

WP2

- **Presentation of end-users techniques studied in the project.**
- **Technical details about instruments involved in the project**

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16NRM06 EMIRIM

**Improvement of emissivity measurements
on reflective insulation materials**



ZAE BAYERN

End-Users Techniques



- **TIR (thermal infrared) - reflectometer / emissiometer**
 - measurement of the total hemispherical normal reflectance R_{hn}
 - determination of the total normal emissivity ε_n and determination of the total hemispherical emissivity ε
- **Spectrometer with integrating sphere**
 - measurement of the spectral normal hemispherical reflectance $R_{nh}(\lambda)$
 - determination of the total normal emissivity ε_n and determination of the total hemispherical emissivity ε
- **Assumption: near-normal values \approx normal values**

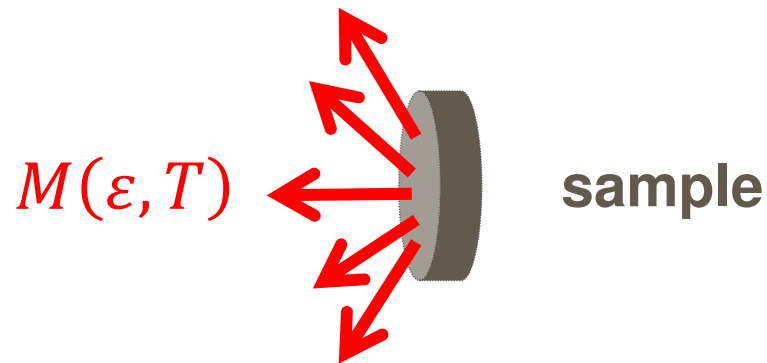
Total Hemispherical Emissivity



Total hemispherical emissivity ε is a measure for the total amount of energy emitted by thermal radiation from a surface into the surrounding at a given temperature T .

→ emissive power of a real surface $M(\varepsilon, T)$:

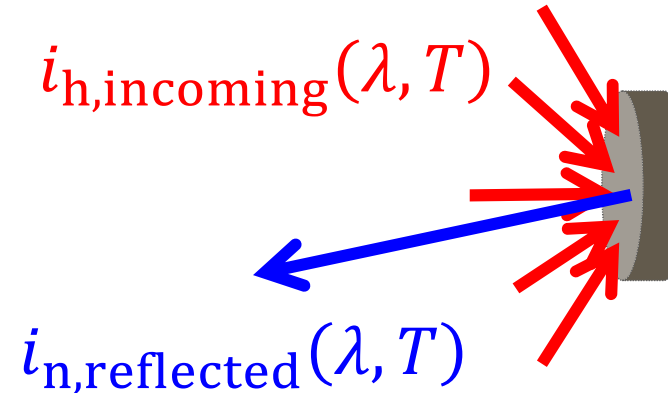
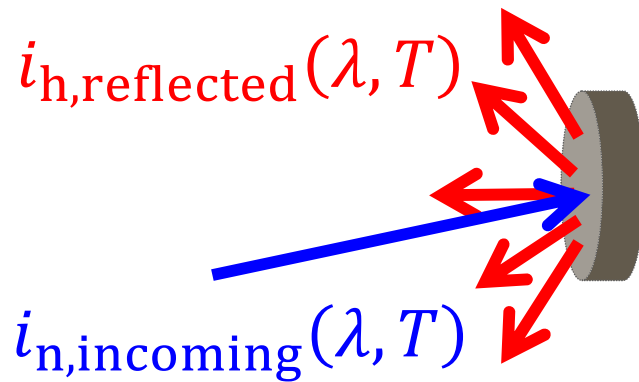
$$M(\varepsilon, T) = \varepsilon \cdot \sigma \cdot T^4 \text{ [W}\cdot\text{m}^{-2}], \sigma: \text{Stefan-Boltzmann-constant}$$



