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From spectrophotometry to appearance measurements

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Outline

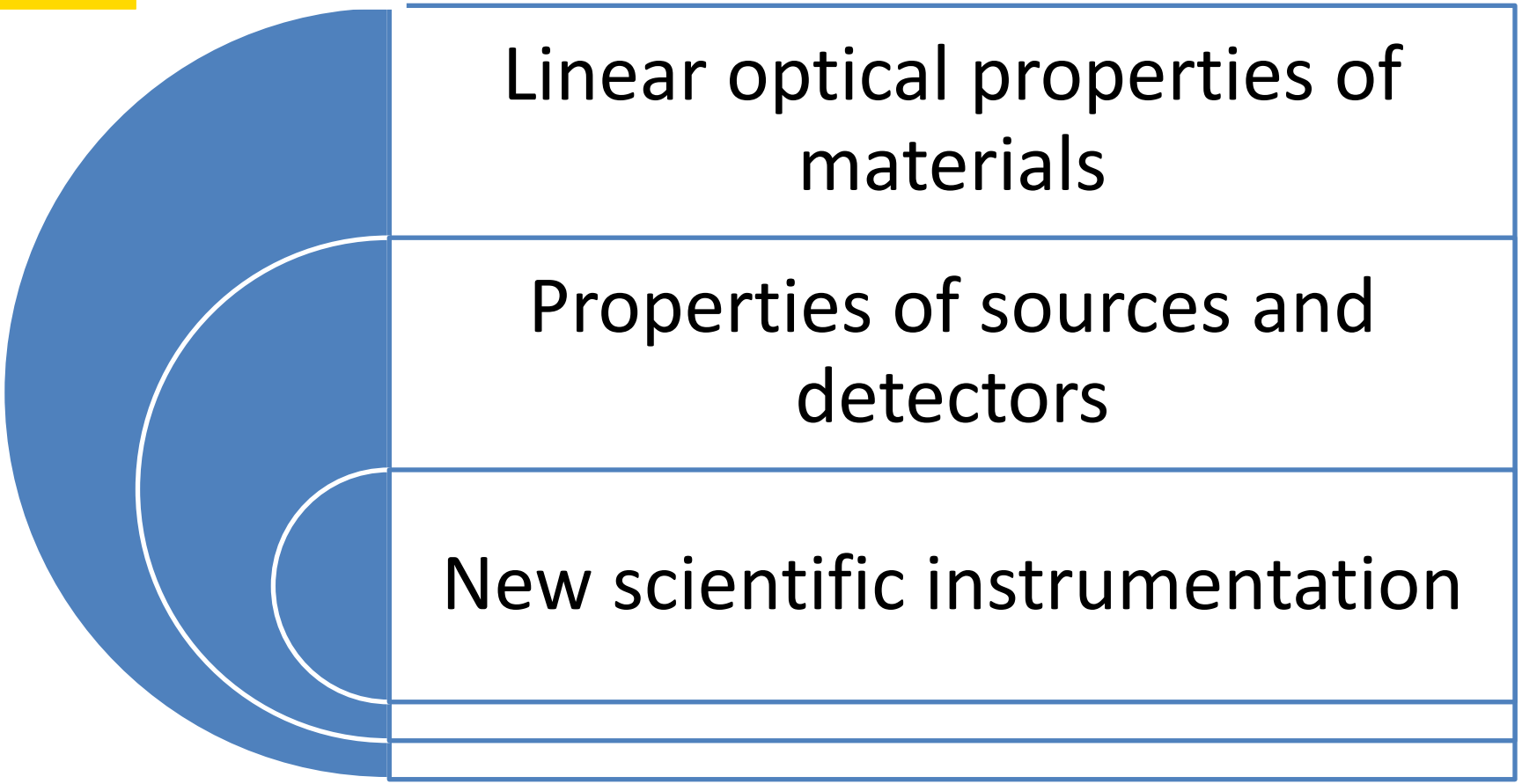
- Description of the research group "Measurement of Optical Radiation".
- The measurement of the scattering function: GEFE goniospectrophotometer.
- Next developments.

