Slava Artyushenko, *art photonics GmbH, Berlin*

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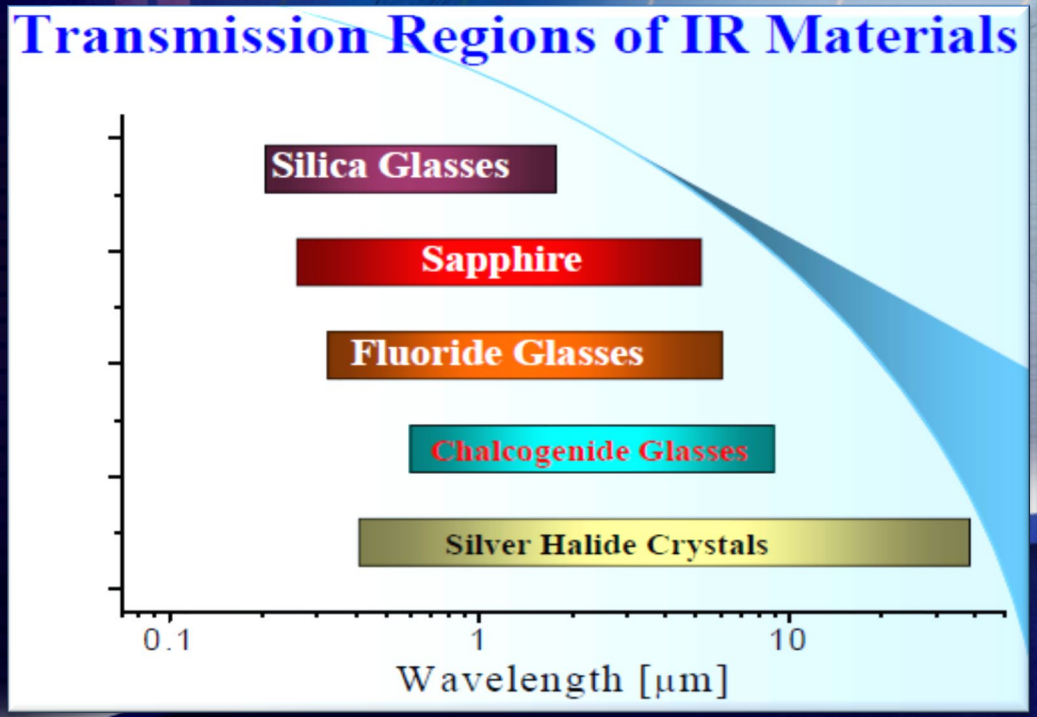
Flexible Solutions for Mid-IR Photonics: IR-Fibers and Hollow Waveguides



EPIC Online Technology Meeting on Mid-IR Photonics

EPIC
European Photonics Industry Consortium

Fibre Material Solutions in 0.25-16µm range

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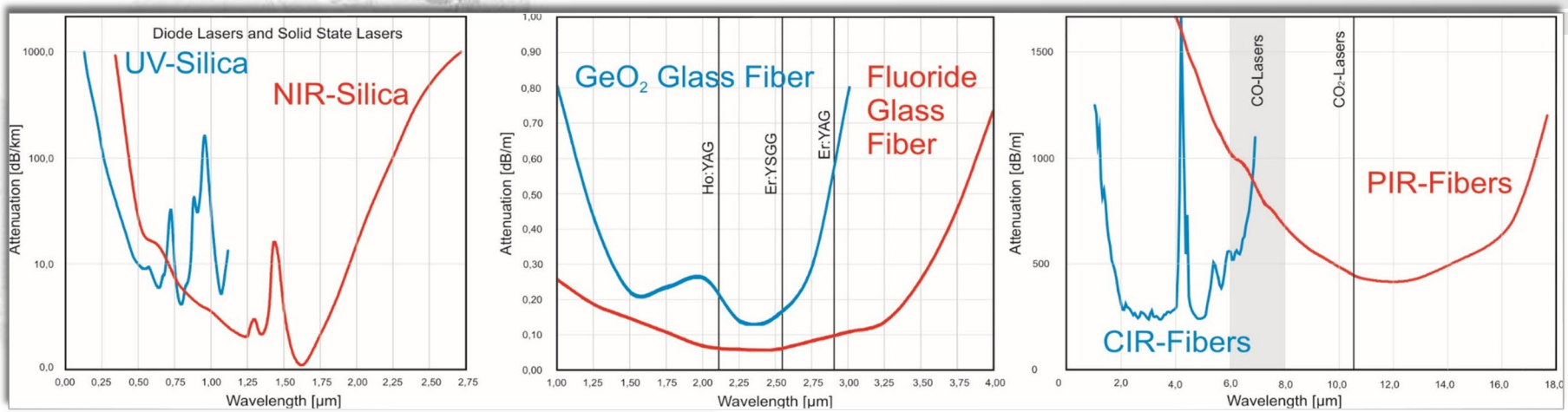