total hemispherical emissivity ε

Normal Hemispherical Reflectance

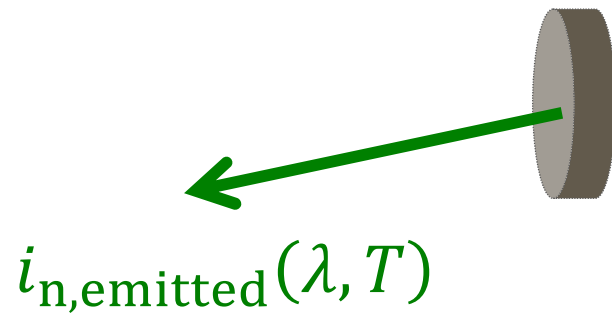
Spectral normal hemispherical reflectance $R_{nh}(\lambda)$
= spectral hemispherical normal reflectance $R_{hn}(\lambda)$



$$R_{nh}(\lambda, T) = \frac{i_{h,reflected}(\lambda, T)}{i_{n,incoming}(\lambda, T)} \left(= R_{hn}(\lambda, T) = \frac{i_{n,reflected}(\lambda, T)}{i_{h,incoming}(\lambda, T)} \right)$$

Spectral Normal Emissivity

Spectral normal emissivity ε_n
= spectral normal absorptivity α_n



$$\varepsilon_n(\lambda, T) = \frac{i_{n,\text{emitted}}(\lambda, T)}{i_{\text{bb}}(\lambda, T)} = \left(\alpha_n(\lambda, T) = \frac{i_{n,\text{absorbed}}(\lambda, T)}{i_{n,\text{incoming}}(\lambda, T)} \right)$$

Total Normal Emissivity



Spectral normal emissivity $\varepsilon_n(\lambda, T)$

$$\varepsilon_n(\lambda, T) = 1 - R_{nh}(\lambda, T) = 1 - R_{hn}(\lambda, T)$$

for opaque samples with vanishing transmittance.

Total normal emissivity $\varepsilon_n(T)$

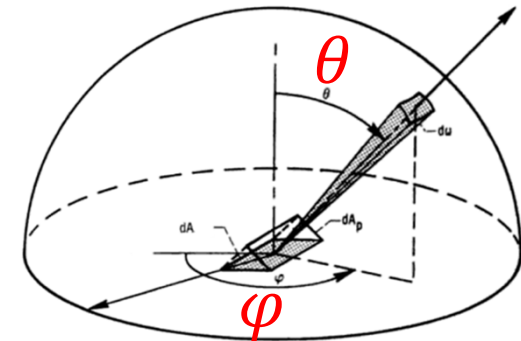
$$\varepsilon_n(T) = \frac{\int_0^{\infty} \varepsilon_n(\lambda, T) \cdot i_{bb}(\lambda, T) \cdot d\lambda}{\int_0^{\infty} i_{bb}(\lambda, T) \cdot d\lambda}$$

Total Hemispherical Emissivity

Total normal emissivity $\varepsilon_n(T)$

= total directional emissivity $\varepsilon_d(\theta, \varphi, T)$ at $\theta = 0^\circ$