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Research group: “Measurement of Optical Radiation” (GIMRO)

- Dra. Alicia Pons
- Dr. Joaquín Campos
- Dra. Mª Luisa Hernanz
- Dr. Alejandro Ferrero
- J. Luis Velázquez
- Elisa Borreguero
- Berta Bernad
- J. Manuel García
- J. Luis Bris

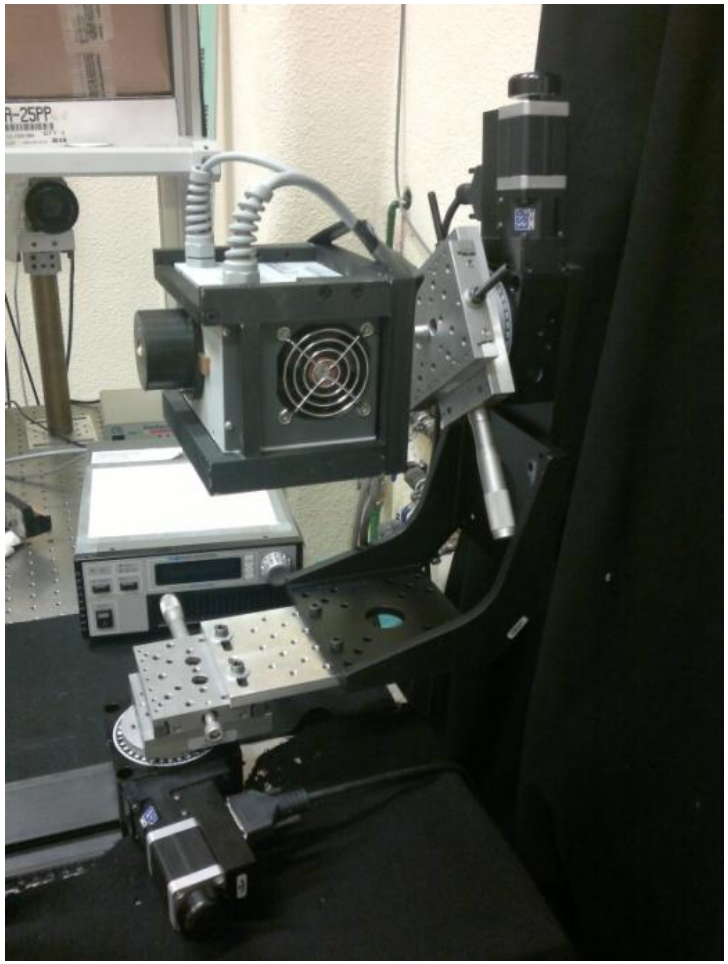


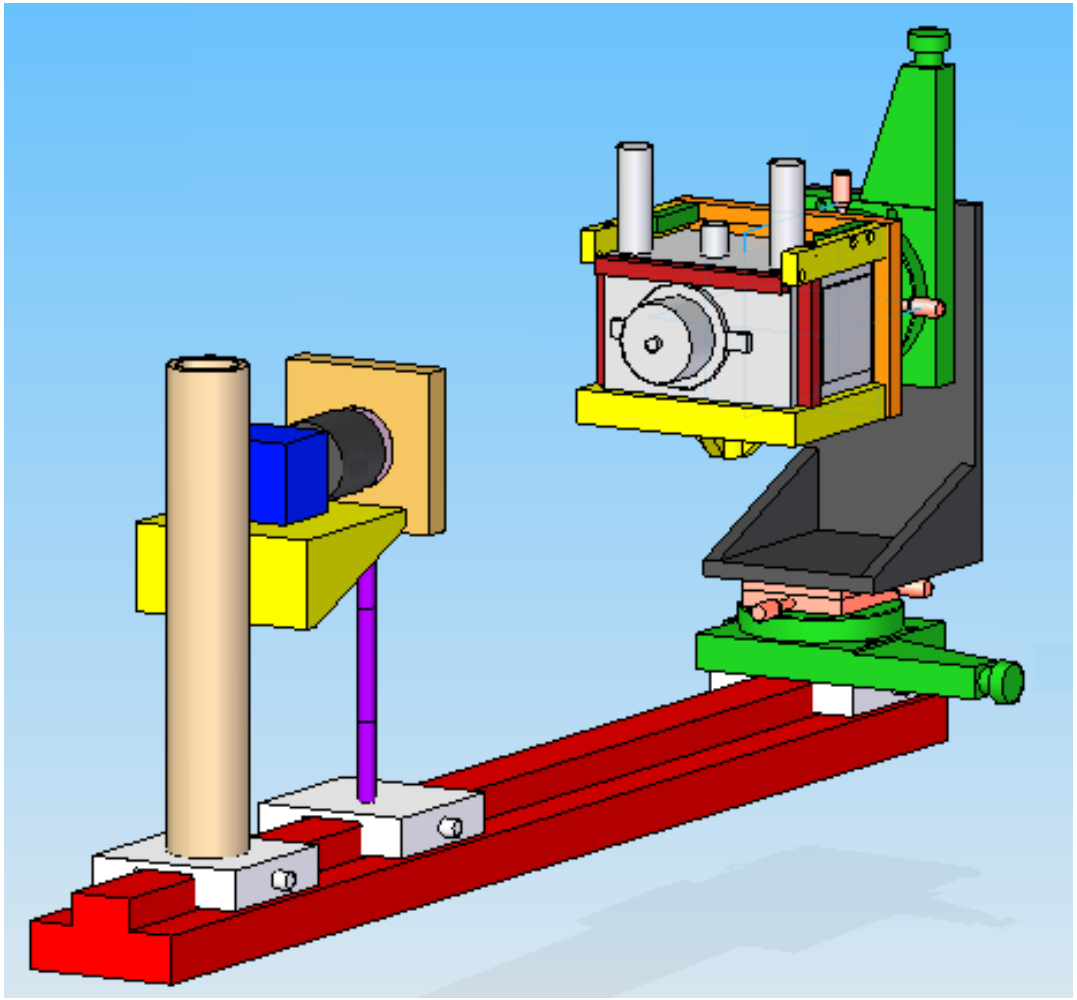
GIMRO: research lines

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LEDs characterization





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Radiometric characterization of cameras