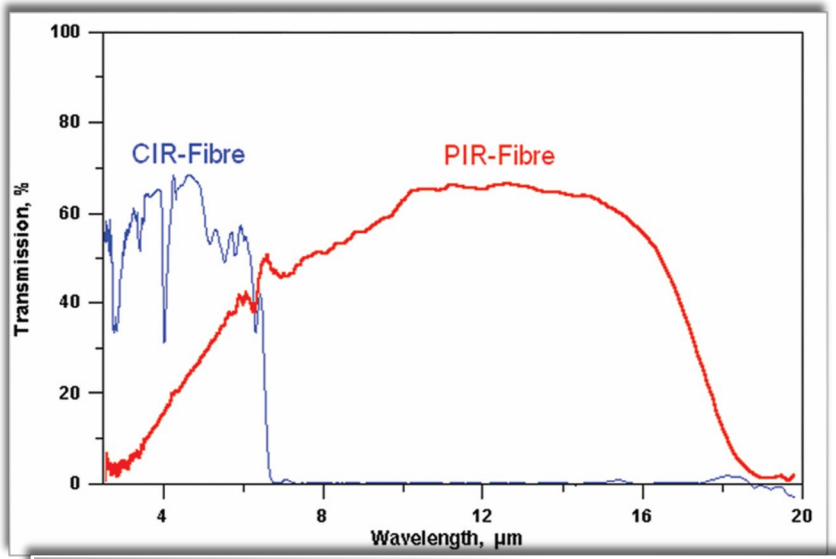

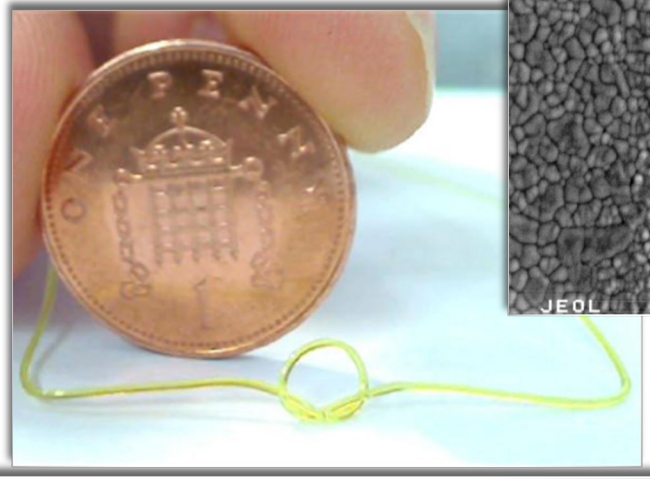

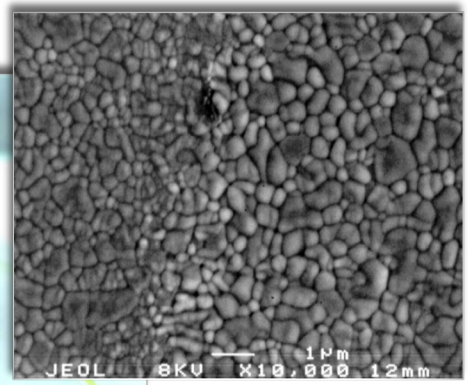

Polycrystalline IR-fibers (PIR-fibers) extruded from AgCl:AgBr crystals with sub-micron structure are the best for 3-17µm. They are non-toxic, non-hygroscopic, and very flexible