$$\varepsilon_n(T) = \varepsilon_d(\theta = 0, \varphi, T)$$

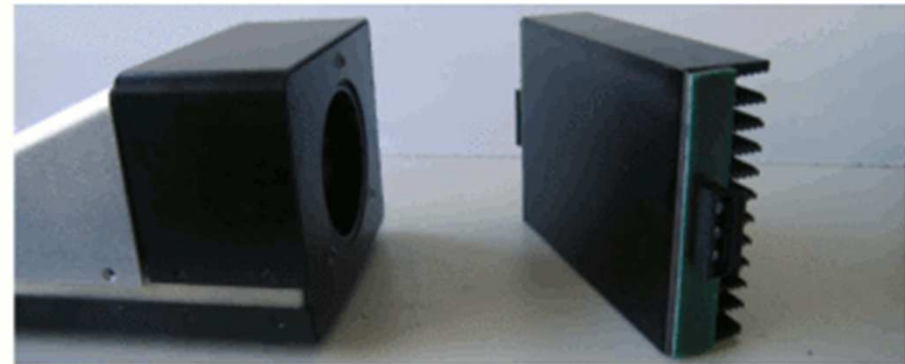
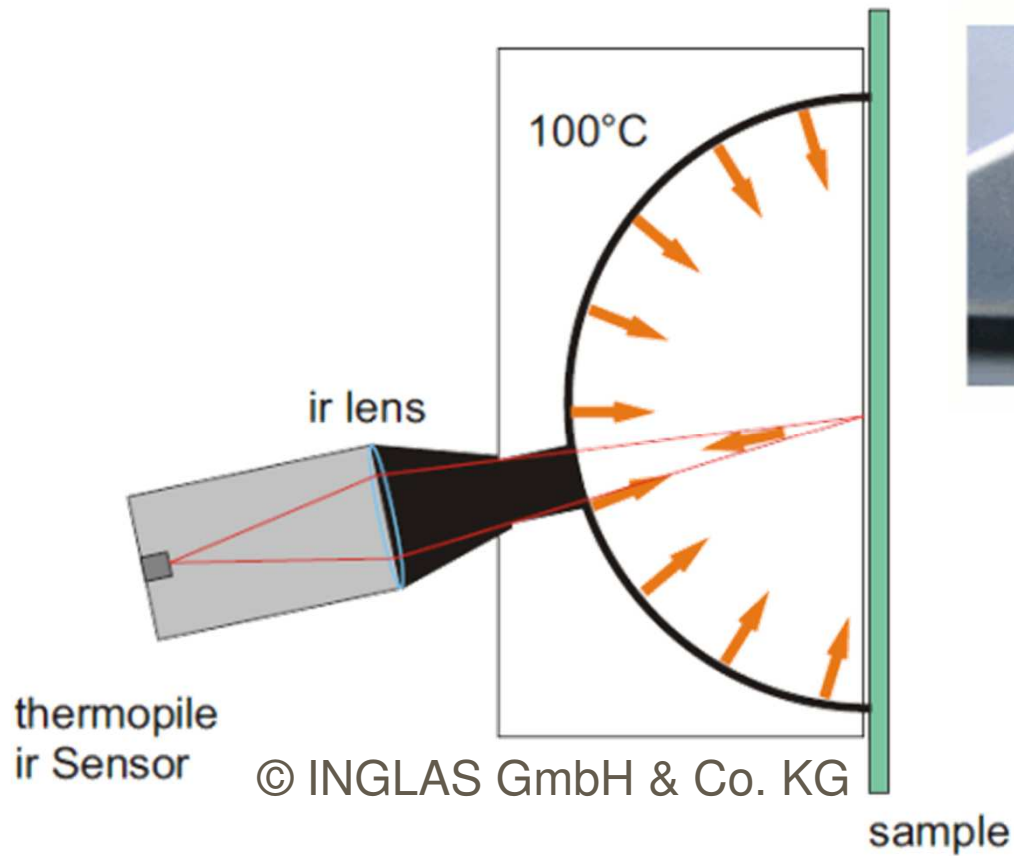


Total hemispherical emissivity $\varepsilon(T)$

$$\varepsilon(T) = \frac{1}{\pi} \cdot \int_{\text{hemi-sphere}} \varepsilon_d(\theta, \varphi, T) \cdot \cos \theta \cdot d\omega$$

Reflectometer / Emissiometer

Determination of the total normal emissivity $\varepsilon_n(T)$
by measuring the hemispherical normal reflectance $R_{hn}(T)$