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The measurement of the scattering function

$$\mathrm{d}L_s = S(\mathbf{r}_i, \mathbf{x}_i, \lambda_i; \mathbf{r}_s, \mathbf{x}_s, \lambda_s)\,\mathrm{d}\Phi$$

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The measurement of the scattering function

$$S\left(\theta_i, \mathbf{x}_i, \lambda_i; \mathbf{r}_s, \mathbf{x}_s, \lambda_s\right)$$



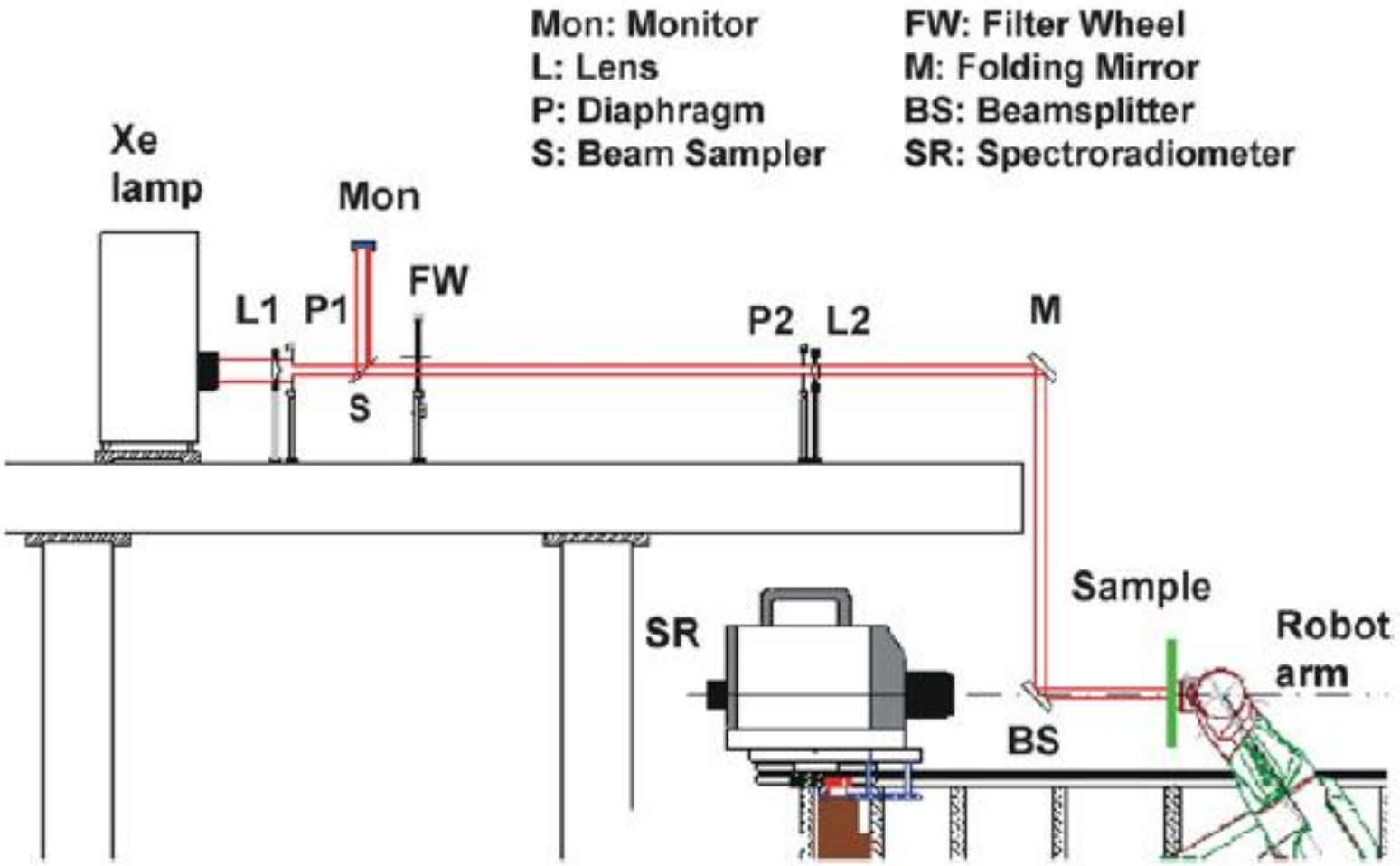
$$BRDF\left(\theta_i; \mathbf{r}_s; \lambda\right)$$