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CIR-Fibers – the best for spectral range 1-6(9)μm

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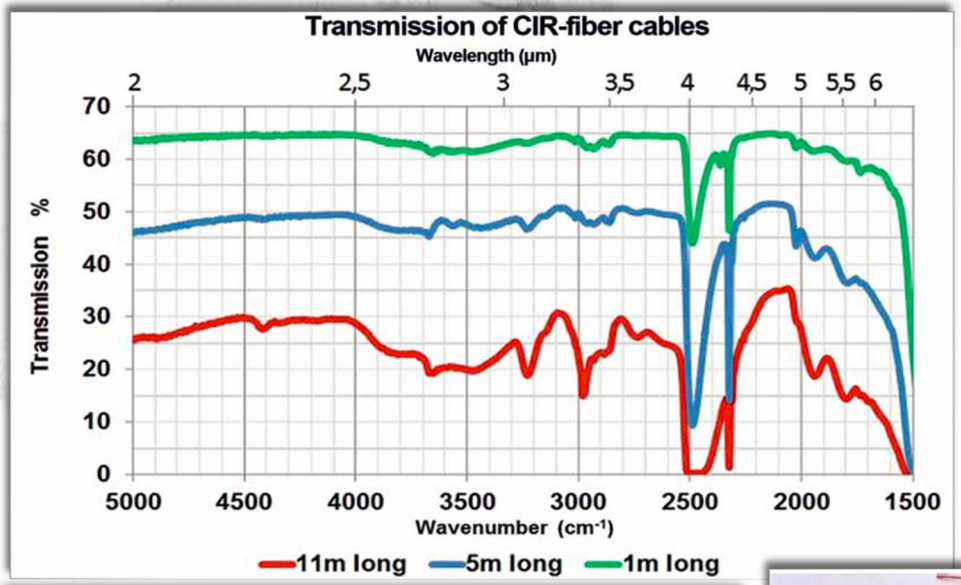
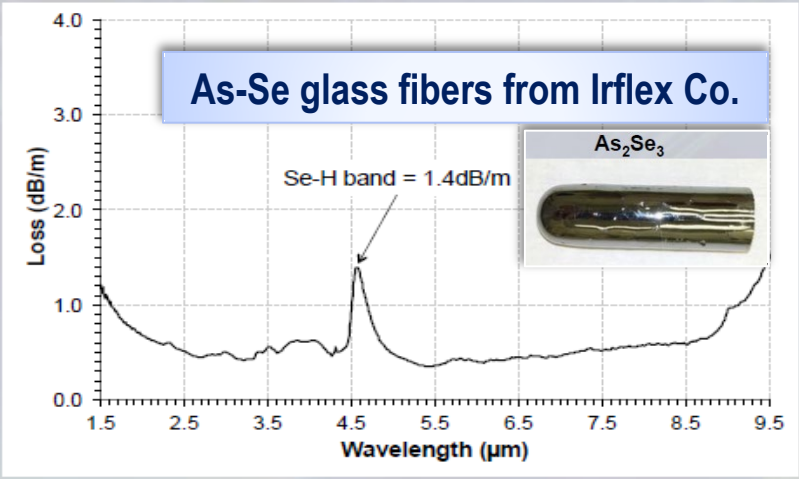
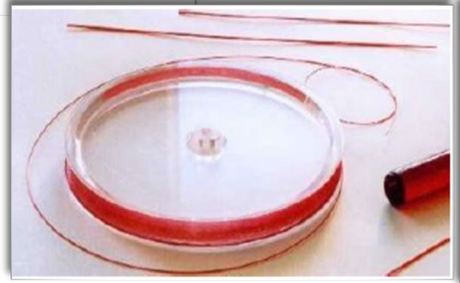
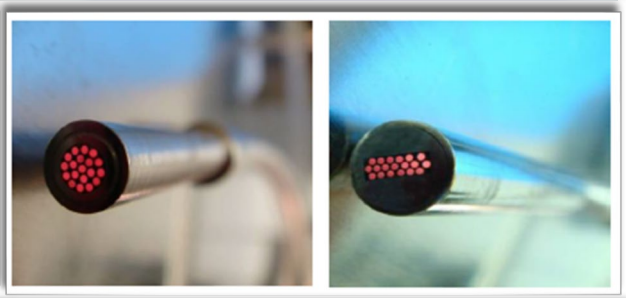