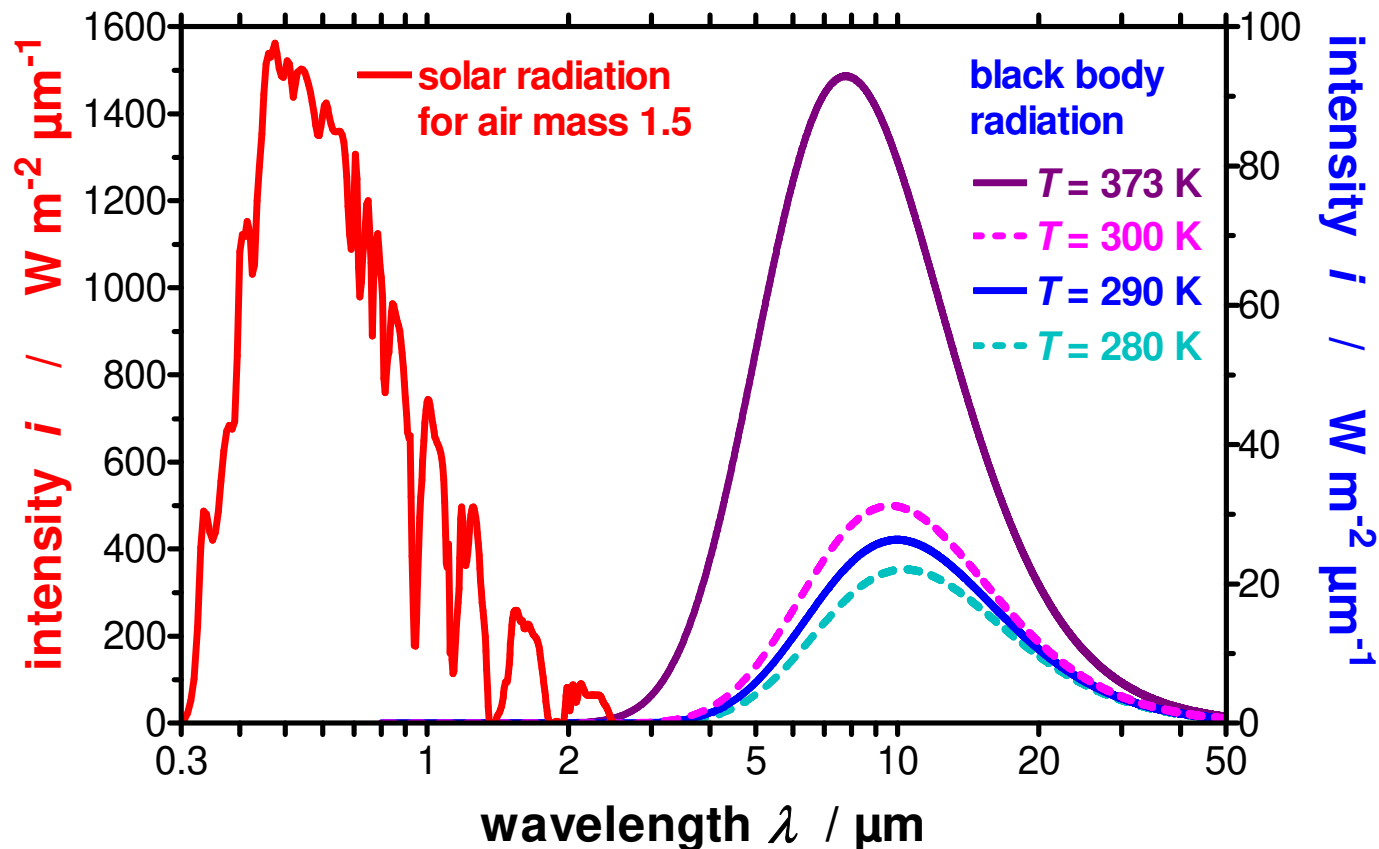
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Reflectometer / Emissiometer