Homogeneous,
no translucent,
no fluorescent.

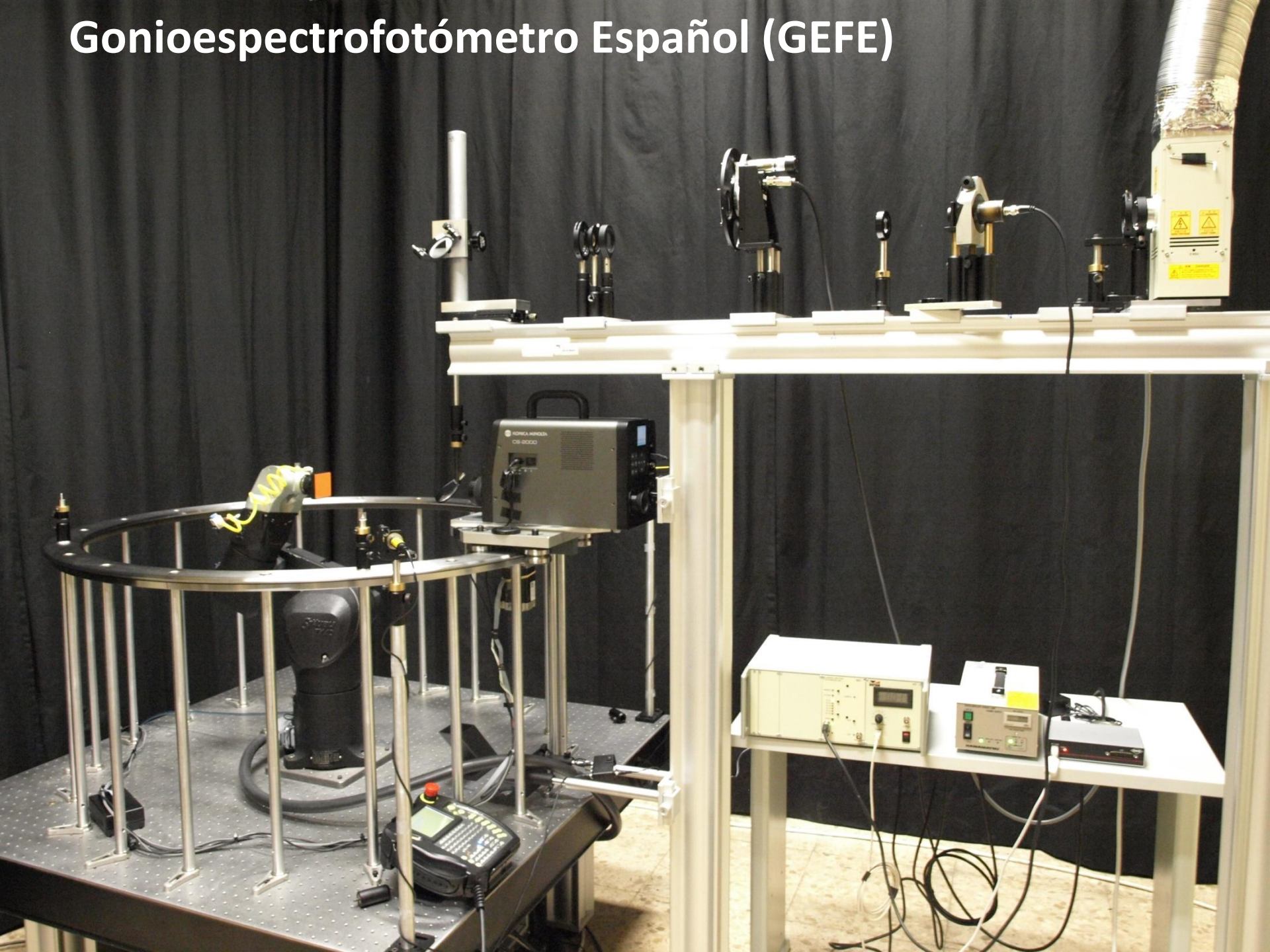
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Gonioespectrofotómetro Español (GEFE)



