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LumaSense Technologies

Specialty Techniques for Monitoring Process Temperature & Gas Concentrations

Phosphorescent Decay
Infrared Radiation
Photoacoustic Spectroscopy

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LumaSense Is A Global Company With Decades of Experience In Multiple Sensing Technologies

LumaSense Technologies

Luxtron	Mikron	Impac	Innova AirTech Instruments	Andros
Fiber Optic Temp *1978, California, US*	Thermal Imaging *1969, New Jersey, US*	Non-Contact Temp *1958, Germany*	Gas Analyzers *1975, Denmark*	Gas Analyzers *1969, California, US*

LumaSense Technologies Key Facts:

- ~250 employees in nine sites worldwide
- Multiple Decades of experience serving various OEMs
- Deep applications engineering talent in multiple disciplines
- Core competency in gas analysis
- Financial strength and profitability
- Offices in 9 countries
- Headquarters in California, USA

Five product families all based on different types of optical technologies

- Two gas analysis product families based on distinct technologies
  - Non-Dispersive Infrared
  - Dispersive Infrared
  - Photo-Acoustic Spectroscopy
- Three temperature product families
  - Fiber optic
  - Non-Contact Infrared (pyrometers)
  - Thermal Imaging

Luxtron Fluoroptic: Benefits / Advantages

Immune

- Unaffected by EMI, Microwave and RF Interferences
- Electrically Non-conductive Fiber Optic Temp Probes

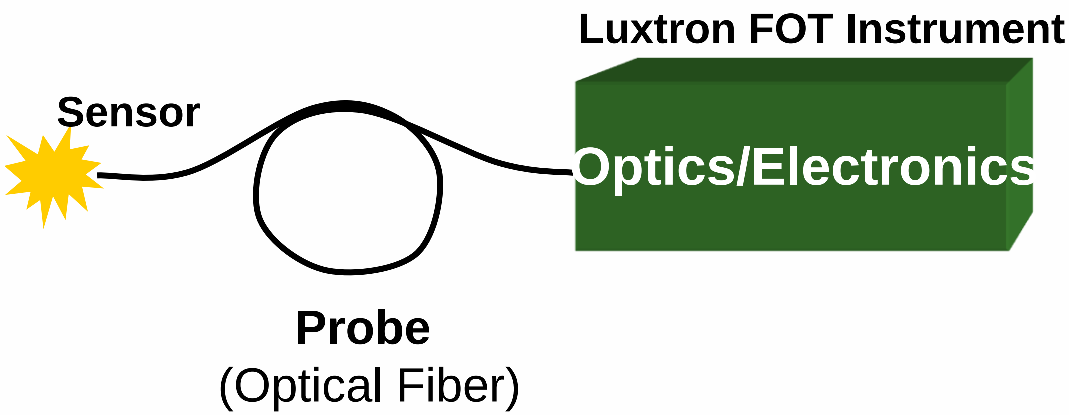
Inert

- Chemically Inert, Inorganic Ceramic Sensor
- Stable, Self-calibrating/auto gaining System

Invisible

- Minimally Intrusive (Probes as Small as 200µm dia)

Luxtron Fluoroptic: System Overview



Measurement is Based on a Temperature Sensitive Phosphorescent Sensor Attached to the Probing End of a Fiber Optic Cable

Electronics Measure the Decay Time of the Fluorescence that is Temperature Dependent

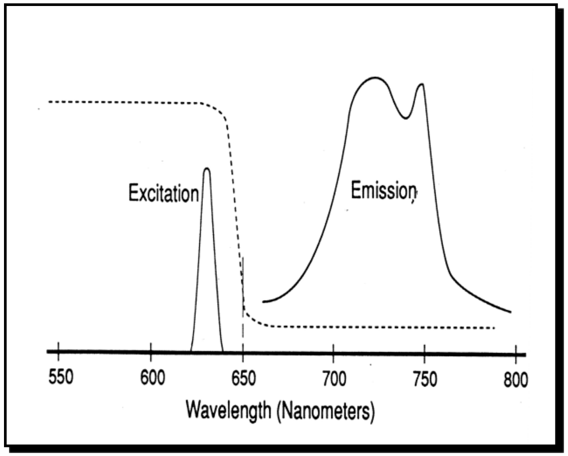
A Single Optical Fiber Transmits Both the Excitation and the Fluorescence Signal

Depending on probe construction, measures temperatures btw -100C & +330C

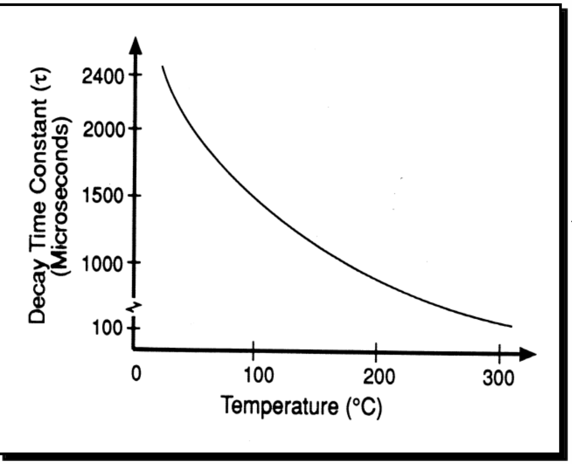
Luxtron Fluoroptic: Operating Principle

Spectra of Temperature Sensitive

Phosphorescent Ceramic

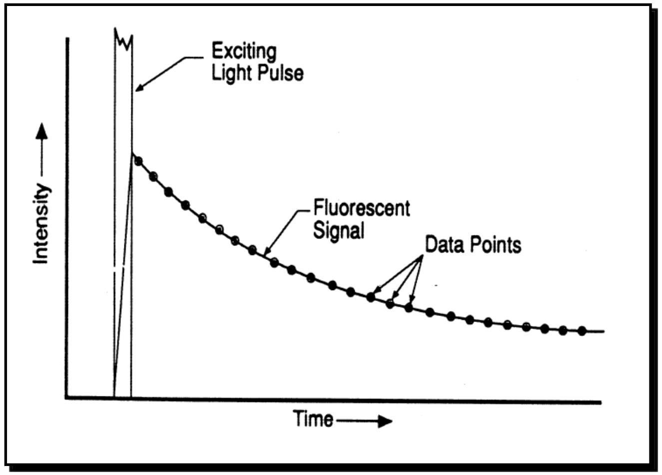


Decay Time of Emitted Light is Proportional to Temperature



Plot Representation of Method for

Extracting Fluorescent Decay Time



Luxtron Fluoroptic: Standard Instruments

R & D Lab End-User Instruments

- 812 (2 chnl, 2-4 Hz)
- FOT Lab Kit (4 chnl, 1-4 Hz)

OEM Modules

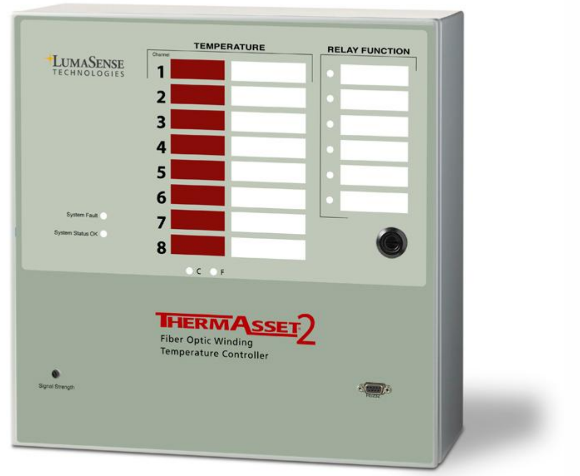
- M600 (1-4 chnl, 1-4 Hz)
- 800 (1-2 chnl, 2-10 Hz)

Closed Loop Control Systems

- ThermAsset2 (2-8 chnl, 6 relay)
- LumaSMART (2-16 chnl /relay)