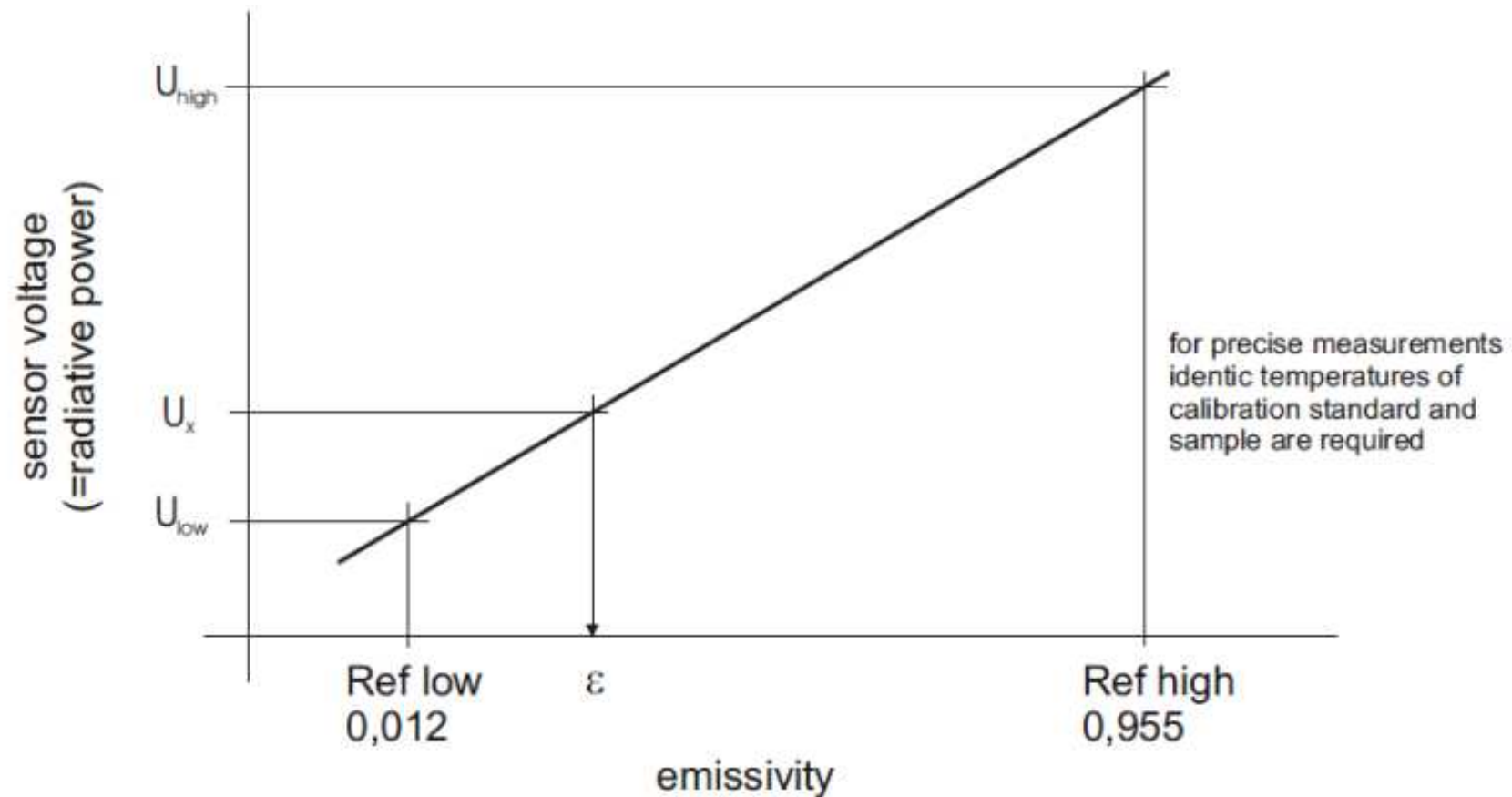
Determination of the total normal emissivity $\varepsilon_n(T)$
by measuring the hemispherical normal reflectance $R_{hn}(T)$