- Transmission window: 1.5μm to 9.5μm
- Minimum Loss: <0.5 dB/m at 5.5μm



CIR-fibers & bundles from As-S glass





**1. Kapany,N.S. & Simms,R. J.,*
"Recent developments of infrared fiber optics,"
Infrared Physics, vol. 5, pg. 69, 1965

Fiber Glass Type	Advantages	Drawbacks	Applications
Chalcogenide IR (CIR-) Glasses: As-S, As-Se, As-Se-Te, etc.	Transmittance in 0.7-6μm (As-S) or in 2-11μm range (GeAsSeTe) Stable for 250-400K Non-hygroscopic	• Brittle • Toxic • Low Tg (450K) • High dn/dT	• Spectroscopy Probes for gases & liquids • Flexible Radiometry • IR-imaging bundles • Fiber cables for QCL & IR-LED

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Crystalline Fibers & Hollow Waveguides for 0,5-18µm

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

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AgHal PIR-Fiber – the best for IR-imaging in 4-16µm

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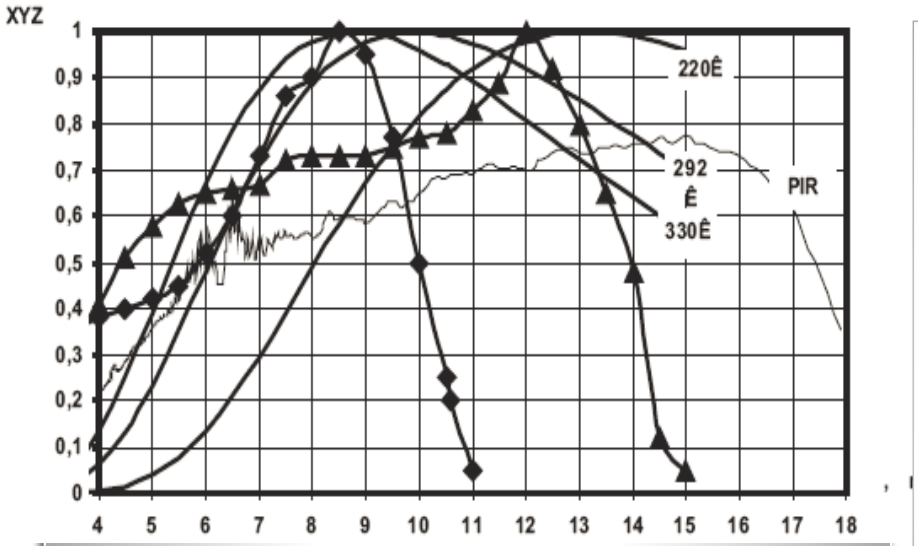
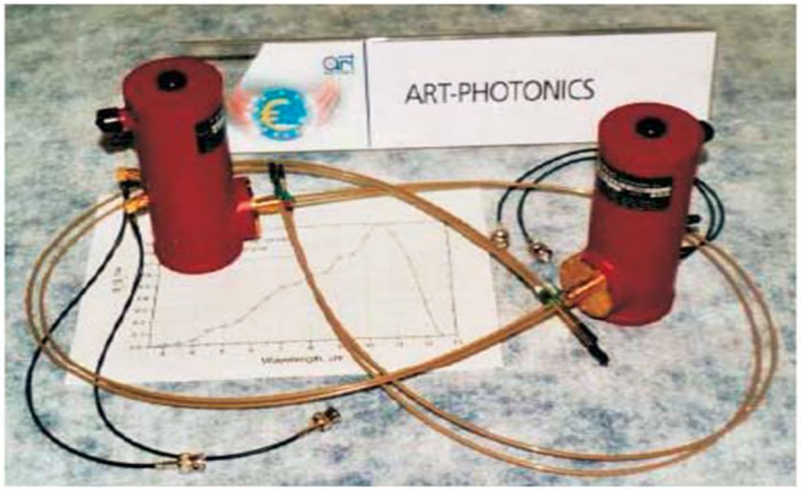


