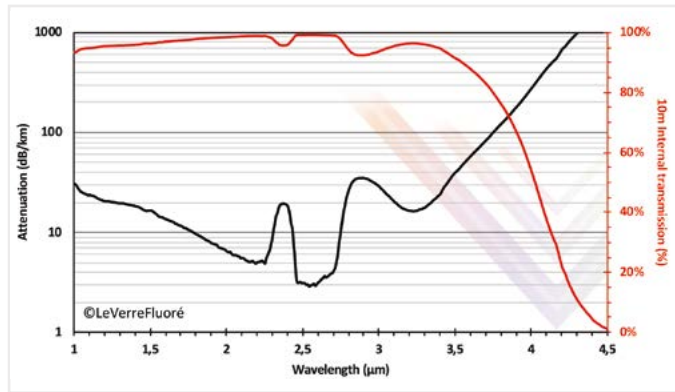
## Discover our range of standard ZFG single mode fibers



Single mode

Note that, thanks to their non linear properties, our single mode fibers are widely used for supercontinuum generation and are integrated in commercial supercontinuum sources Electro-MIR 4100 and 4800, developed in collaboration with LEUKOS.

*Find out more about our fiber non linear properties on our website.*

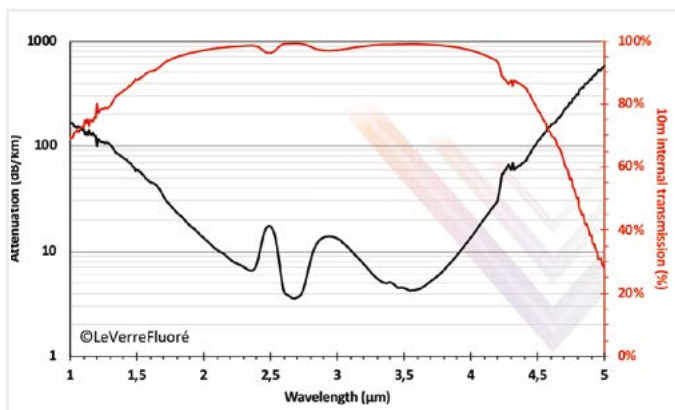


### Specifications

Typical background loss	< 10 dB/km
Fresnel loss (backwards reflection)	4% per face (air)
Coating material	UV curable acrylate
Operating temperature	- 180 to 150 °C

Standard fiber	Core/ clad diameter	Numerical aperture	Cutoff wavelength	Operating wavelength	Short term bend radius	Long term bend radius	Price/m
ZFG SM [1.95] 6.5/125	6.5/125 μm	0.23	1.95 μm	0.3-3.90 μm	≥ 15 mm	≥ 45 mm	40 €
ZFG SM [2.55] 8.5/125	8.5/125 μm	0.23	2.55 μm	0.3-4.5 μm	≥ 15 mm	≥ 45 mm	110 €
ZFG SM [2.2] 7.5/150	7.5/150 μm	0.23	2.2 μm	0.3-4.0 μm	≥ 15 mm	≥ 45 mm	155 €
ZFG SM [2.3] 14/250	14/250 μm	0.125	2.3 μm	0.3-4.1 μm	≥ 25 mm	≥ 75 mm	330 €

## Discover our range of standard IFG single mode fibers

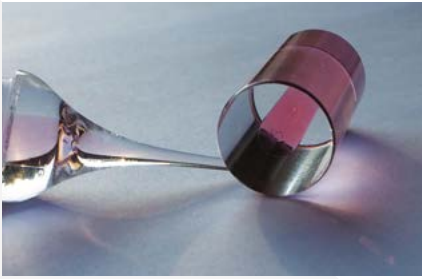


### Specifications

Typical background loss	< 15 dB/km
Fresnel loss (backwards reflection)	4% per face (air)
Coating material	UV curable acrylate
Operating temperature	- 180 to 150 °C