Reflectometer / Emissiometer

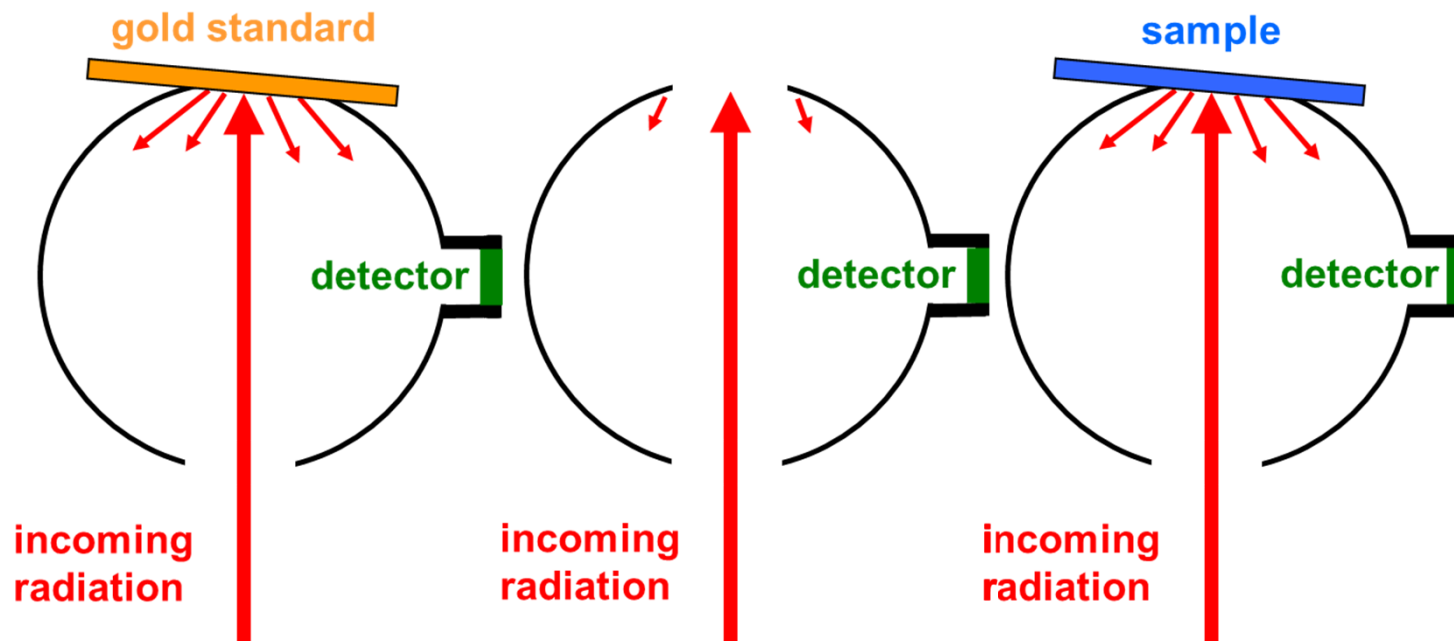


Determination of the total normal emissivity $\varepsilon_n(T)$
by measuring the hemispherical normal reflectance $R_{hn}(T)$