PIR-fiber transmission range is in perfect match with Spectral Radiance of Black Body at 0-100°C

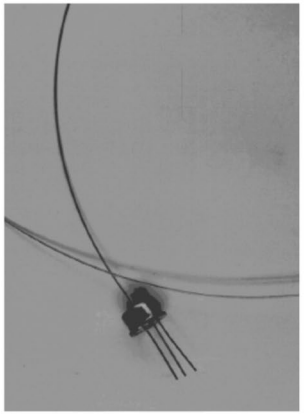


FIBRE-COUPLED
THERMOPILE INFRARED
RADIATION SENSOR

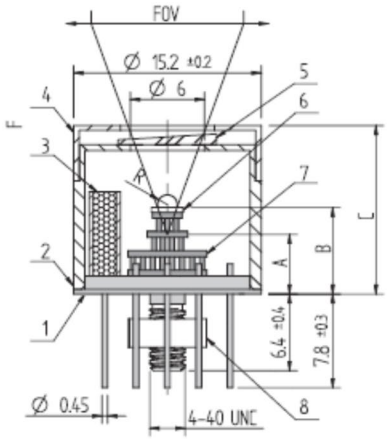
TS-100-PIR-fiber Sensor

FEATURES:

* Ambient Temperature Operation
* 4 – 18 µm Spectral Response
* Rugged Construction
* Flexible PIR-Fiber with 0.1-10m length
* Hermetically Sealed
* Excellent Long-Term Stability
* High Reliability
* Self-Generating Voltage
  No Bias Required
  No 1/f Noise



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



A – distance from the bottom, of the TO8 package to the focal plane

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PIR-fibers - the best for Flexible IR-imaging in 4-16µm

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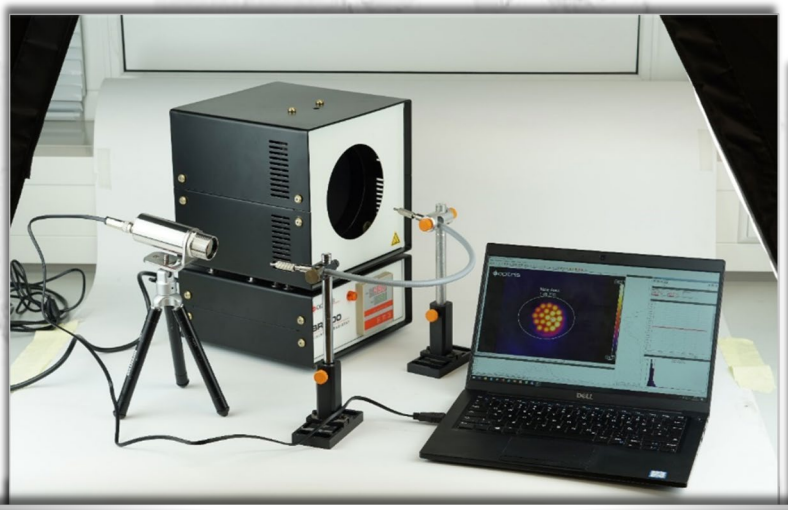
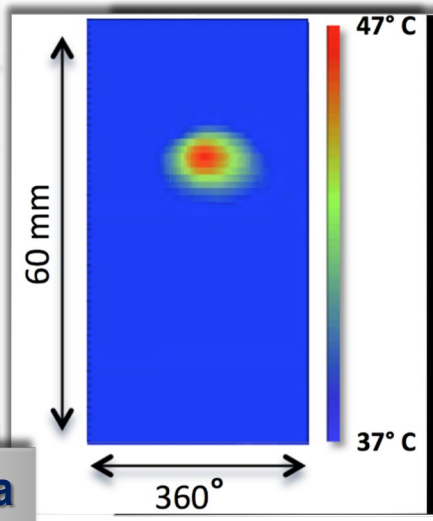
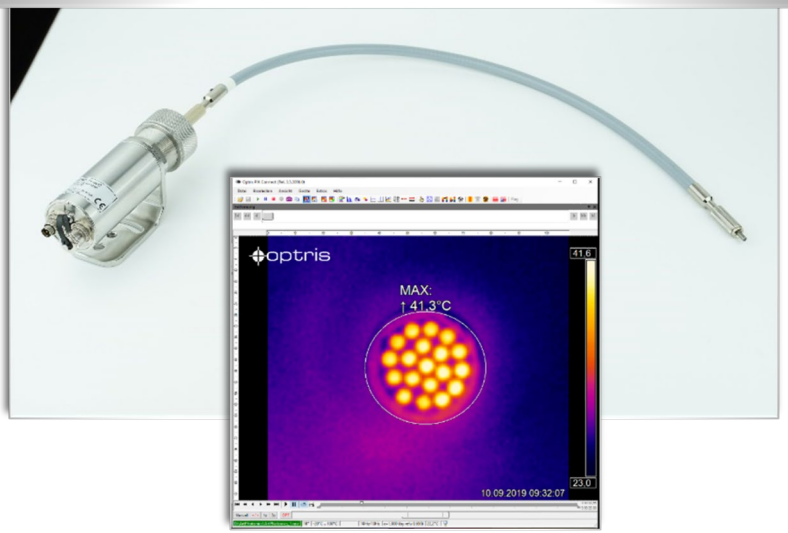