Luxtron 812

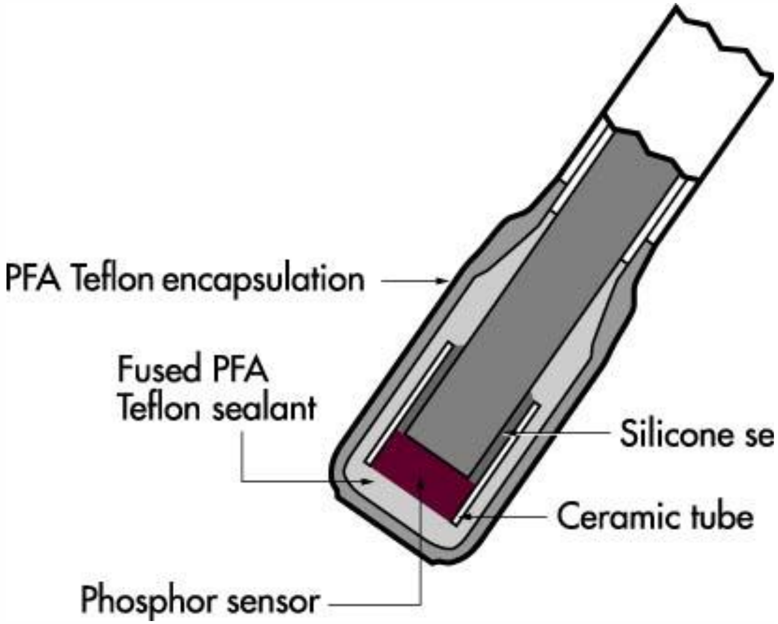
ThermAsset2

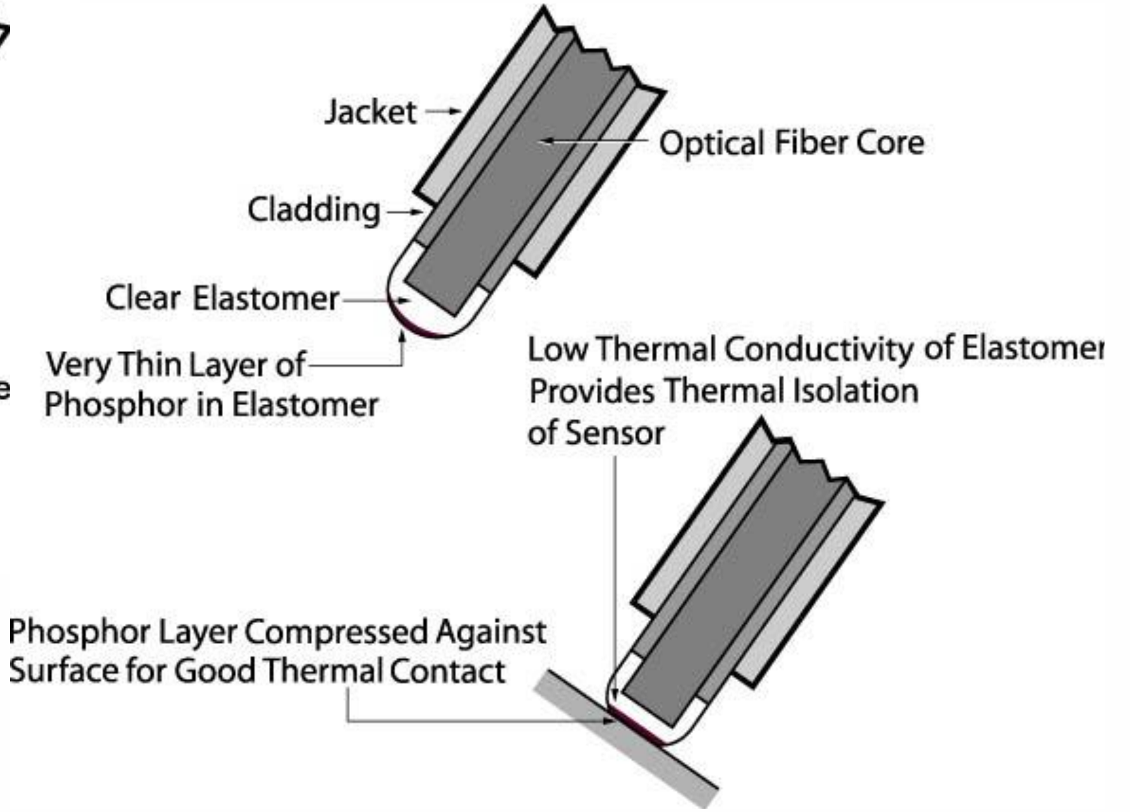


LumaSMART

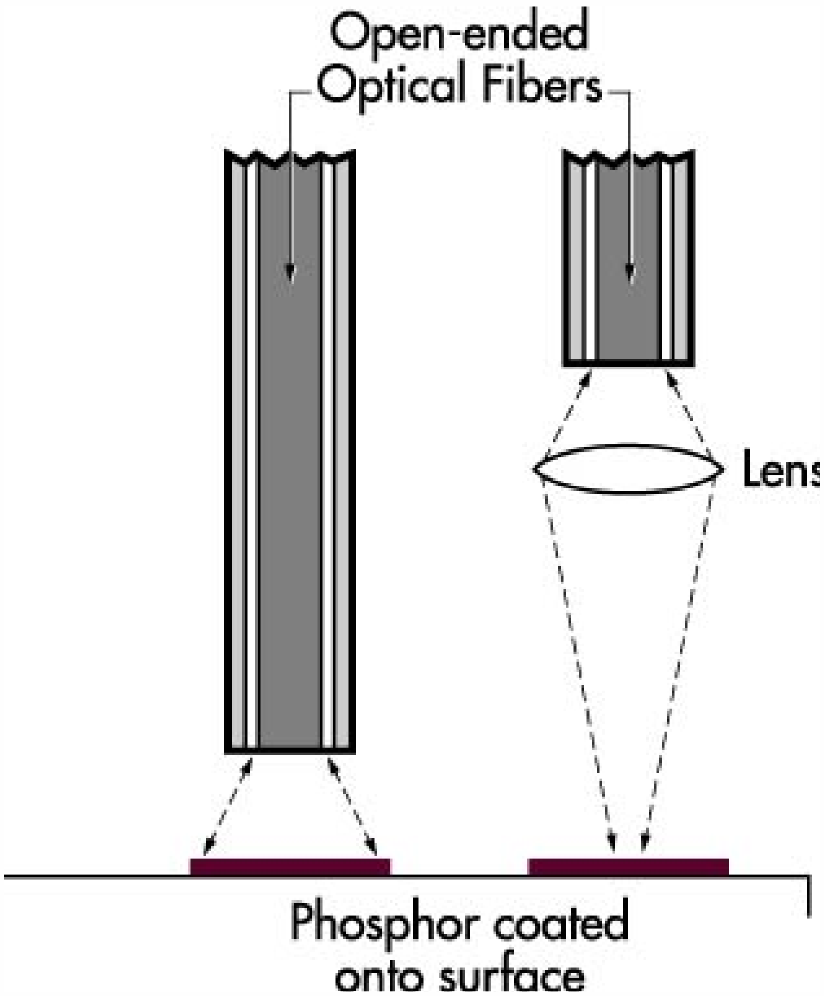
m600 Series

Luxtron Fluoroptic: Standard Probe Schematics

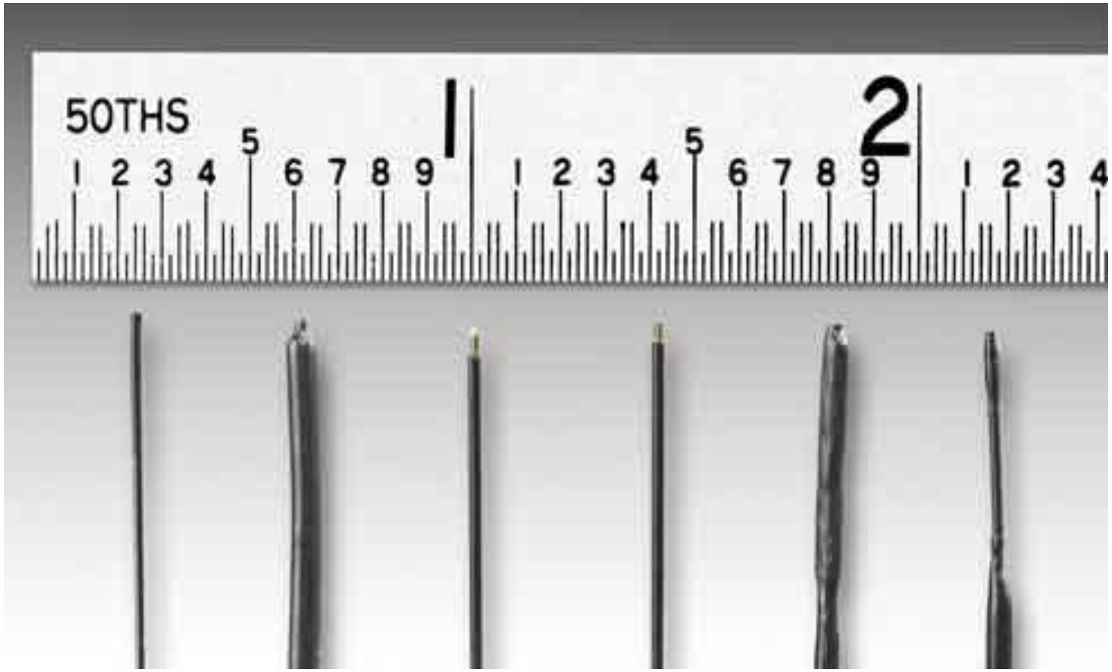




Luxtron Fluoroptic: Standard Probe Schematics

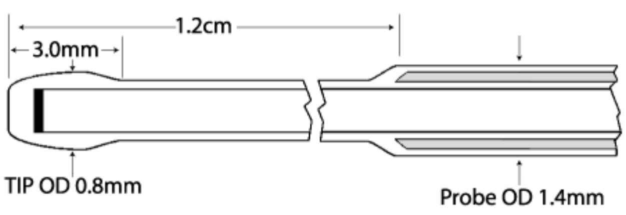


Luxtron Fluoroptic: Standard Probes



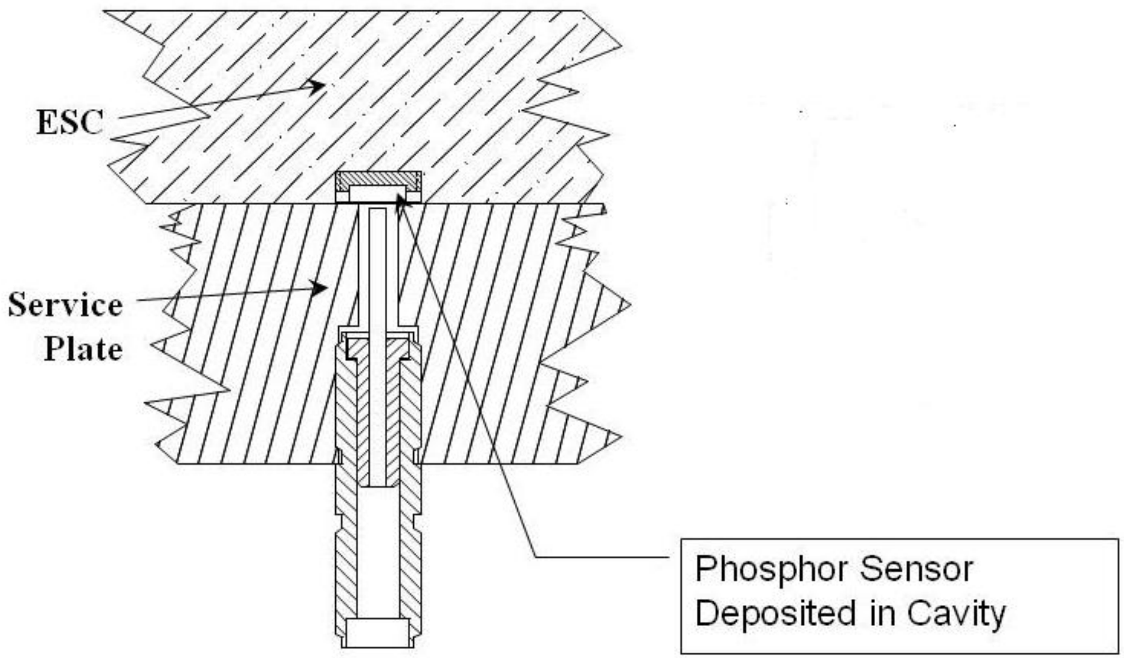
STF - fast response immersion

Temperature Range	0 to 295 °C
Response Time	1.25 seconds in still air, 250 milliseconds in water
Connector Type	ST



Luxtron Fluoroptic: Custom OEM Probes

Luxtron Fluoroptic: Application Electrostatic Chuck



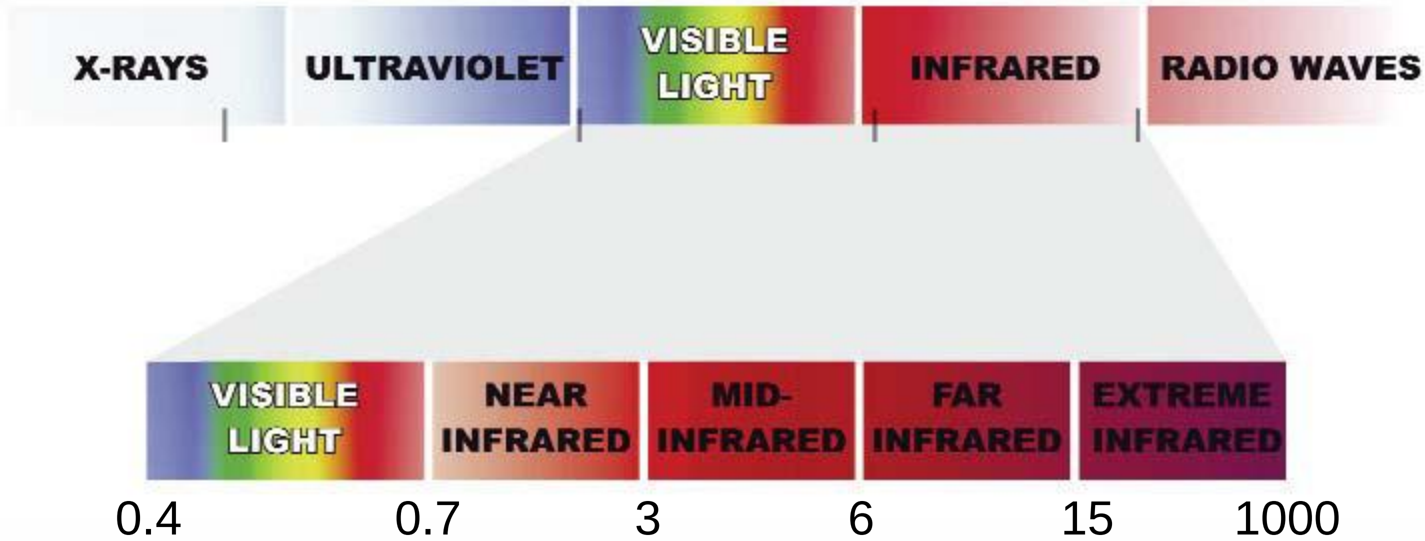
Luxtron Fluoroptic: Application Wafer Backside Temp