Standard fiber	Core/ clad diameter	Numerical aperture	Cutoff wavelength	Operating wavelength	Short term bend radius	Long term bend radius	Price/m
IFG SM [2.95] 7.5/125	7.5/125 μm	0.30	2.95 μm	0.3-5.5 μm	≥ 15 mm	≥ 45 mm	200 €
IFG SM [3.3] 8.5/125	8.5/125 μm	0.30	3.3 μm	0.3-5.5 μm	≥ 15 mm	≥ 45 mm	200 €
IFG SM [3.7] 9.5/125	9.5/125 μm	0.30	3.7 μm	0.3-5.5 μm	≥ 15 mm	≥ 45 mm	200 €

## Discover our range of active rare earth doped fibers

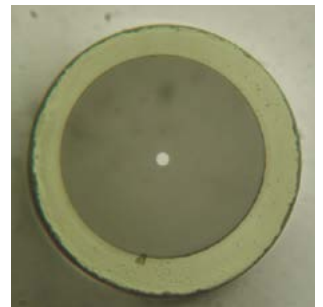


Thanks to their high rare earth solubility (Er, Ho, Tm, Dy, Pr, Yb, Nd, Ce, Sm... up to 100 000 ppm) and low phonon energy, dozens of transitions are active in fluoride glasses.

As a result, combined to their high transparency, fluoride fibers are used for **laser generation** and **amplification** in **mid-infrared** range, but also in **visible** range.

### Some single mode fibers (not exhaustive)

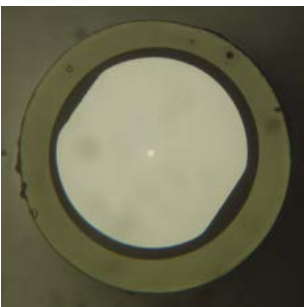
Rare earth	Molar content	Øcore/clad	Cutoff wavelength	Typical application
Tm	5000 ppm	3/125 µm	0.9 µm	Laser and amplifier (TDFA) around 1.5 µm
Dy	2000 ppm	12.5/125 µm	2.6 µm	<ul style="list-style-type: none"> <li>• Yellow laser</li> <li>• Laser around 3.32 µm</li> <li>• Emission around 4.3µm</li> </ul>
Ho	5000 ppm	7.5/125 µm	2.4 µm	Laser around 2.9 µm



### Some double-cladding fibers (not exhaustive)

LVF delivers a large variety of ZFG or IFG double cladding fibers. Most of them exhibit a double D-shape on the first cladding in order to improve the pump absorption.

Hereinbelow, some significant realizations with LVF RE-doped fibers.



Rare earth	Molar content	Øcore/clad	Cutoff wavelength	Typical application
Erbium	70 000 ppm	15/240*260/290 µm (also available as PM)	2.5 µm	Laser around 2.9 µm
Erbium	10 000 ppm	16.5/240*260/290 µm	2.7 µm	Laser around 3.5 µm
Holmium	100 000 ppm	16/90*100/155 µm	4.2 µm	Laser around 3.9 µm
Praseodymium Ytterbium	3 000 ppm 20 000 ppm	5/125/200 µm	1.3 µm	Visible lasers
Undoped		14/250/290 µm	2.3 µm	

### Standard rare earth doped fibers prices

Fiber	Specifications	Price/m
ZFG single mode fiber	Øclad = 125 µm	220 €
IFG single mode fiber	Øclad = 125 µm	300 €
ZFG double cladding double D-shape Er-doped fiber	Øcore/1 <sup>st</sup> clad/2 <sup>nd</sup> clad = 15/240*260/290 µm (λc = 2.2 µm)	600 €

λc : cutoff wavelength



## Discover our range of **fiber patch cables**

Any Passive or Active fiber manufactured by LVF can be wired.