19xPIR-fiber bundle for OPTRIS IR-Camera

Securus PIR-Fiber IR-Endoscope





16xPIR-fiber bundle

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Hollow Waveguides Design for CO- or CO2-Lasers

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HWG from Polymicro for CO2-laser and from Rutgers Uni for CO-laser

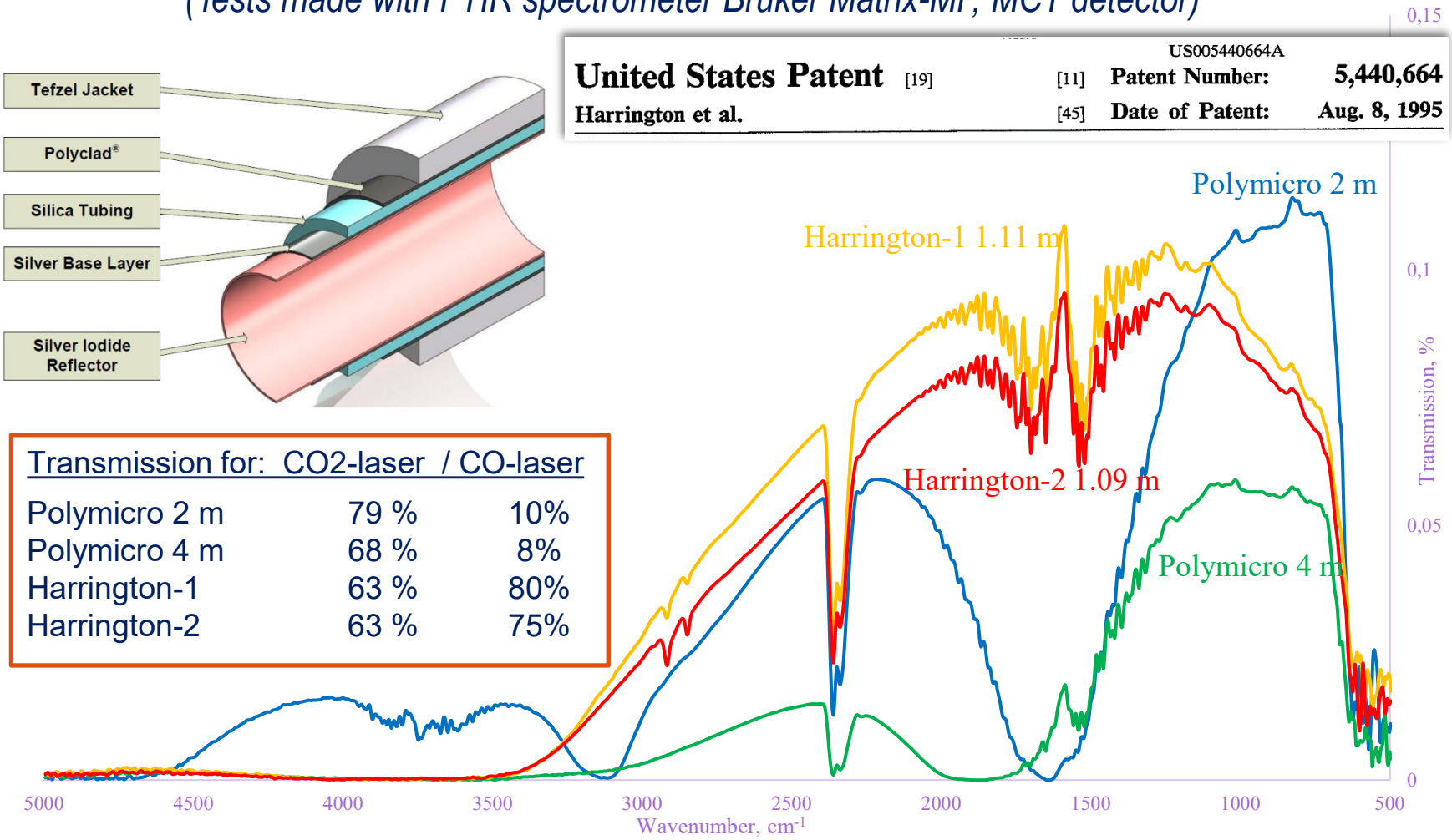
(Tests made with FTIR spectrometer Bruker Matrix-MF, MCT detector)