Vacuum Sealed for Thru-Chuck Wafer Backside Temperature Measurement

Impac Pyrometers: Benefits / Advantages

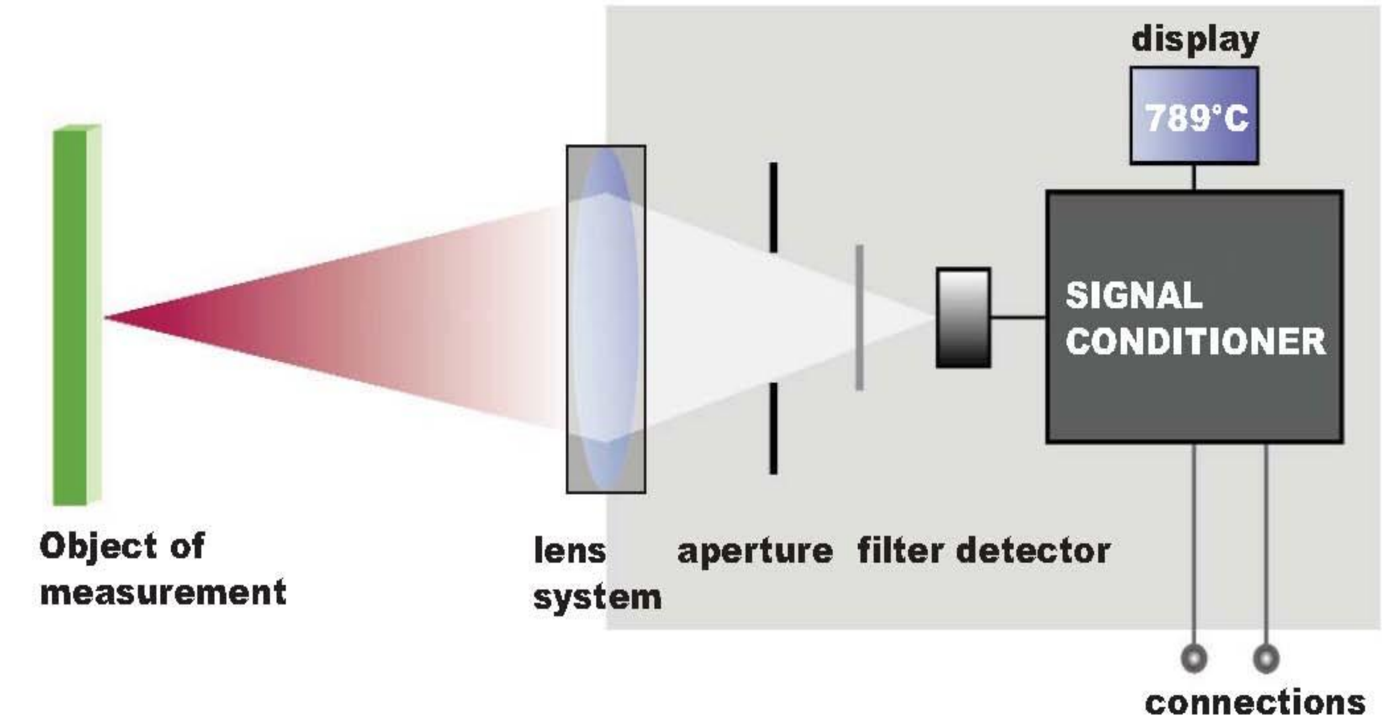
- Unaffected by EMI, Microwave and RF Interferences
- Non-contact temperature measurement
- Variety of wavelength detectors optimized for specific materials
- Lens optics for small spots at remote distances
- Light pipe optics for sensing temperature in confined spaces
- 100s of Models Offered to service temp range from -50C to 3500C
- Emissivity measuring “TR” Model

Impac Pyrometers: Measure Infrared Radiation



Wavelength in microns (um)

Impac Pyrometers: Operating Principle



Detector converts radiation into an electrical signal interpreted for temperature based on Planks Equation (next slide)

Fig. 16:
Components of a pyrometer

Impac Pyrometer: Operational Theory

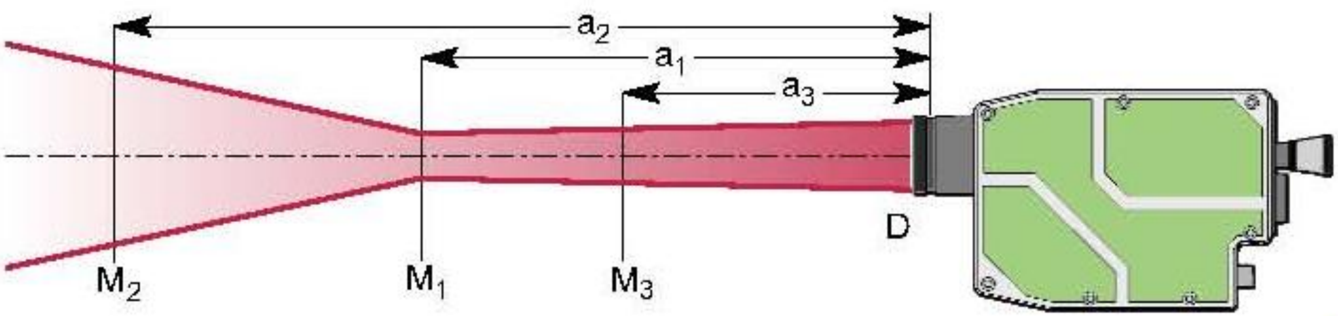
– Based on Planck's Equation for Blackbody Radiation:

$$E(\lambda,T) = \frac{\varepsilon \cdot C_1 \lambda^{-5}}{e^{\frac{C_2}{\lambda T}} - 1}$$

- – E (l,T) = Energy emitted, W/(m2 · μm)
- – e = Emissivity (1 for perfect blackbody)
- – λ= Wavelength in μm (microns)
- – T = Temperature ºK
- – C1 = First radiation constant; 3.743 x 108 W·μm4/m2
- – C2 = Second radiation constant; 1.4387 x 104μm · K

Impac Pyrometers: Wide range of measuring distances and spot sizes

M_1 = spot size at nominal measuring distance a_1
M_2 = spot size at measuring distance $a_2 > a_1$
M_3 = spot size at measuring distance $a_3 < a_1$
D = aperture (clear diameter of optics)



$$M_2 = \frac{a_2}{a_1}(M_1 + D) - D \qquad M_3 = \frac{a_3}{a_1}(M_1 - D) + D$$

Fig. 14: Field-of-view diagram

Spot sizes as small as 0.5mm at several meters distance

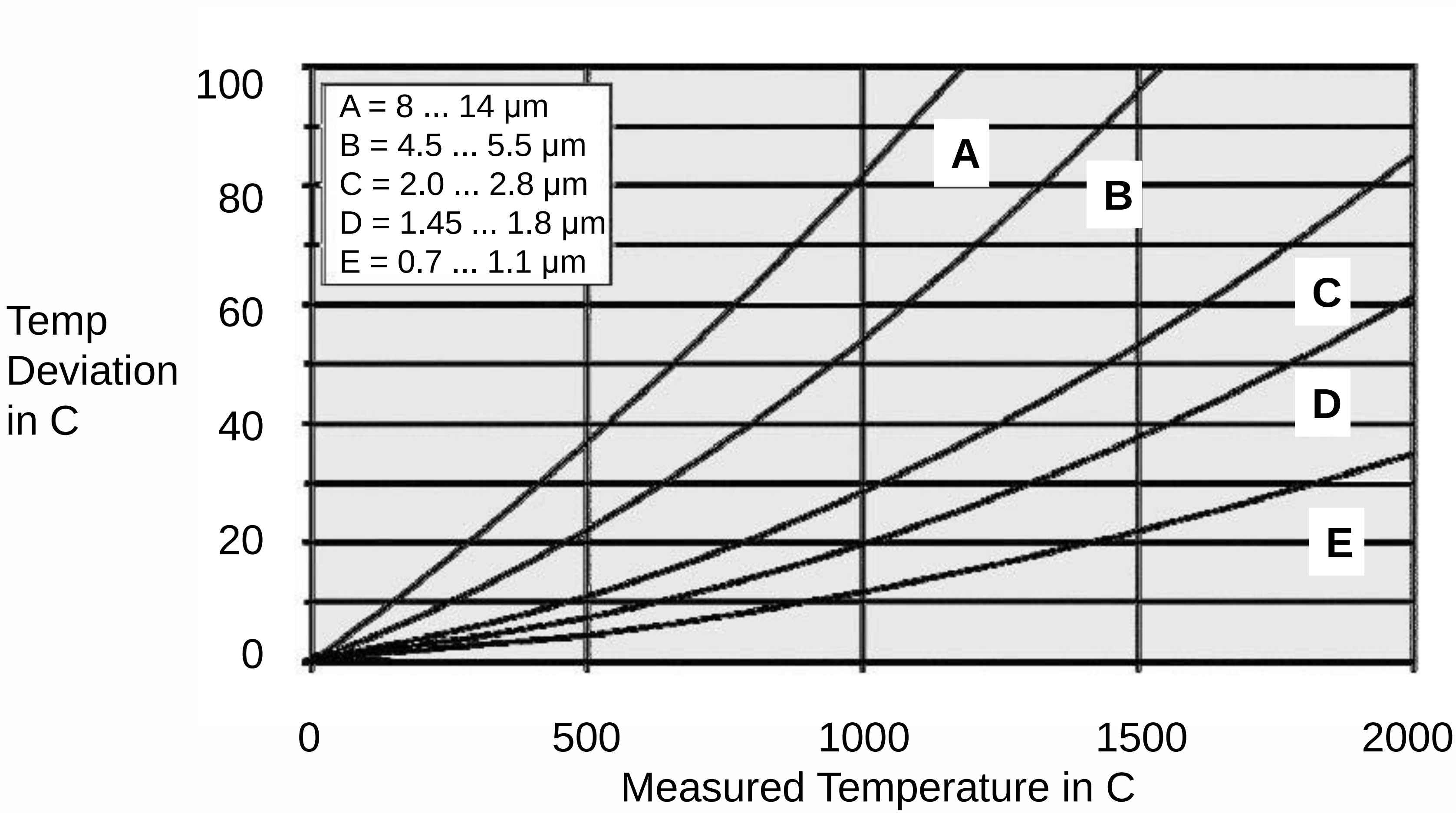
Impac Pyrometers: Material Specific Wavelengths

0,676 µm	Molten metals	(min. 1100°C)
0.8...1.1 µm	Molten glass, metals, ceramics	(min. 600°C)
0.88 µm	Compound Semiconductor	(min 220C w/ Model 88 Photrix)
0.9 µm	Silicon Wafer	(min 210C w/ Model 90 Photrix)
0.7…1,65 µm	Metals, Ceramics	(min 30C w/ Model Std Photrix
1.45...1.8 µm:	Metals, ceramics	(min. 70°C w/ Model 155 Photrix)
2.0...2.8 µm	Metals	(min. 50°C)
3...5 µm:	Metals, ceramics	(min. 5°C)
3.43 µm	Plastic foils	(min. 50°C)
3.9 µm	Flame heated furnaces	(min. 75°C)
5.14 µm:	Glass surfaces	(min. 100°C)
8...14 µm:	Non-metal surfaces	(min. -40°C)
8...14 um	Coated metals	(min -40C)

