Flexible Solutions for Mid-IR Photonics: IR-Fibers and Hollow Waveguides
Polycrystalline IR-fibers (PIR-fibers) extruded from AgCl:AgBr crystals with sub-micron structure are the best for 3-17µm. They are non-toxic, non-hygroscopic, and very flexible.
CIR-Fibers – the best for spectral range 1-6(9)µm

Chalcogenide IR (CIR-) Glasses: As-S, As-Se, As-Se-Te, etc.

Advantages
- Transmittance in 0.7-6µm (As-S) or in 2-11µm range (GeAsSeTe)
- Stable for 250-400K
- Non-hygroscopic

Drawbacks
- Brittle
- Toxic
- Low Tg (450K)
- High dn/dT

Applications
- Spectroscopy Probes for gases & liquids
- Flexible Radiometry
- IR-imaging bundles
- Fiber cables for QCL & IR-LED

*1. Kapany, N.S. & Simms, R. J., "Recent developments of infrared fiber optics," Infrared Physics, vol. 5, pg. 69, 1965
### Crystalline Fibers & Hollow Waveguides for 0.5-18µm

<table>
<thead>
<tr>
<th>Crystal Fiber Type</th>
<th>Advantages</th>
<th>Drawbacks</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sapphire Al-O Fiber</strong></td>
<td>• 0.5-3.4µm range</td>
<td>• No cladding</td>
<td>• High Power Delivery for Er-Laser Surgery</td>
</tr>
<tr>
<td><strong>Single-Crystalline</strong></td>
<td>• Non toxic</td>
<td>• Stiff &amp; Brittle</td>
<td>• Spectroscopy Probes</td>
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<tr>
<td></td>
<td>• Stable up to 2000°C</td>
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<tr>
<td><strong>Polycrystalline IR-PIR-Fibers:</strong></td>
<td>• Transmittance in the broadest 3-18µm range</td>
<td>• High scattering from 0.6 to 3µm</td>
<td>• Spectroscopy Probes</td>
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<tr>
<td><strong>Extruded from Silver Halide (Thallium Halide) solid solutions</strong></td>
<td>• Non-brittle</td>
<td>• Slightly UV-sensitive</td>
<td>• Flexible Radiometry/Pyrometry</td>
</tr>
<tr>
<td></td>
<td>• Non toxic</td>
<td>• Corrosive in contact with some Metals</td>
<td>• IR-imaging bundles</td>
</tr>
<tr>
<td></td>
<td>• Non-hygroscopic</td>
<td></td>
<td>• Power delivery (50W) for CO-/CO2-lasers</td>
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<td></td>
<td>• Stable in 5–600K</td>
<td></td>
<td>• Fiber cables for QCL &amp; IR-LED</td>
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<tr>
<td><strong>Hollow Waveguides (HWG)</strong></td>
<td>• High Transmittance</td>
<td>• Sensitive to bending (3dB at 10cm radius)</td>
<td>• High Laser Power Delivery for Er:YAG, CO- &amp; CO2-lasers</td>
</tr>
<tr>
<td><strong>Silica or Polymer tubes with inner reflective coating</strong></td>
<td>• High Laser Damage</td>
<td>• High losses for NA&gt;0.1</td>
<td>• Spectral sensors for gas flow through hollow waveguide cell</td>
</tr>
<tr>
<td><strong>+ Omniguide – hollow 1D photonic crystals with inner multi-layer mirror</strong></td>
<td>• Threshold (&gt;2kW) for Er:YAG / CO2-lasers</td>
<td>• Interference spectral bands (see slide later)</td>
<td>*Omniguide hollow PC-fibers – enables high transmission in 9-11µm to be used for medical CO2-lasers &lt;15W</td>
</tr>
<tr>
<td></td>
<td>• No Fresnel reflection</td>
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</tbody>
</table>

*Omniguide hollow PC-fibers – enables high transmission in 9-11µm to be used for medical CO2-lasers <15W

**Hollow OmniGuide 1D-photonic crystals transmits better under bending vs HWG**

**Hollow OmniGuide 1D-photonic crystals contains toxic glass in multi-layer mirror**
AgHal PIR-Fiber – the best for IR-imaging in 4-16µm

PIR-fiber transmission range is in perfect match with Spectral Radiance of Black Body at 0-100°C

TE-cooled MCT-detectors from VIGO (TO8-package)

EPIC Online Technology Meeting on Mid-IR Photonics

Slava, sa@art photonics.com
PIR-fibers - the best for Flexible IR-imaging in 4-16µm

Securus PIR-Fiber IR-Endoscope

19xPIR-fiber bundle for OPTRIS IR-Camera

16xPIR-fiber bundle

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Hollow Waveguides Design for CO- or CO2-Lasers

HWG from Polymicro for CO2-laser and from Rutgers Uni for CO-laser
(Tests made with FTIR spectrometer Bruker Matrix-MF, MCT detector)

Transmission for: CO2-laser / CO-laser

- Polymicro 2 m: 79% (CO2), 10% (CO)
- Polymicro 4 m: 68% (CO2), 8% (CO)
- Harrington-1: 63% (CO2), 80% (CO)
- Harrington-2: 63% (CO2), 75% (CO)

United States Patent

US005440664A
Patent Number: 5,440,664
Harrington et al.
Date of Patent: Aug. 8, 1995

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Slava, sa@artphotonics.com
PIR-Fiber & Hollow Waveguide Cables for CO-, CO2- & Quantum Cascade Lasers

- The most flexible cables for CO- & CO2-laser power delivery
- Stable transmission under small bending radius
- SMART-technology to suppress Fresnel reflection losses

PIR-fiber coupled 7xQCL-System

CO- & CO2-lasers:

COHERENT

SMART - Special Micro Anti-Reflection Treatment

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Slava, sa@artphotonics.com
CIR- & PIR-fiber ATR-probes for FTIR-spectrometers

Transmission spectra of ATR probes.

- Probe length 1.5m

- D-ATR
- ZnSe
- Si
- Zr-O

Process Control with ATR-Probe coupled FTIR

HT-ATR-Probe (gas cooled) at 220°C