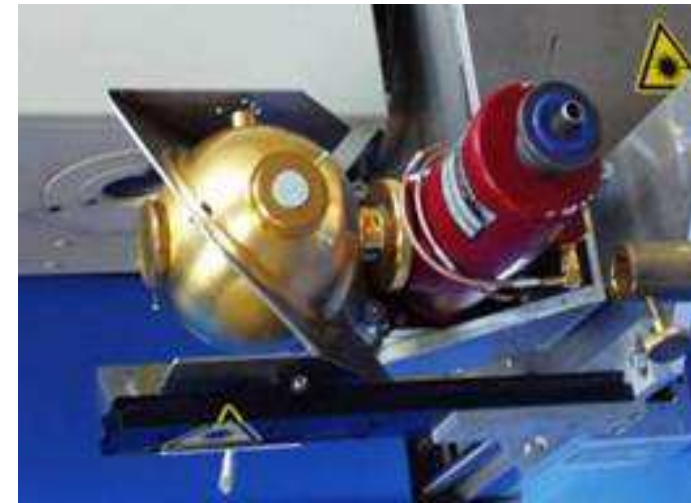
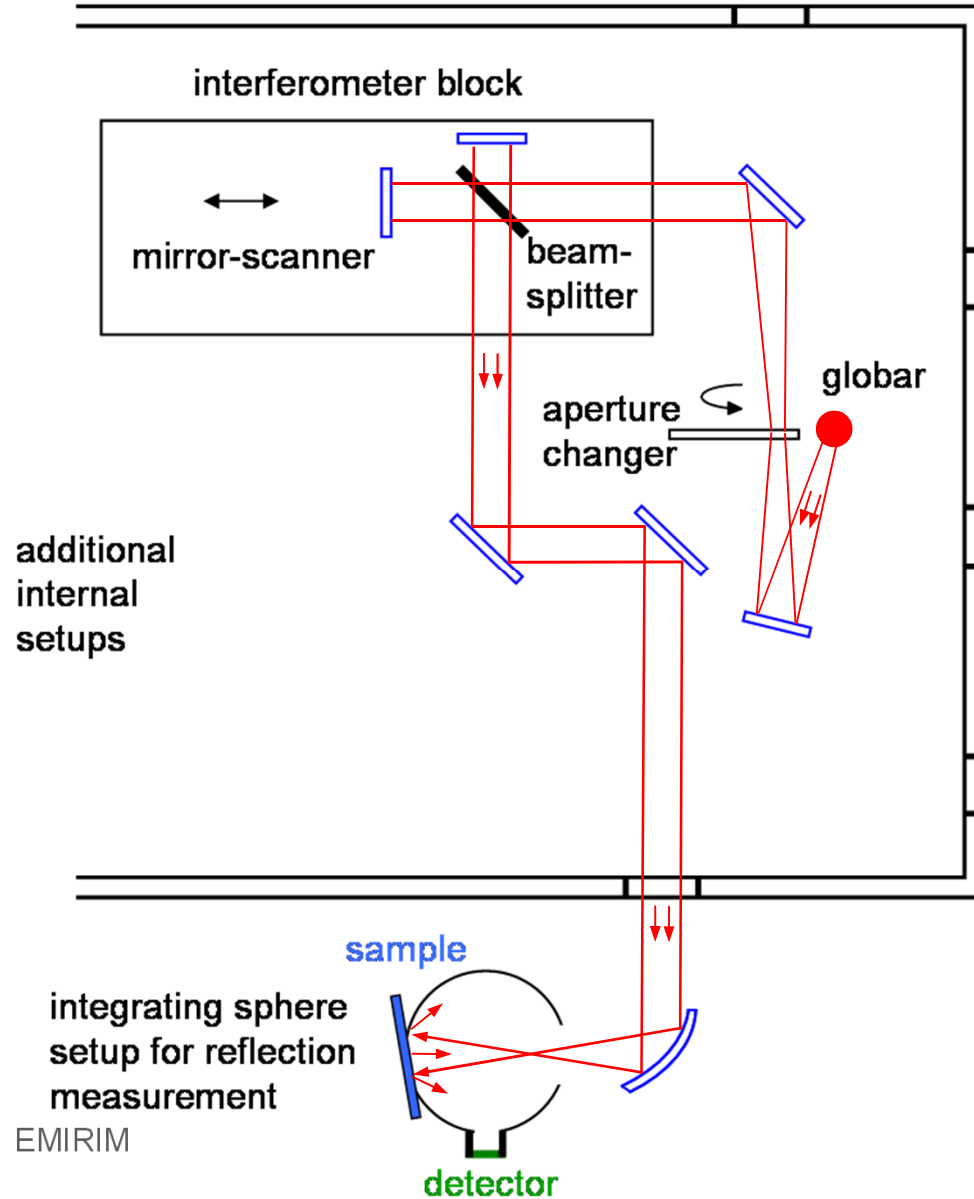
Integrating Sphere

Determination of the spectral normal emissivity $\varepsilon_n(\lambda, T)$
by measuring the normal hemispherical reflectance $R_{nh}(\lambda, T)$