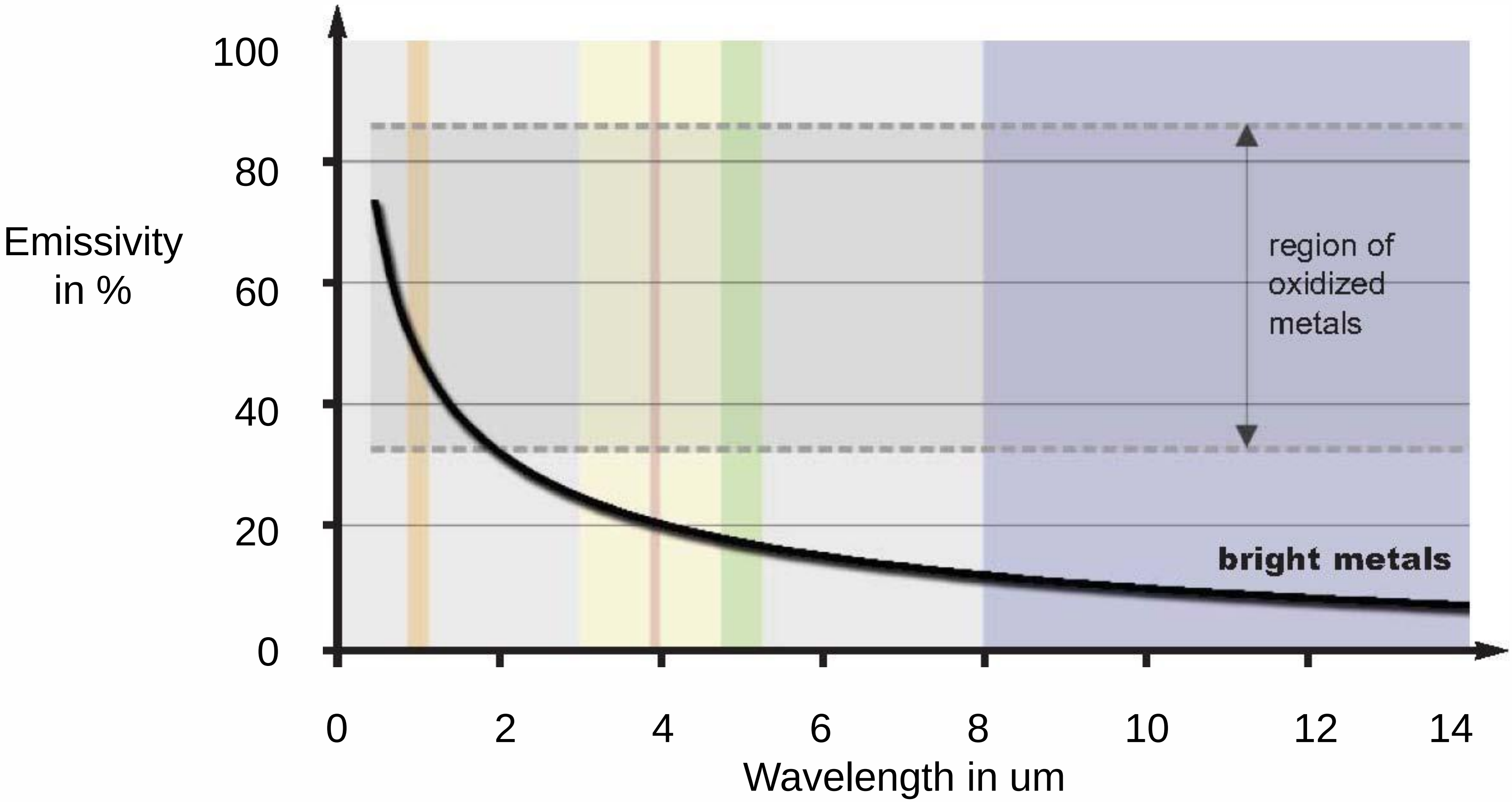
Spectral radiance peak wavelengths differ by material: Pick the correct wavelength pyrometer

Impac Pyrometers: Use Shortest Possible Wavelength

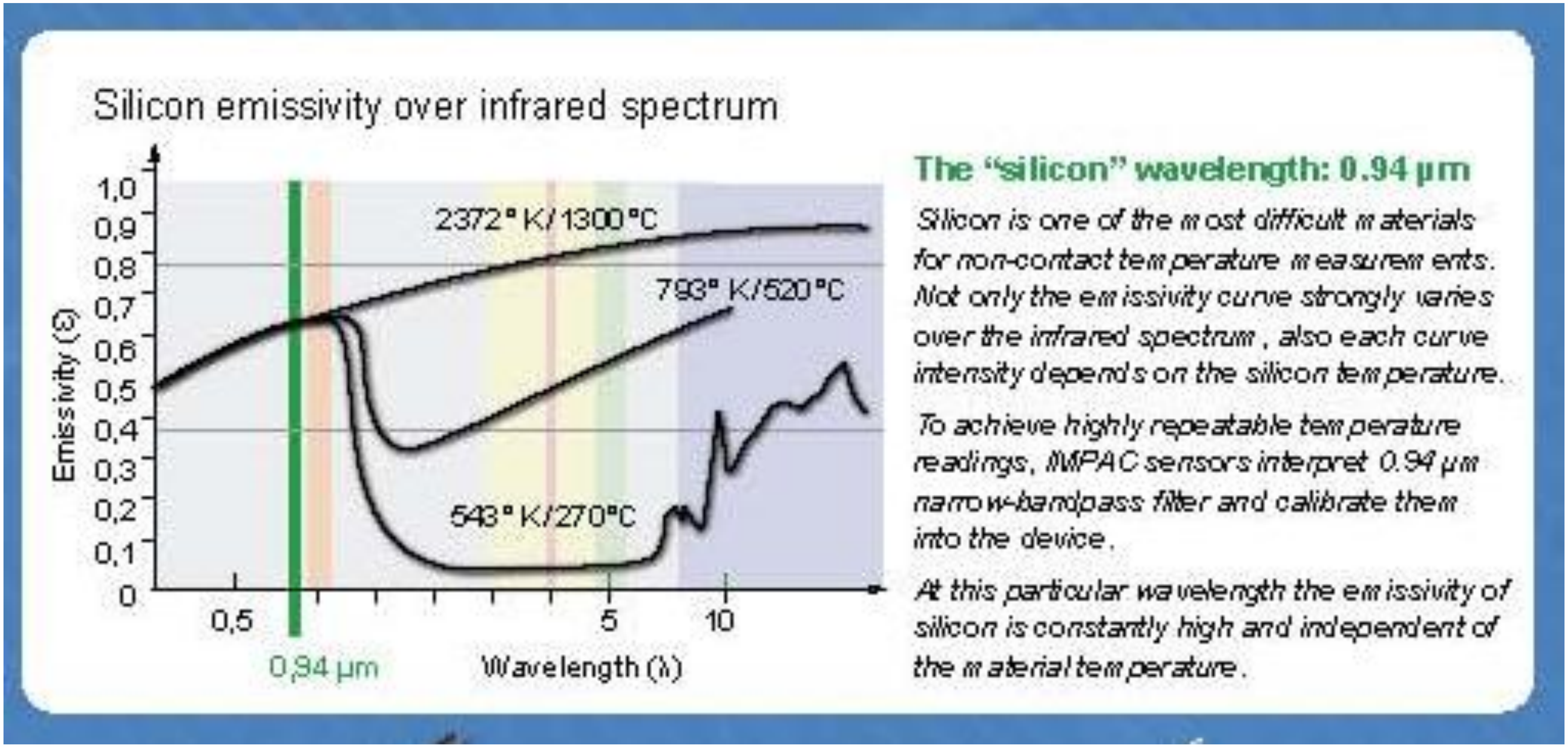
Measurement Errors with Emissivity Setting Off by 10%



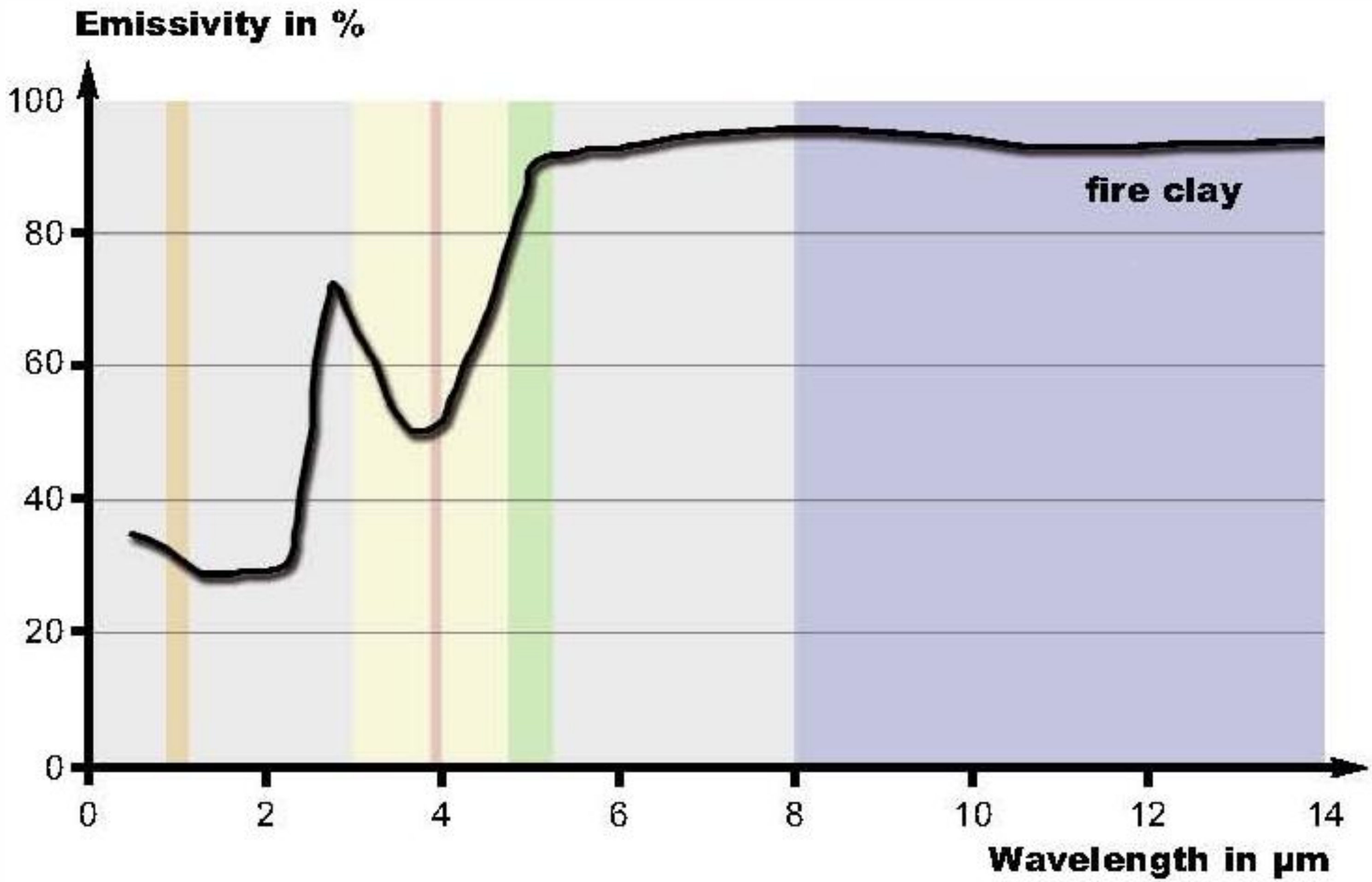
Impac Pyrometers: Shiny Metals Emissivity