US005440664A

United States Patent [19] [11] **Patent Number: 5,440,664**

Harrington et al. [45] **Date of Patent: Aug. 8, 1995**

Transmission for: CO2-laser / CO-laser		
Polymicro 2 m	79 %	10%
Polymicro 4 m	68 %	8%
Harrington-1	63 %	80%
Harrington-2	63 %	75%



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PIR-Fiber & Hollow Waveguide Cables for CO-, CO2- & Qantum Cascade Lasers

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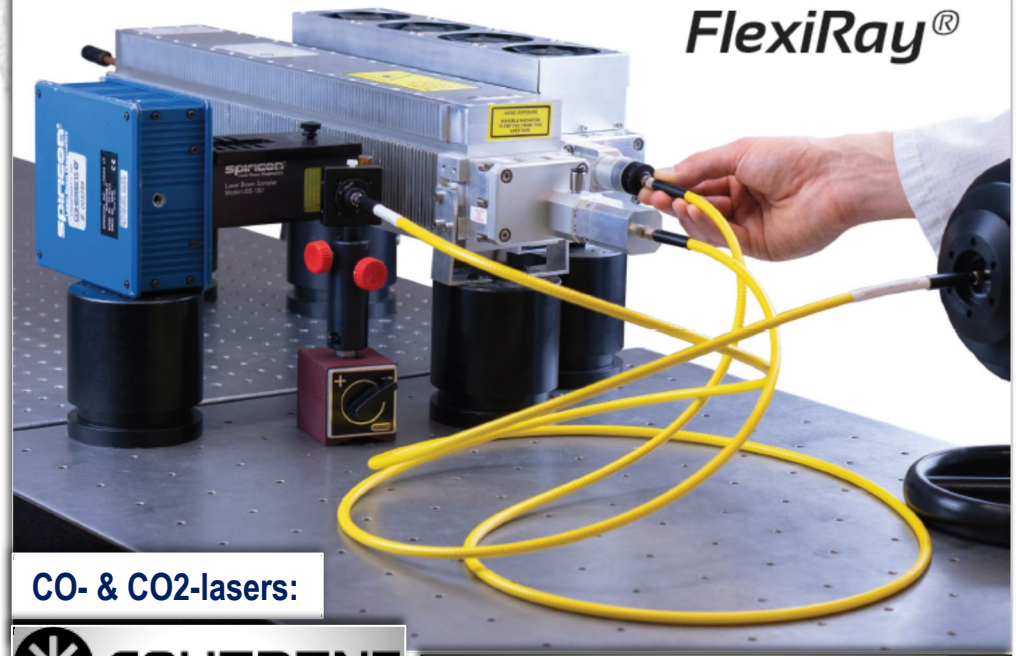
- The most flexible cables for CO- & CO_2-laser power delivery
- Stable transmission under small bending radius
- SMART-technology to suppress Fresnel reflection losses