Gonioespectrofotómetro Español (GEFE)



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Table 1. Specifications of the spectroradiometer CS-2000 A.

Spectral range	380 nm to 780 nm
Resolution	0.9 nm/pixel
Bandwidth	4 nm
Field of view	0.1°, 0.2°, 1°
Minimum measurement distance	350 mm
Spectral accuracy	±0.3 nm
Minimum integration time	0.005 s

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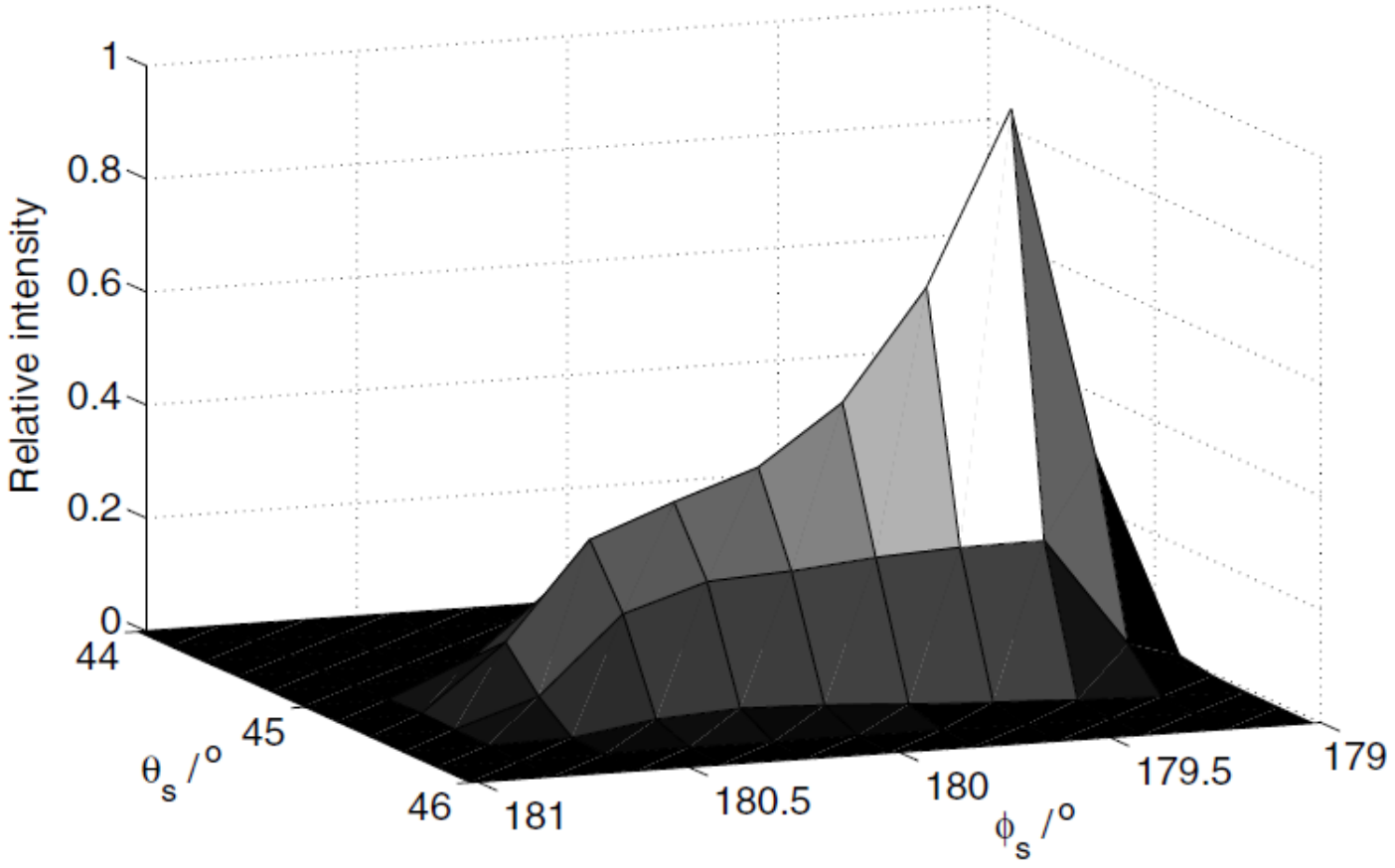


Figure 5. Incident beam's radiance: angular distribution in two perpendicular directions. The data were obtained aided by a mirror, with an incidence polar angle of 45°, an observation field of view of 0.1° and an angular step of 0.2°.