Impac Pyrometers: Use 0.94um for Silicon



Impac Pyrometers: Emissivity of non-Metals



Impac Pyrometers: Use 5.14um for Glass Surface

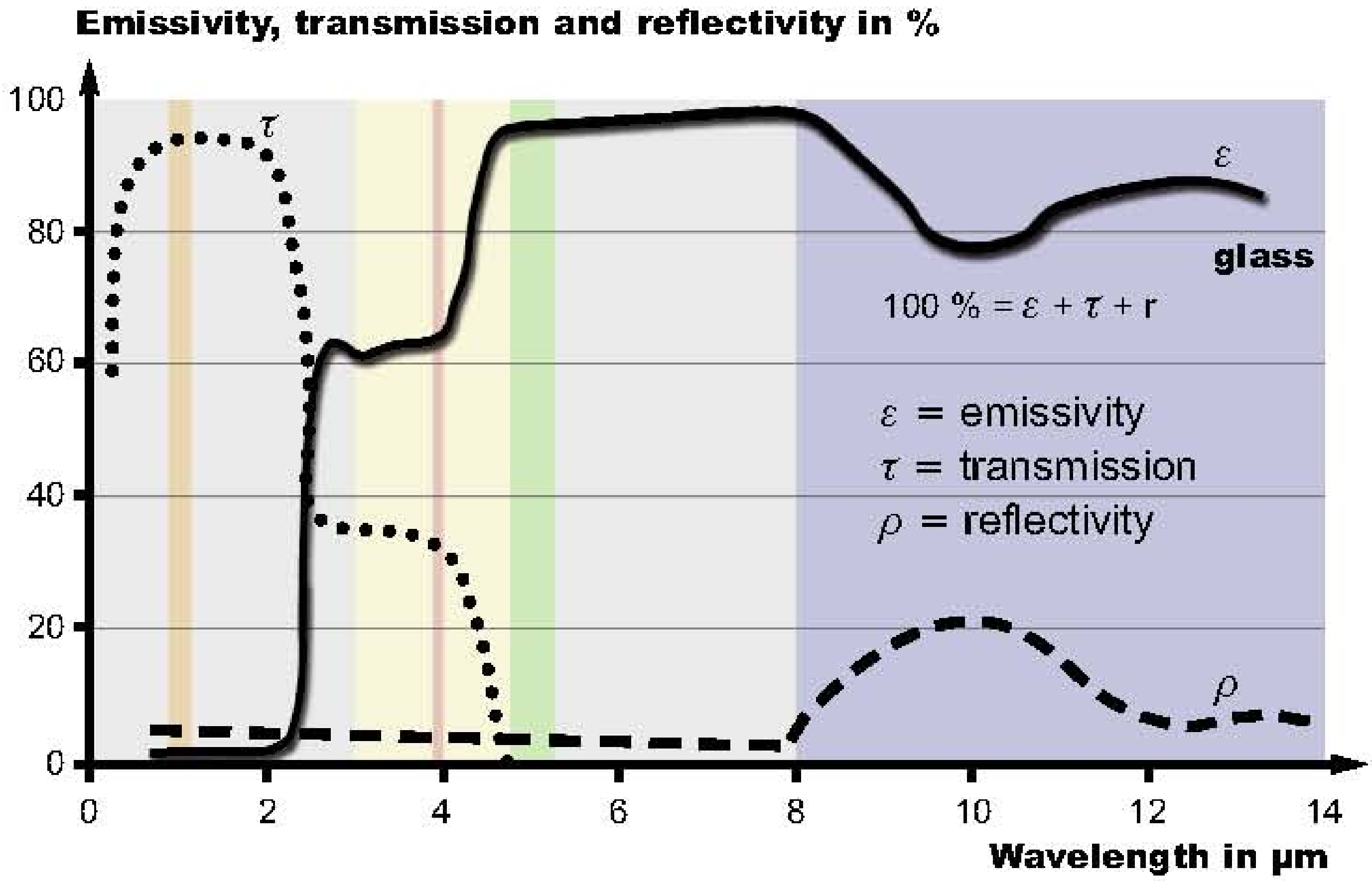


Fig. 11: Emissivity, transmission and reflectivity (qualitative) of glass

Impac Pyrometers: Determining Emissivity

- Consult Material Tables
- Comparison with Contact Thermometers (e.g.: thermocouples)
- Partial Blackening of the Surface (i.e.: force the emissivity towards 1)
- Drill Material to Make Black Body (depth = 6 x diameter)

Impac Pyrometers: Ratio Pyrometers Immune to Attenuation

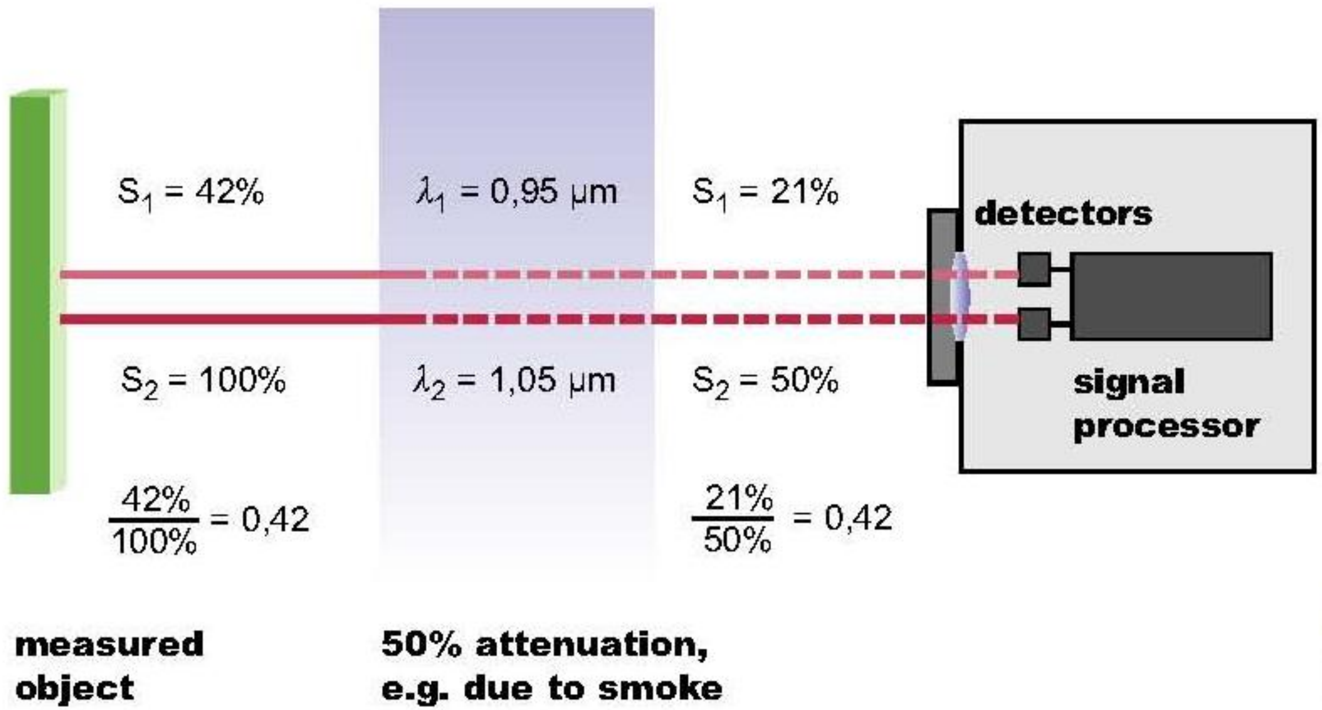


Fig. 17: Principle of a ratio pyrometer

Temperature based on emission signal strength ratio at two different wavelengths

Impac Pyrometers: Viewing Windows

- Crown glass (BK_7) is used in pyrometers which measure in the short wavelength band (up to 2.7 µm). Crown glass is very stable, resistant to chemicals and easy to clean.

crown glass

- Water-free quartz glass (Infrasil) is also used in short wavelength pyrometers (up to 3 µm).

quartz glass

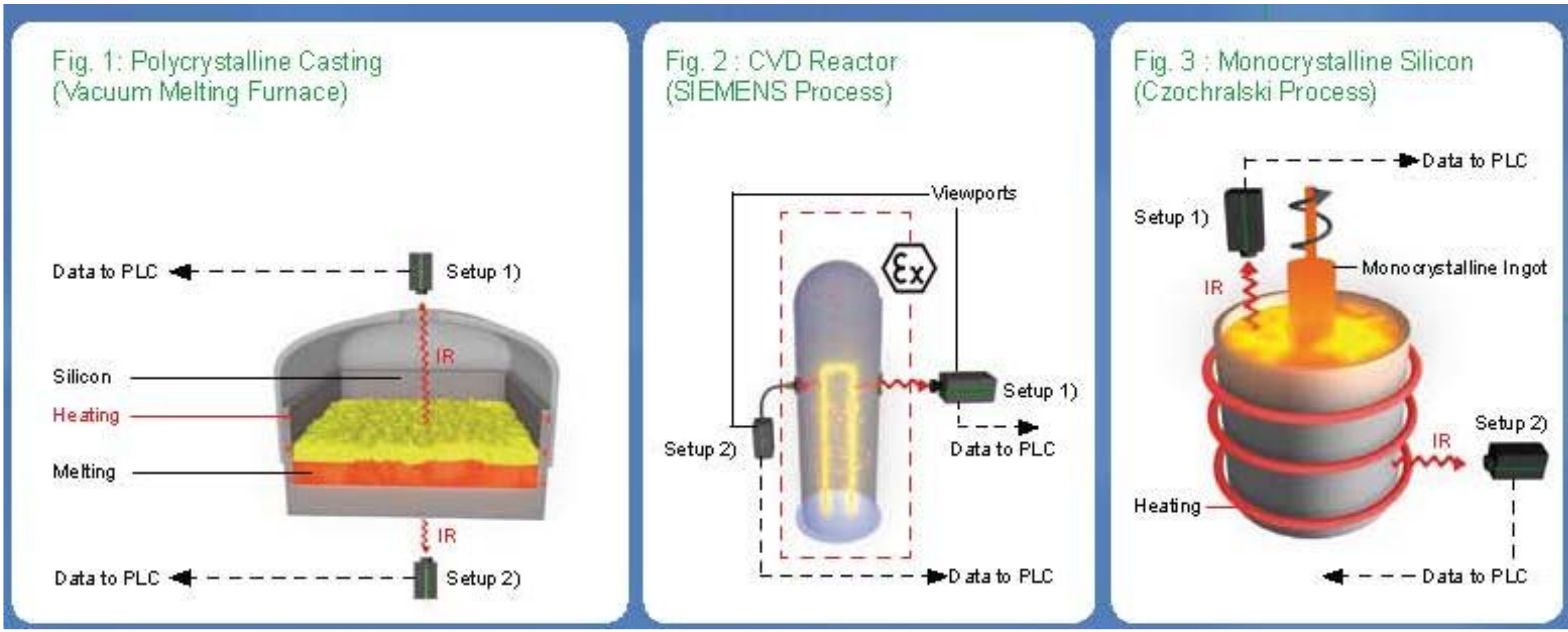
- Calcium fluoride (CaF_2, fluorite) is used especially where glass is measured. It can be used up to 10 µm and has a high transmission coefficient.