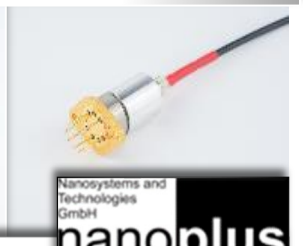
FlexiRay®



CO- & CO2-lasers:

COHERENT

PIR-fiber coupled 7xQCL-System



nanosystems and Technologies GmbH nanoplus

MIRACLE
miracleproject.eu

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CIR- & PIR-fiber ATR-probes for FTIR-spectrometers

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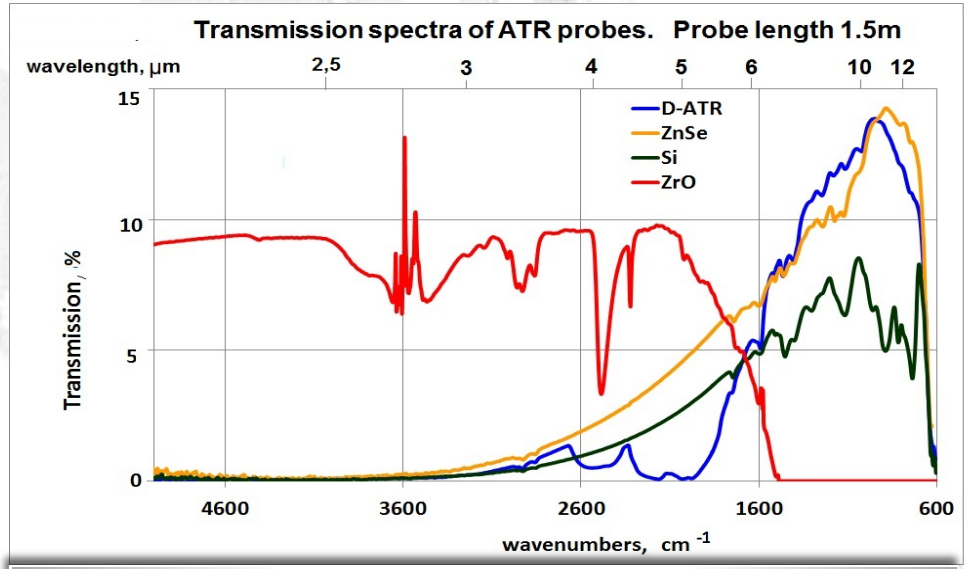
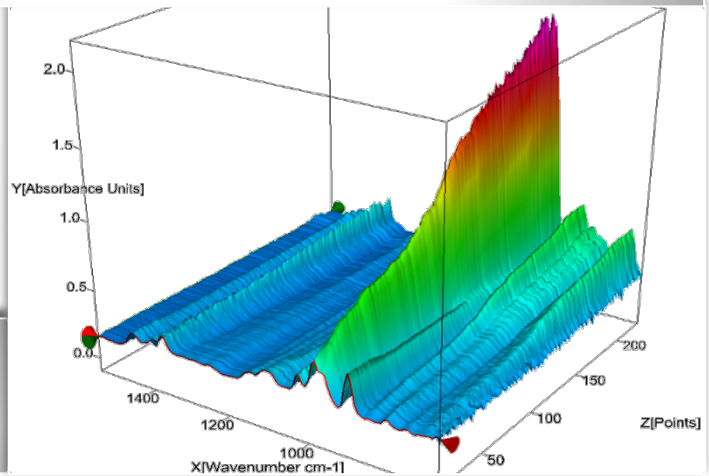


Process Control with ATR-Probe coupled FTIR

HT-ATR-Probe (gas cooled) at 220°C



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