Gonioespectrofotómetro Español (GEFE)

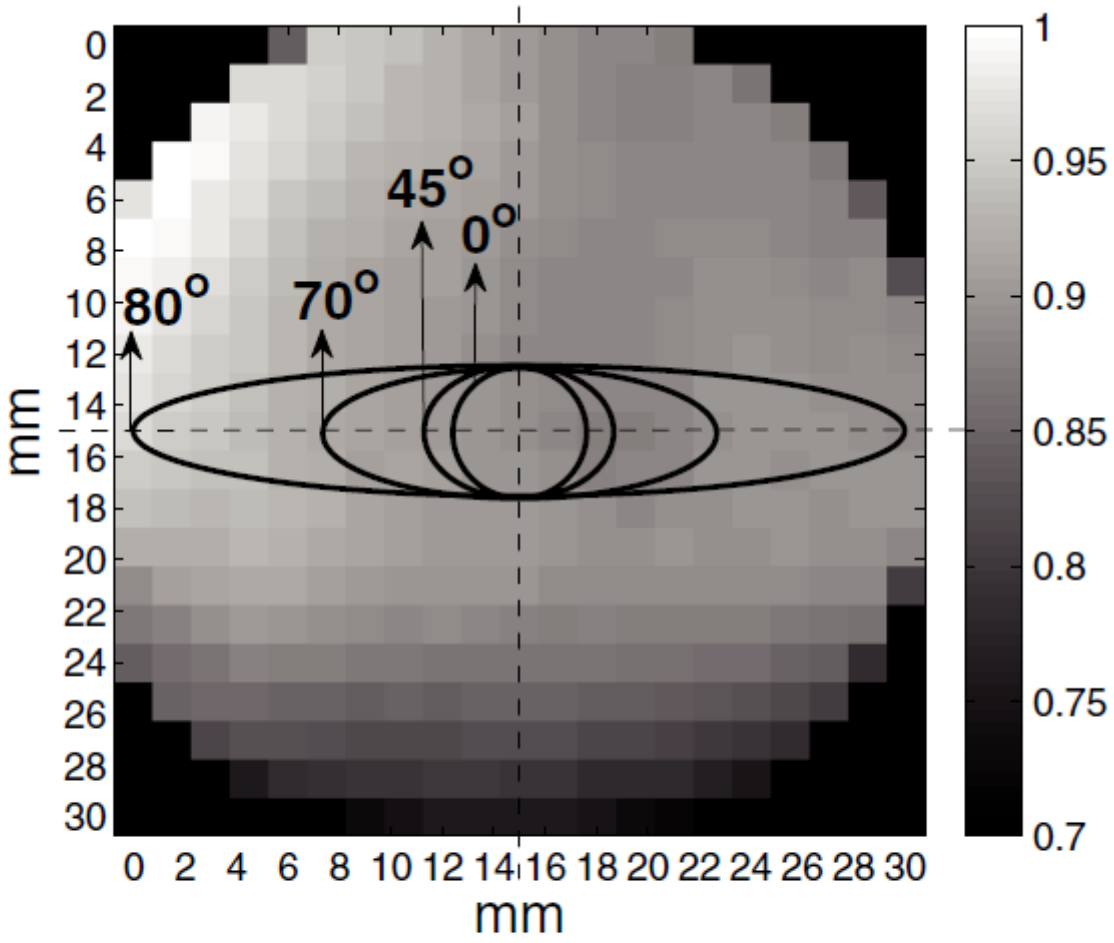


Figure 6. Spot's uniformity across the sample. The circle and the ellipses represent the regions that are seen by the spectroradiometer, with a 1° field of view, for different values of θ_s (0°, 45°, 70°, 80°) and for $\theta_i = 0°$.