calcium fluoride

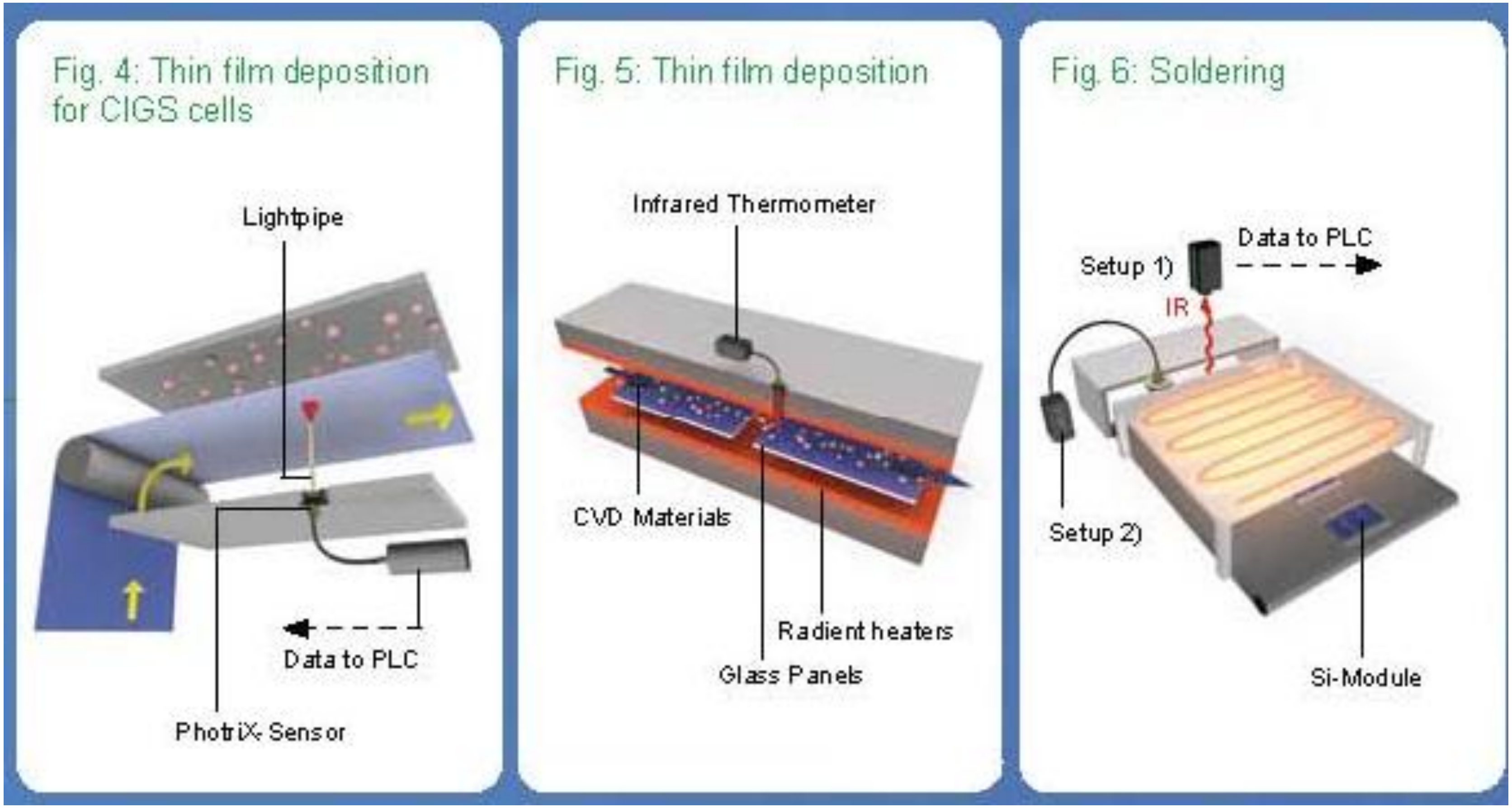
- Germanium lenses are useful for pyrometers which measure in the long wavelength band (up to 18 µm). They have a non-reflective surface for the desired region and are opaque to visible light..

germanium

Impac Pyrometer: Application - Ingots & Substrates



Impac Pyrometer: Application: Solar Cell Mfg



Impac Pyrometer: Photrix Lens and Light Pipe

Bent Tip Lightpipe

Fiber Optic connection between detector and collection optics (Lens or Lightpipe)