### Main features:

- Standard cable length: up to 50 m
- Connectors: SMA 905, FC/PC, FC/APC, Diamond, custom
- Protective standard tubing : hytrel, Kevlar, stainless steel jacket or peek



### Examples of fiber patch cables specifications

	Standard fiber	Price per cable 1m / 2m
SINGLE MODE	ZFG SM [1.95] 6.5/125	182 € / 229 €
	IFG SM [2.95] 7.5/125	342 € / 549 €
MULTIMODE	ZFG MM (0.20) 200/260	222 € / 309 €
	IFG MM (0.20) 200/260	282 € / 429 €

### Insertion loss – core/ferrule eccentricity

Standard connector	< 2µm
Optimized connector	< 0.5µm (+100€)



## Discover our range of **fiber bundles and probes**



### Fiber bundles & backscatter probes main features

Fiber content	Up to hundreds
Fiber arrangement	Linear, round, square... Coherent or not

- Splitting light source into several channels
- Combining light from several sources
- Qualified for **harsh environment**
- Qualified for **industrial use**

## Discover our range of **hermetic feedthroughs**



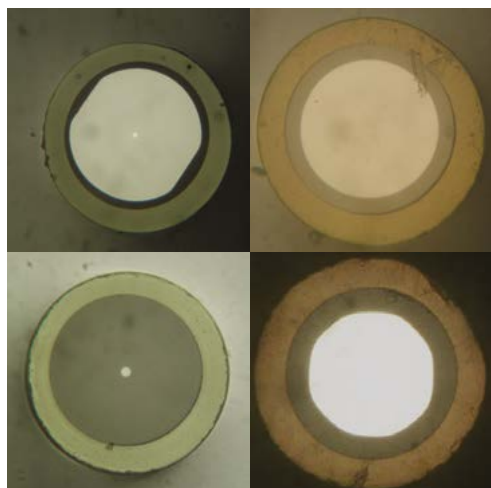
Our hermetic feedthroughs are compatible with any wired active or passive fiber.

- Customized number of channels
- Housing material: stainless steel
- With standard flange or not (stand alone)
- Qualified **up to 1.5 10<sup>-9</sup> mbar.l.s<sup>-1</sup>**
- Qualified for **industrial use**

## Discover our range of **custom fibers** and **bulk glasses**

If you cannot find a fiber that complies your needs among our **hundreds of designs in stock**, LVF experts will support you to design a **fiber dedicated** to your **application**.

### Customize!



	SINGLE MODE	MULTIMODE
Core size	$\geq 1 \mu\text{m}$	Up to $1000 \mu\text{m}$
Numerical aperture	0.06-0.35	0.12-0.32
Cut off	$\geq 200 \text{ nm}$	NA
Rare earth	Doped or co-doped (Er, Ho, Dy, Tm, Pr, Yb, Sm, Ce, ...) Up to 100 000 ppm	
Specificity	<ul style="list-style-type: none"> <li>• Double Cladding (Circular, Double D-Shape or Octagonal 1<sup>st</sup> clad)</li> <li>• Polarization Maintaining</li> </ul>	<ul style="list-style-type: none"> <li>• Octogonal core</li> <li>• Double cladding</li> </ul>
Minimum order quantity	From 8000€ depending on design	From 5000€ depending on design

### Splices & end caps



In order to ensure **long term stability** of fluoride fiber systems in case of applications such as laser generation or Er-YAG laser delivery, LVF offers end capping solutions.

Main benefits are:

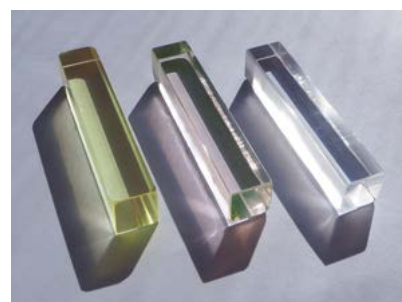
- Reduced **power density** at the output face
- Protection of the fiber tip in case of **emission around  $2.8 \mu\text{m}$**

LVF provides **fluoride splices** between multimode, single mode or double cladding fibers. **Silica-fluoride splices** are also possible depending on requirements.

### Bulk glasses and fluorescent solid-state dyes

LVF can provide any kind of **bulk fluoride glasses** such as parallelepipeds, ribbons, rods or tubes, prisms...

Those bulks can be doped with **rare earths** (Er, Pr, Ho, Tm, Dy,...) depending on your requirements. Homogeneous doping.