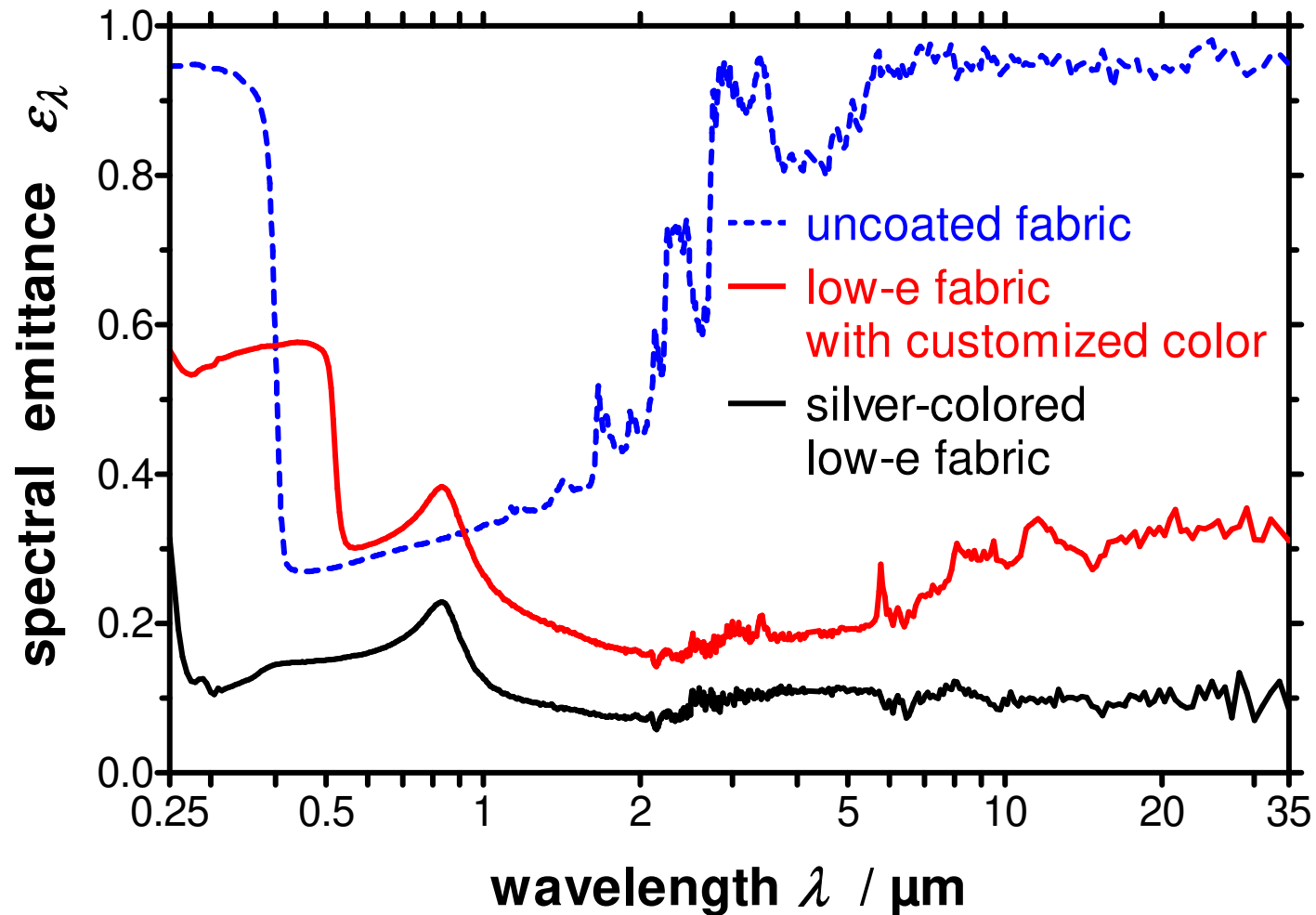
Integrating Sphere

FTIR-spectrometer



Integrating Sphere

Examples for derived spectral normal emissivity $\varepsilon_n(\lambda, T)$



Thank you!

EMPIR



The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

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