Impac Pyrometer: Photrix Configurations

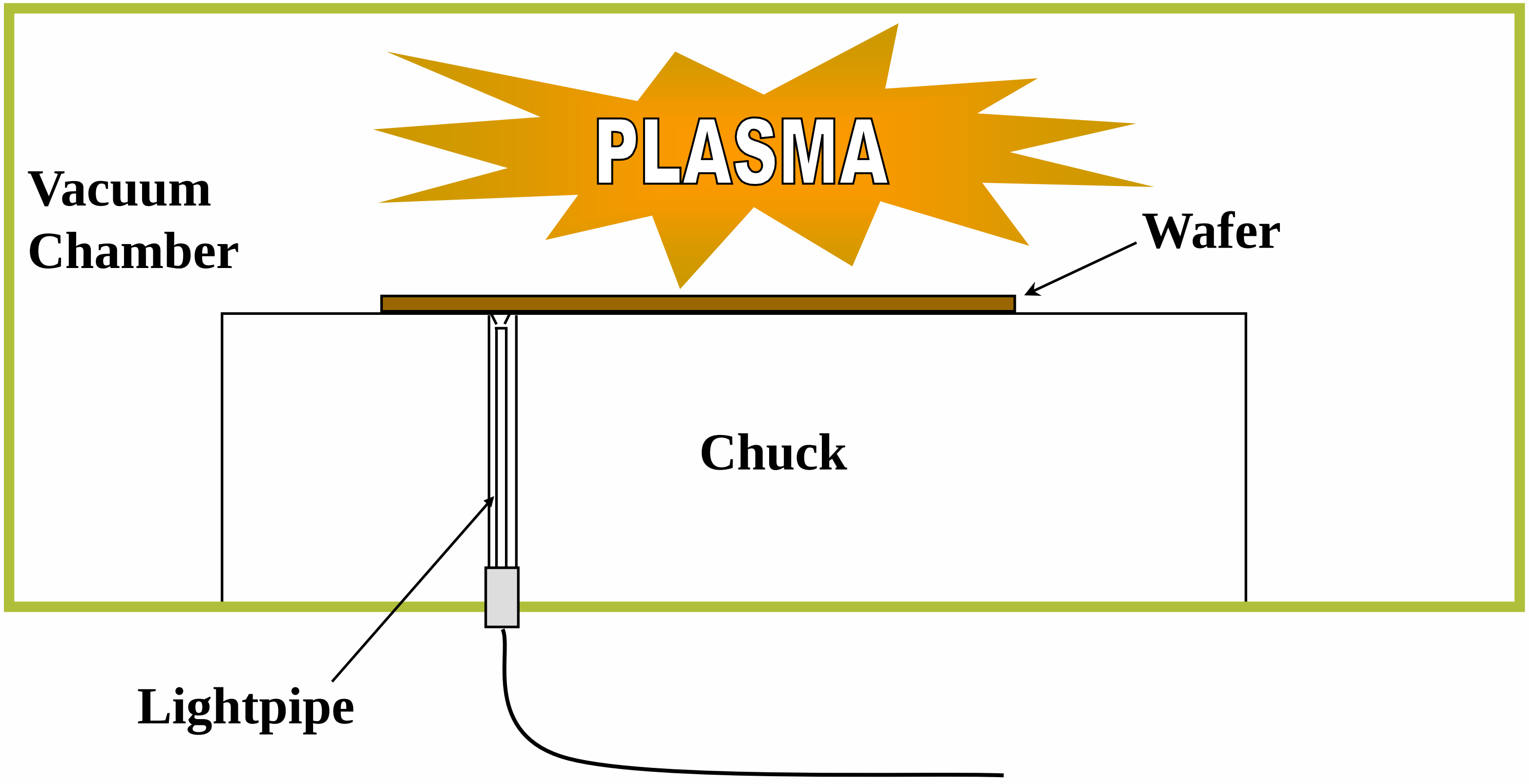
Photrix Integrated Lens Configuration

Fiber Optics to Lens Configuration

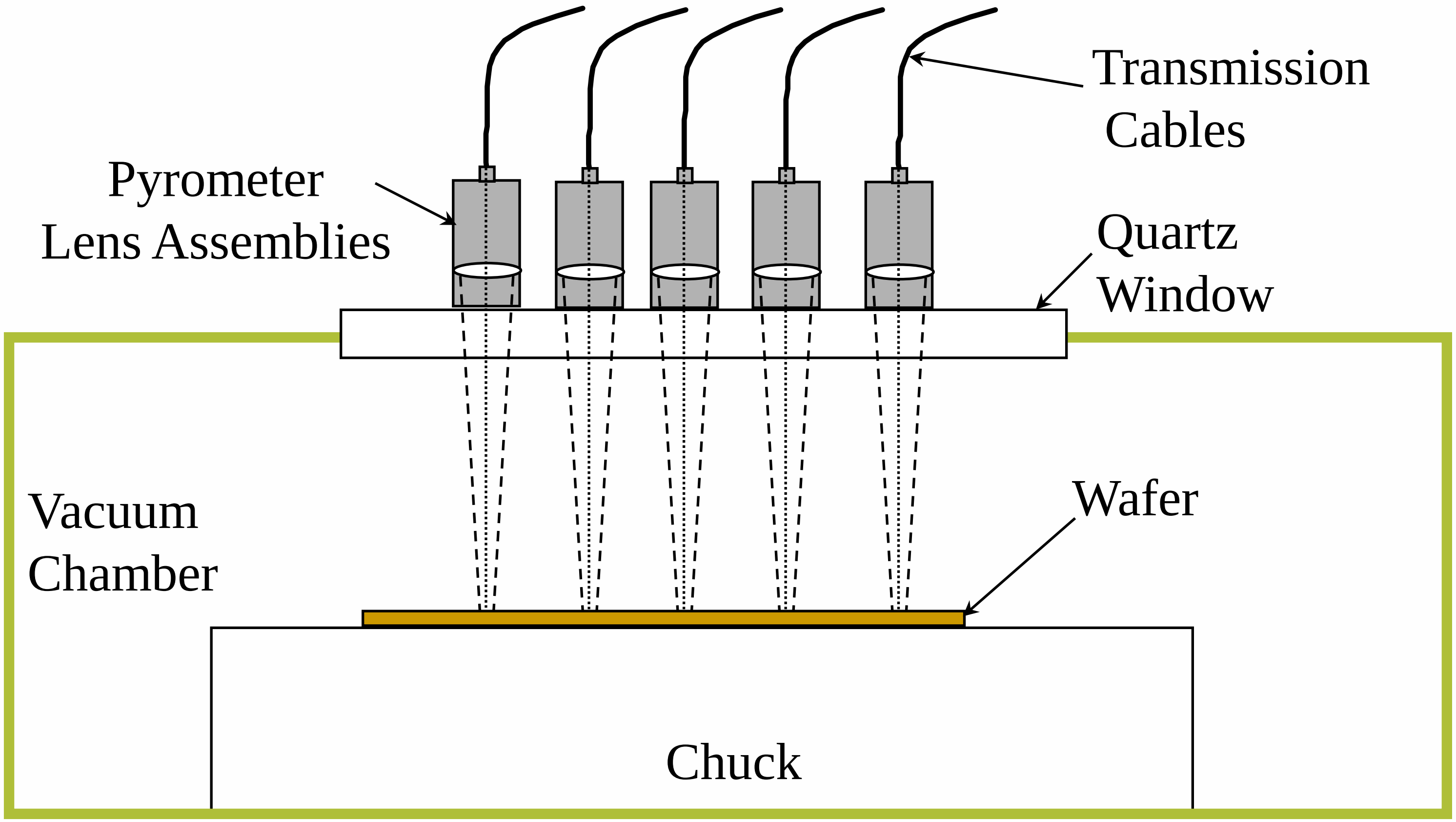
Photrix Direct Lightpipe Configuration

Fiber Optics to Lightpipe Configuration

Impac Pyrometer: Application Backside Wafer Temp

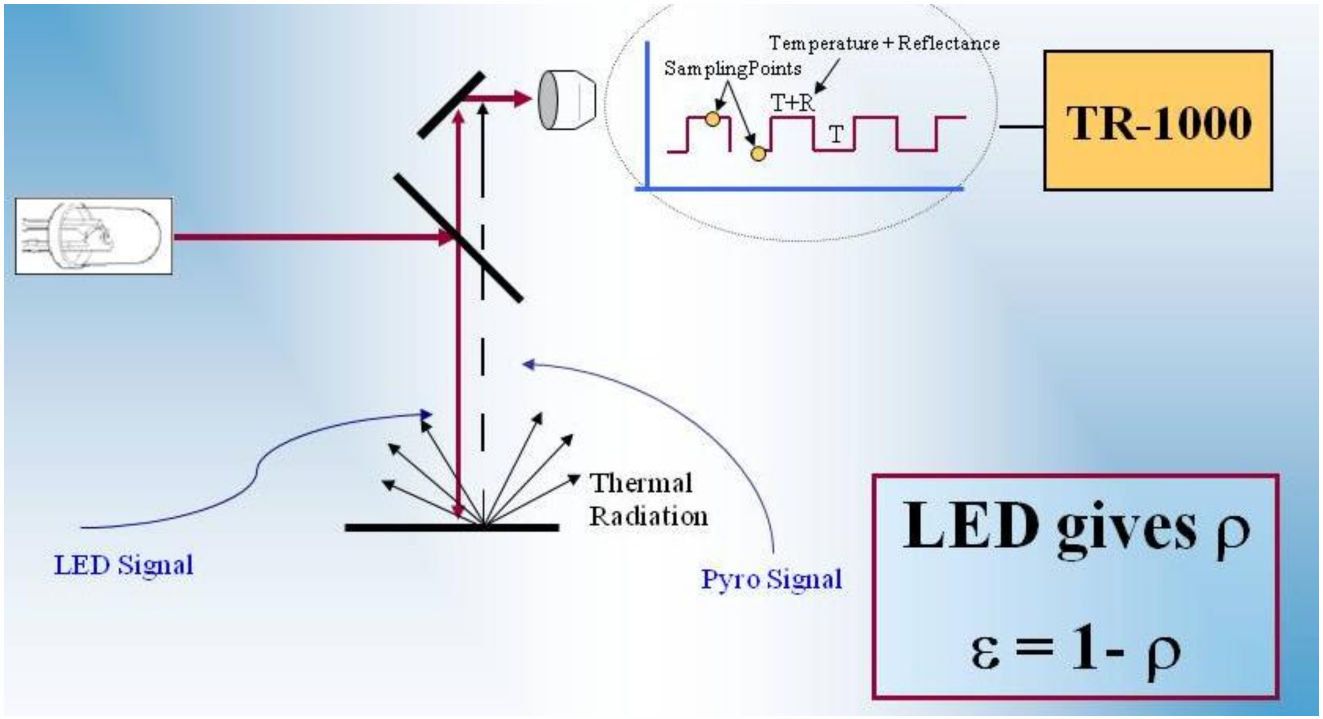


Impac Pyrometer: Application Wafer Temp Profile



Wafer Temperature Profile

Impac Pyrometer: Real Time Emissivity Corrected Temp Measurement with TR Series



TR Series Good For:

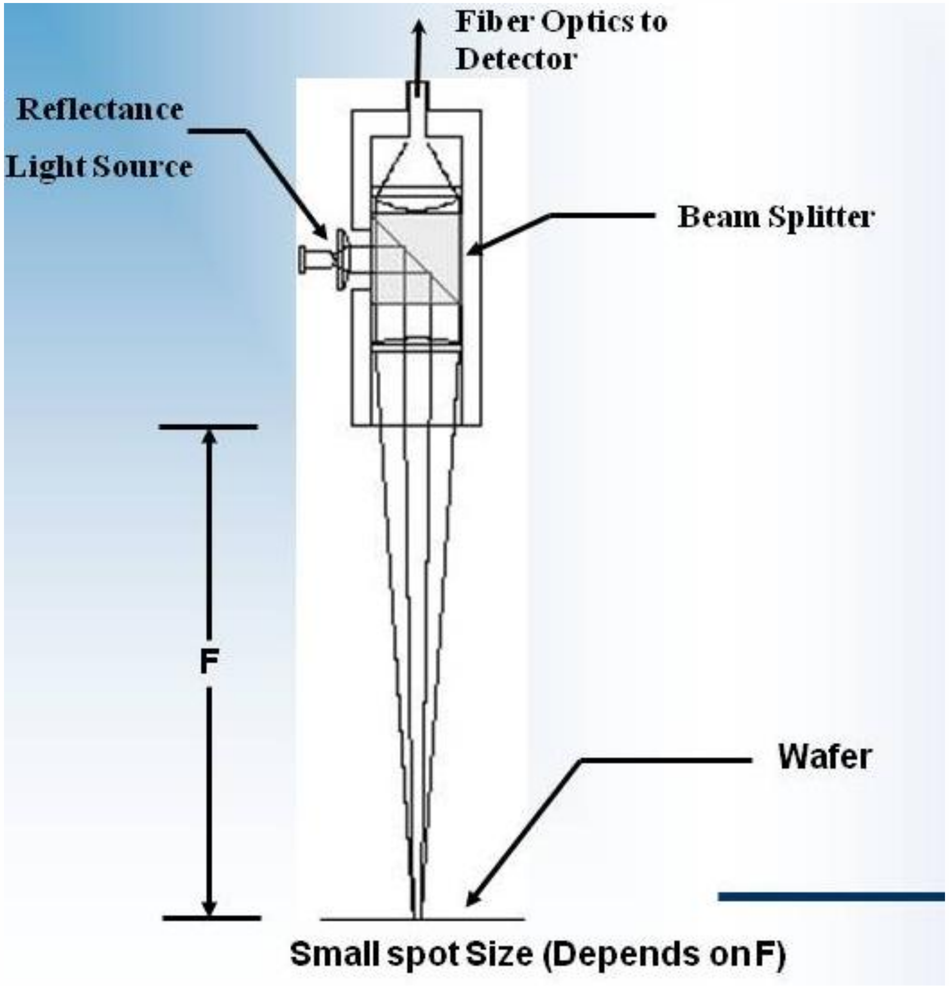
- MOCVD
- MBE
- CVD

- Measured Reflectance is subtracted from one to determine real time emissivity
- Reflectance also used for deposition rate monitoring

Impac Pyrometer: Real Time Emissivity Corrected Temp Measurement with TR Series

Benefits

- Accurate, emissivity corrected temperature measurement
- Precise "fringe" resolution for thin film deposition monitoring

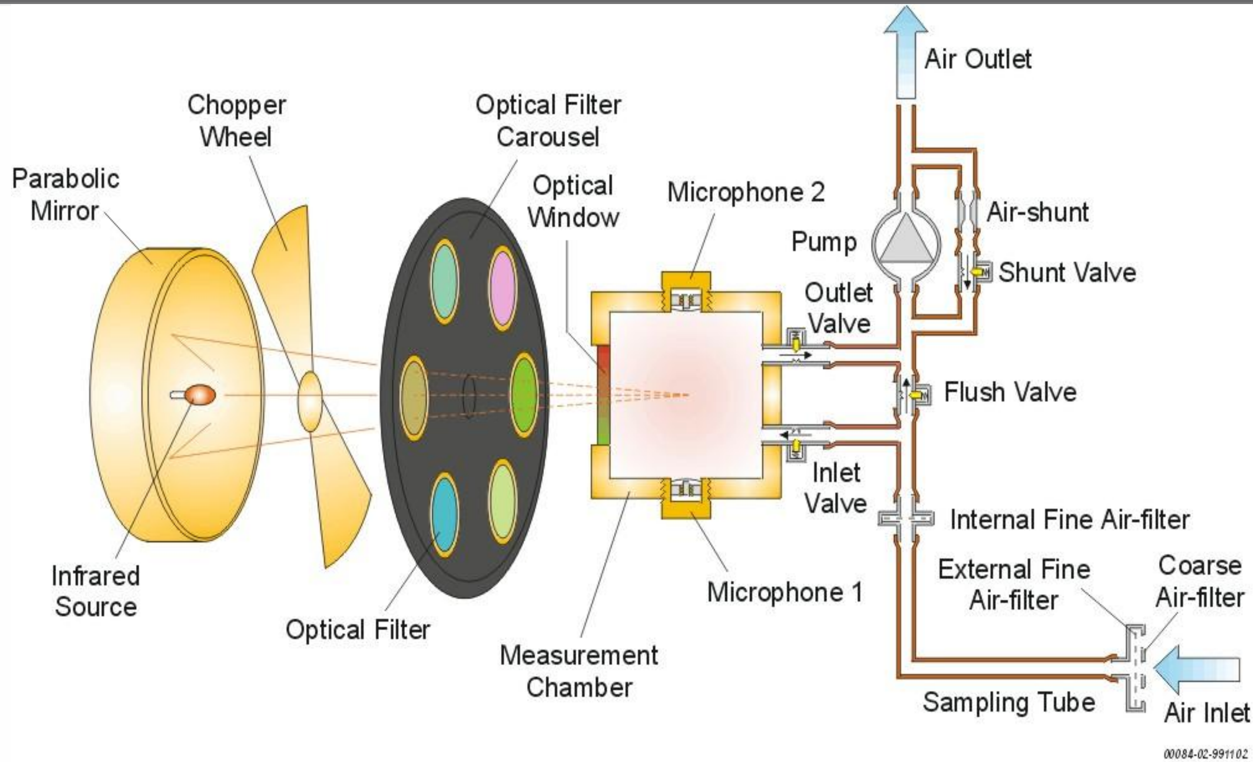


Innova PAS Gas Monitor: Key Attributes

Photoacoustic Spectroscopy Gas Monitoring

- 24/7 Production Proven
- ppb and ppm level detection limits
- Dynamic range = 10000 x detection limit
- Calibrate only 1 or 2 times per year
- No Special Operator Skills Required
- Can be configured to monitor up to 5 gases
- Compatible with 200+ gases
- Rack & Bench Top Models
- Atmospheric Operating Conditions
- Industrial process application in pharmaceutical fermentation
- Can be multiplexed to monitor up to 36 sample locations
- Low sample volume of 10ml
- Cross Compensates for Interfering Gases (in IR Spectra)

Innova PAS Gas Monitor: Measurement Sequence



1. An air sample is drawn into the measurement chamber and the chamber is sealed by the valves.

2. Radiation from the IR-source passes through a chopper and optical filter into the chamber. The IR radiation is absorbed and generates heat and pressure variations.