### Typical bulk specifications

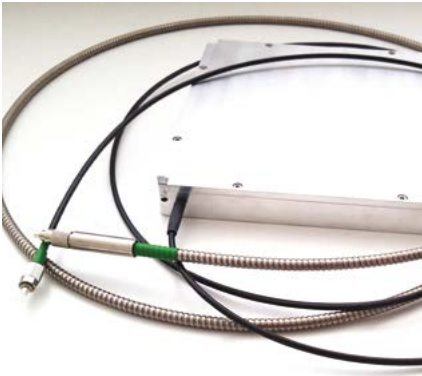
RE concentration	$\pm 100 \text{ ppm}$	
Polishing	Standard grade	High grade
Thickness tolerance	$\pm 100 \mu\text{m}$	$\pm 10 \mu\text{m}$
Width tolerance	$\pm 200 \mu\text{m}$	$\pm 50 \mu\text{m}$
Surface roughness (*)	70 Angstrom RMS	50 Angstrom RMS
Defects in polished surface (*)	–	20/10 Scratch/Dig

(\*) other grades available upon special request

Bulk fluoride glasses can be used for fluorescence or wavelength calibration in **UV, visible** and **mid-infrared** range, as well as for glass science, studying specific properties of fluoride glasses.

Main applications: calibration of UV sources with visible sensors (UV to VIS light conversion), calibration of spectrometers and imagers...

## Discover our range of mid-infrared solutions



### Fiber modules (laser, amplifier)

In order to make our fibers **easier to handle** and **directly integrable** in a final commercial system, LVF can deliver fiber modules.

The required fiber length is integrated in a **robust housing** and connectorized with FC/PC, FC/APC, SMA or custom connectors depending on customer need. This is a **plug-and-play** module.

Depending on power requirements, an **endcap** might also be spliced at the input and/or output of the fiber.

### Supercontinuum sources

**Electro-MIR 4100** and **4800** are the commercial supercontinuum sources born from **LVF** over 40 years' experience in fluoride fibers and **LEUKOS** over 10 years' experience in the field of supercontinuum laser.

Thanks to their high brightness from 700 up to 4100 or 4800 nm, they are an ideal solution for mid infrared applications such as infrared spectrometry, spectral fingerprinting and countermeasures (IRCM).

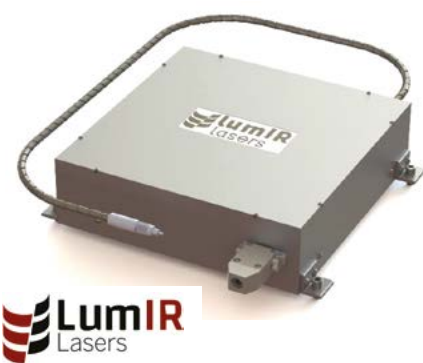
**Robust** and **compact**, unique solutions are proposed in order to ensure **long term reliability** and **industrial compliance**.

**LEUKOS**  
Make a bright future



### Continuous wave 2.8 lasers

Experts at Quebec City's **COPL** – premier research center for midinfrared fiber lasers - and **LVF** have teamed up to launch **LumIR Lasers**, a new force for innovation in mid-IR fiber lasers.



**LumIR 2800** lasers delivers affordable 2.8  $\mu\text{m}$  CW fiber lasers available in 1 to 10 W output powers. All products are currently available as OEM solutions ready to bring unprecedented capabilities to your application, particularly for medical (dentistry, skin resurfacing, ...), industrial (polymer processing, food marking, ...) or research purposes.

**LumIR 3200** laser emitting at 3.1-3.3  $\mu\text{m}$  with power up to 5 W is planned for release in 2021.

### Flow cells

LVF flow cells will allow you to **analyze liquid samples** flowing in the cell by the way of a crosswise **optical control** in both **UV, visible and mid-infrared**.

- Qualified for **industrial infrared spectroscopy** from 0.3 up to 5.5  $\mu\text{m}$
- Liquids and gases analysis
- Qualified for **harsh environment**
- Standard SMA 905, FC/PC, FC/APC and custom connector adapters





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