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Gonioespectrofotómetro Español (GEFE)

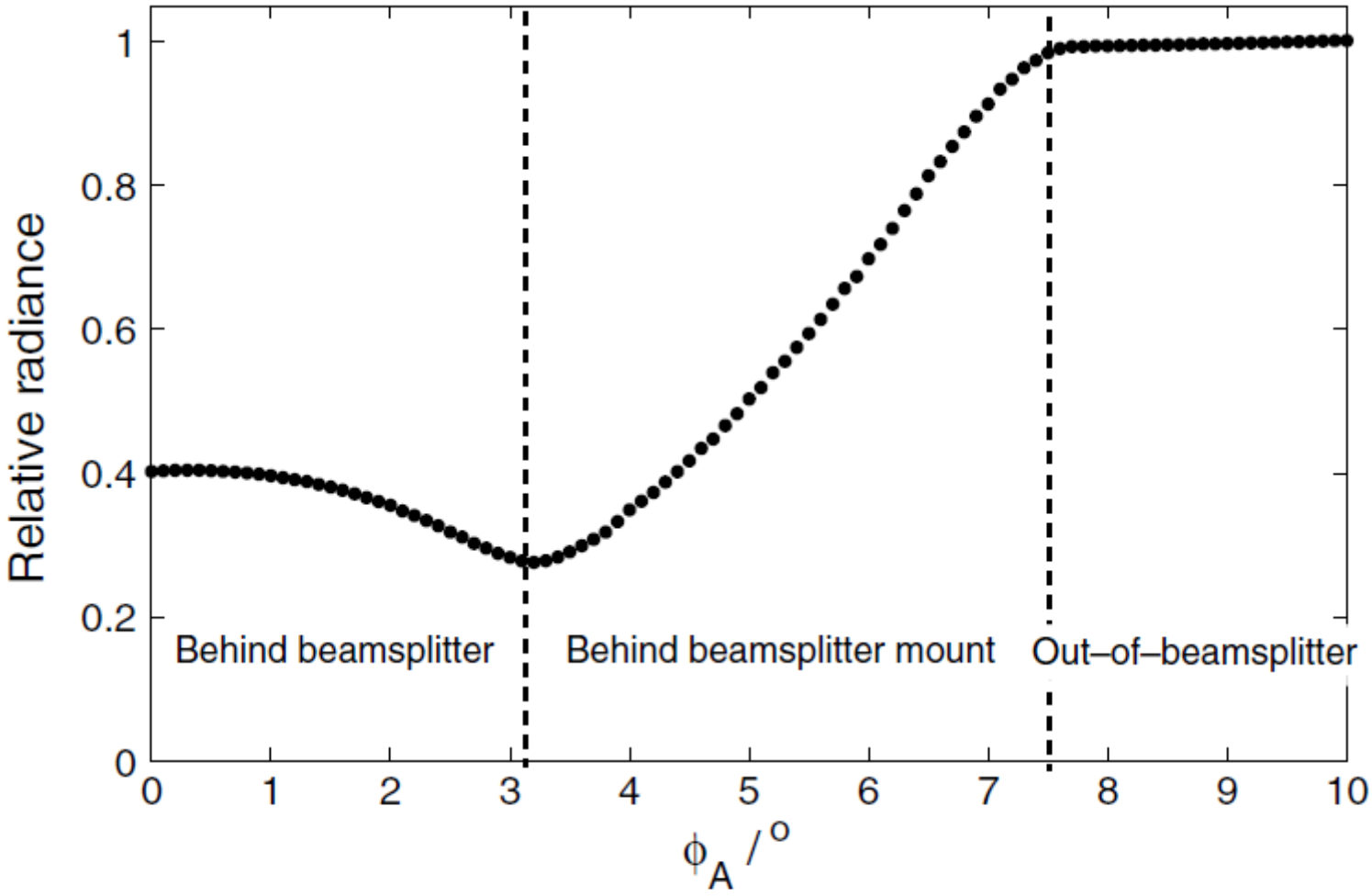


Figure 7. Occlusion: relative radiance measurements performed in the vicinity of ϕ_A.