3. The pressure variations correspond to the chopper frequency, creating a pressure wave which can be detected by the microphones.

4. The microphone signal, proportional to the gas concentration, is post processed and the measurement result is calculated.

Innova PAS Gas Monitor: Optical Filters

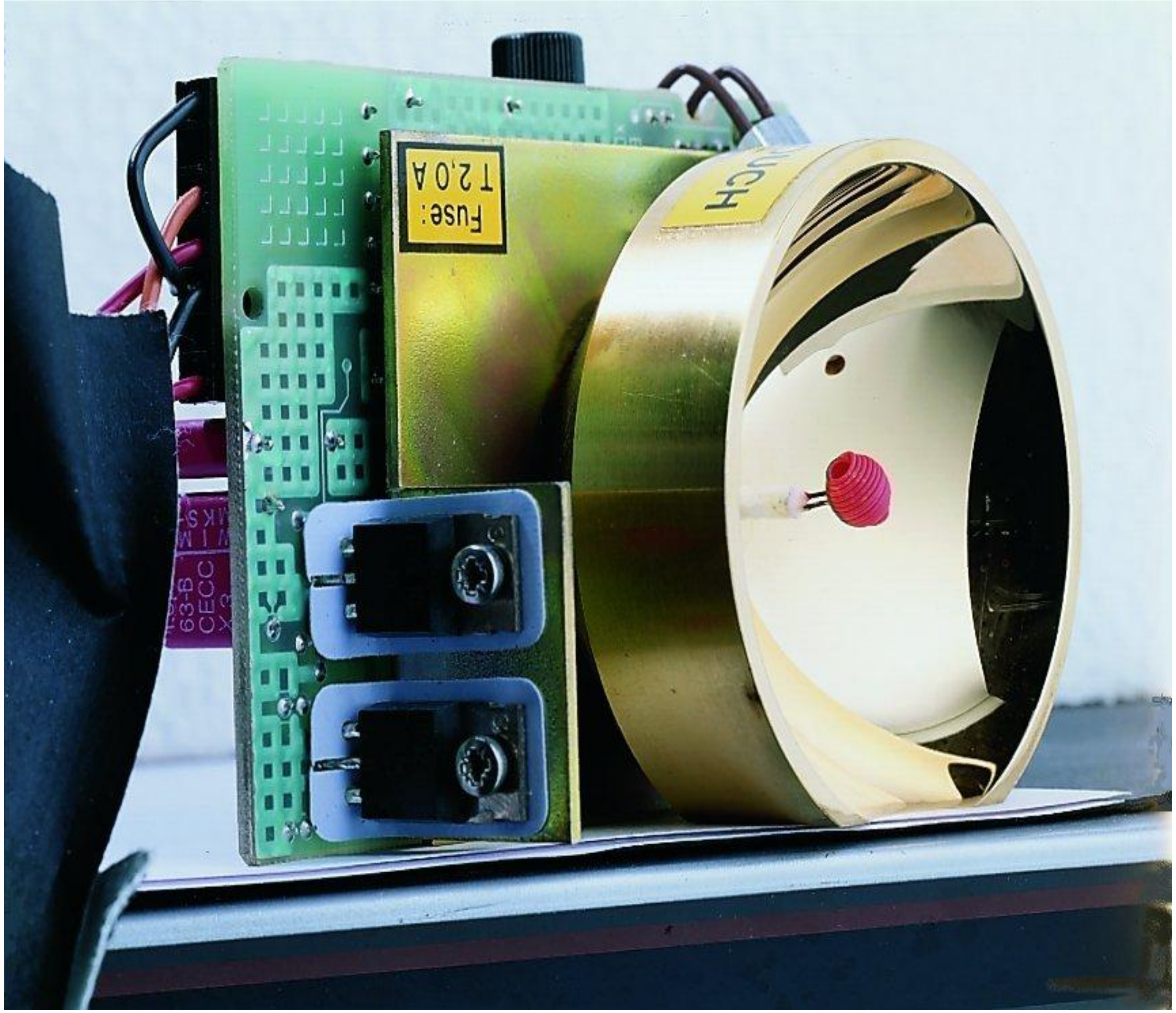
26 standard optical filters covering the infra-red region of interest are offered.

Each filter consist of three elements, to achieve:

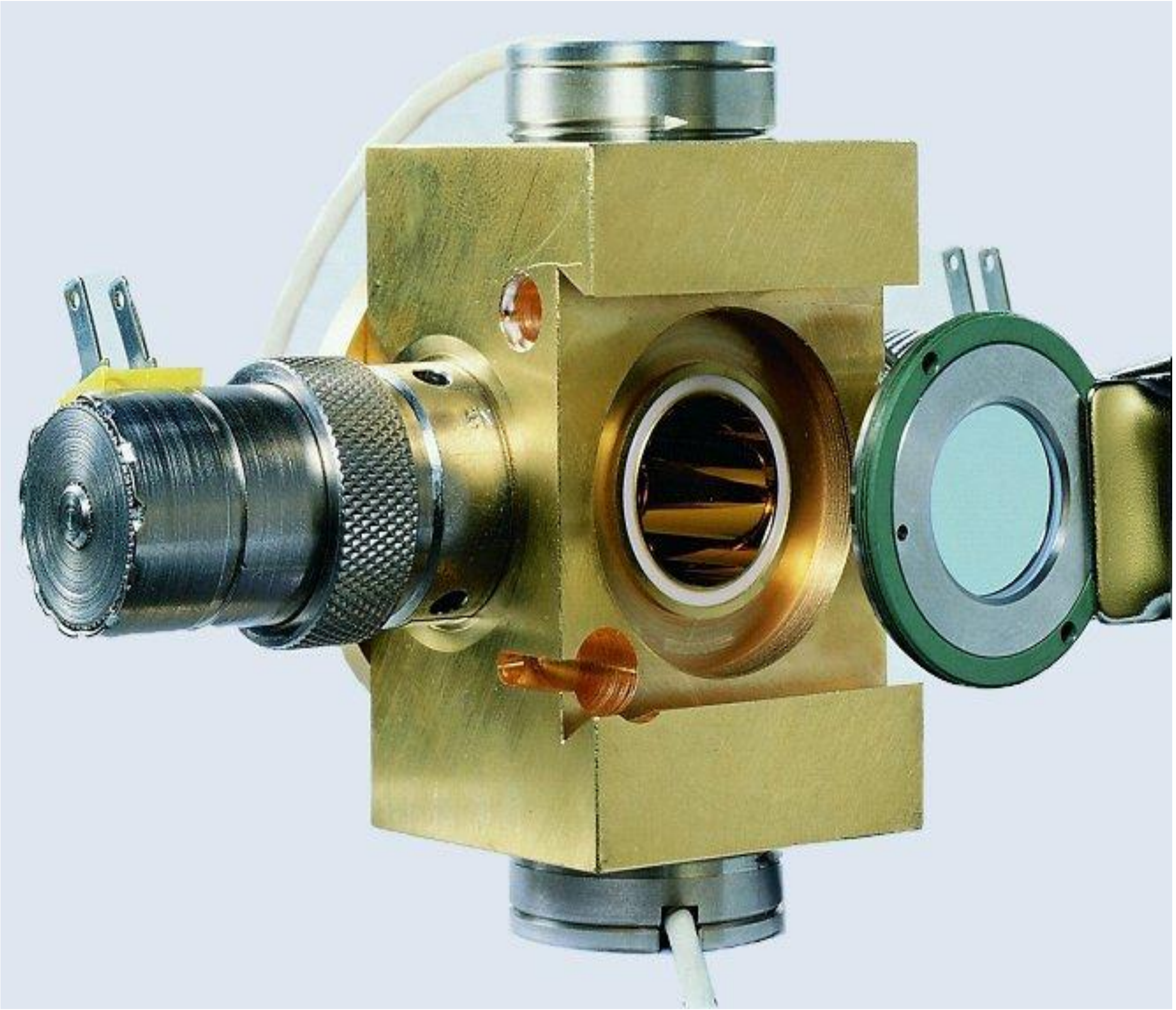
- Well-defined transmission.
- Low leakage, thereby high suppression of interference.
- Not damaged by humidity.
- Complies with MIL-SC-48497A requirements.

Every system includes a filter for Water.

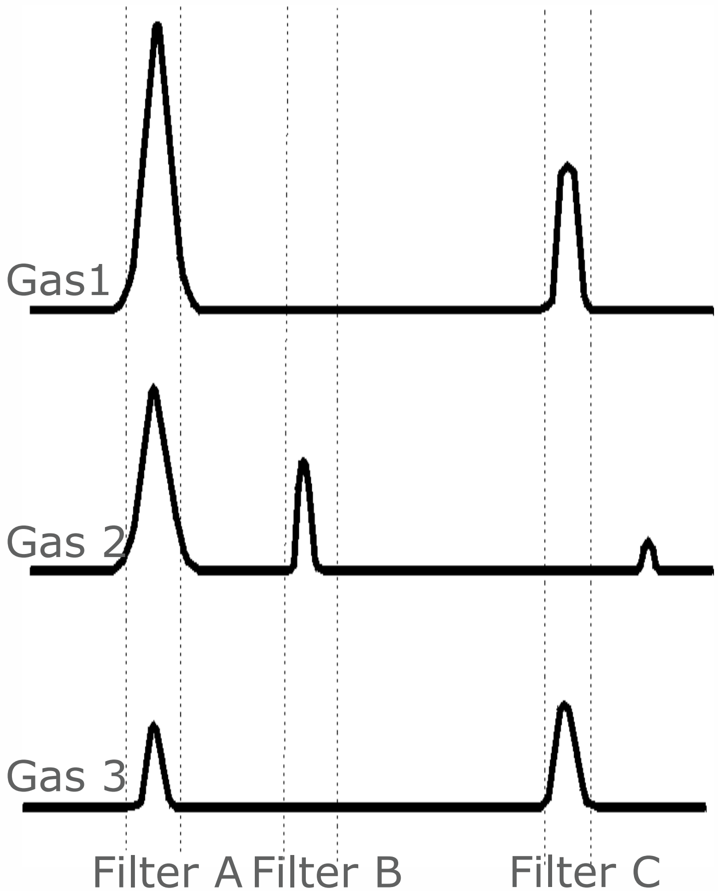
Innova PAS Gas Monitor: IR-Source



Innova PAS Gas Monitor: Photoacoustic Cell



Innova PAS Gas Monitor: Cross-compensation



SA= a1,A x c1+ a2,A x c2+ a3,A x c3

SB= a1,B x c1+ a2,B x c2+ a3,B x c3

SC= a1,C x c1+ a2,C x c2+ a3,C x c3

Where:

SN is Microphone signal measuring with Filter N.

a1,N is absorption of gas 1 on Filter N.

C1 is concentration of gas 1.

Innova PAS Gas Monitor: Select Applications

Animal Husbandry
Atmospheric Research
Automotive
Contaminated soil
Ethylene Oxide Sterilisation
Fermentation monitoring
Food
Formaldehyde
Fuel Cells
Gas Manufacturing
Green House Gases
Headspace
Hospitals
Indoor Air Quality
Industrial Hygiene
Photocatalysis
Photographic Industry
Power Industry
Semiconductor
SF6 in Transformers
Solvent Recovery
Thermal Comfort
Vent Emission
Ventilation Efficiency
Warfare Agents