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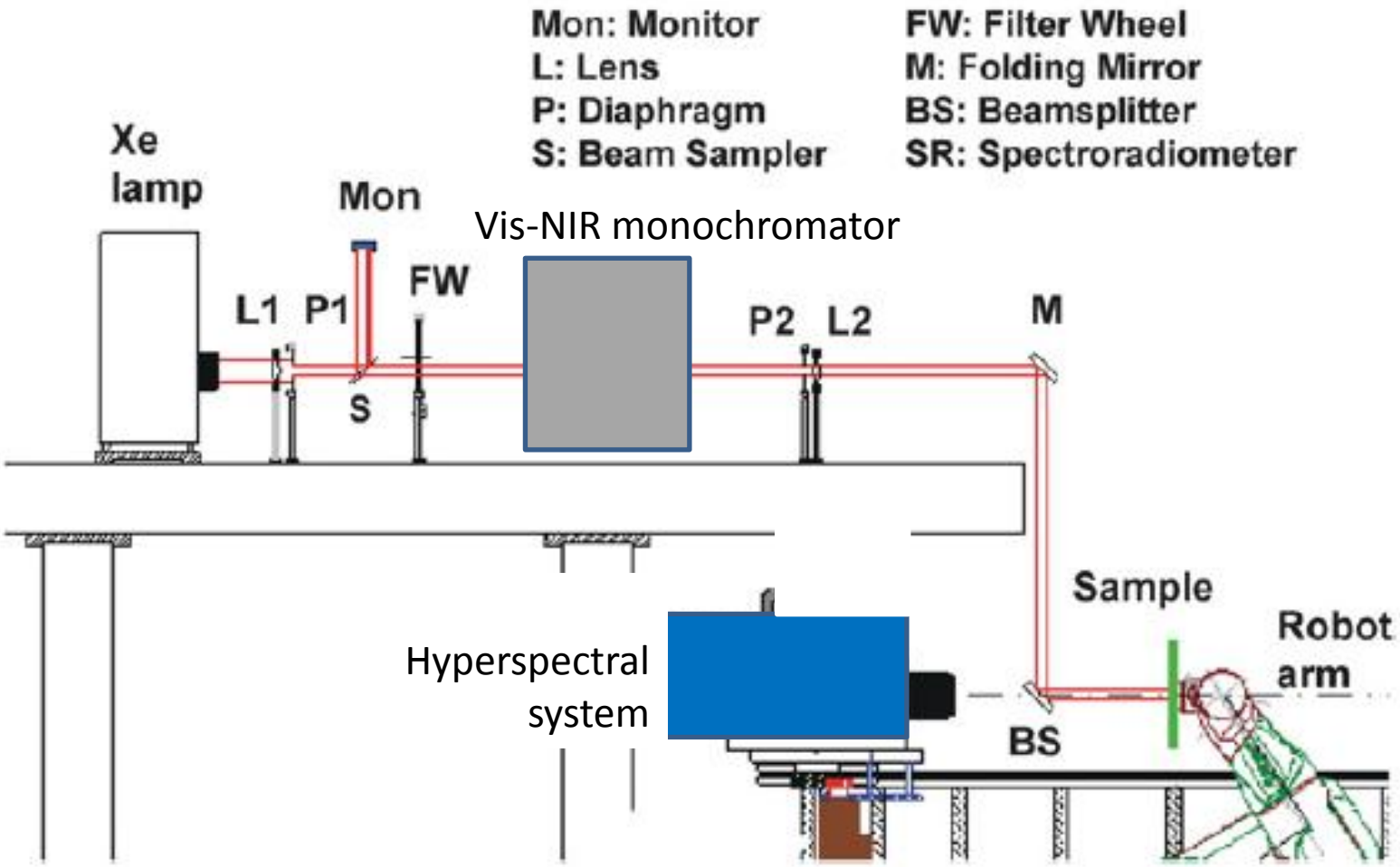
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Table 3. BRDF measurement uncertainty budget.

Uncertainty source	Uncertainty ($k = 1$) (%)	
	Type A	Type B
Spectroradiometer repeatability	<0.3[a]	
Spectroradiometer's linearity		$0.05 \times \mid n \mid$[b]
Temporal drift		0.04
Positioning uncertainty when measuring $L_0(g_0)$		0.16[c]
Positioning uncertainty when measuring $L(g)$		Sample[d]
Irradiance uniformity		<0.4[c,e]
Neutral density filters ($\tau_{r,j}$ and τ_0)		⩽0.35[f]
Beamsplitter transmittance		0.2
$\omega_i^\star$		0.06
$\cos\theta_i$		$\leqslant 10^{-3} \times \tan\theta_i$

Next developments



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Next developments

Present: $BRDF\left(\theta_i;\mathbf{r}_s;\lambda\right)$ **Color**, diffusers, retro-reflectance, **gloss,** goniochromatism…

Spatial resolution (hyperspectral system)

Short-term: $BSSRDF\left(\theta_i,\mathbf{x}_i;\mathbf{r}_s,\mathbf{x}_s;\lambda\right)$ Uniformity, sparkle, **texture**, **translucency**

Vis-NIR monochromator

Long-term: $S\left(\theta_i,\mathbf{x}_i,\lambda_i;\mathbf{r}_s,\mathbf{x}_s,\lambda_s\right)$ Fluorescence, NIR