UV Fluorescence from Integrating Spheres Measurement and Theory

Ping-Shine Shaw, Zhigang Li, Uwe Arp, and Keith R. Lykke
National Institute of Standards and Technology, Gaithersburg, MD, USA

NIST

Outline:

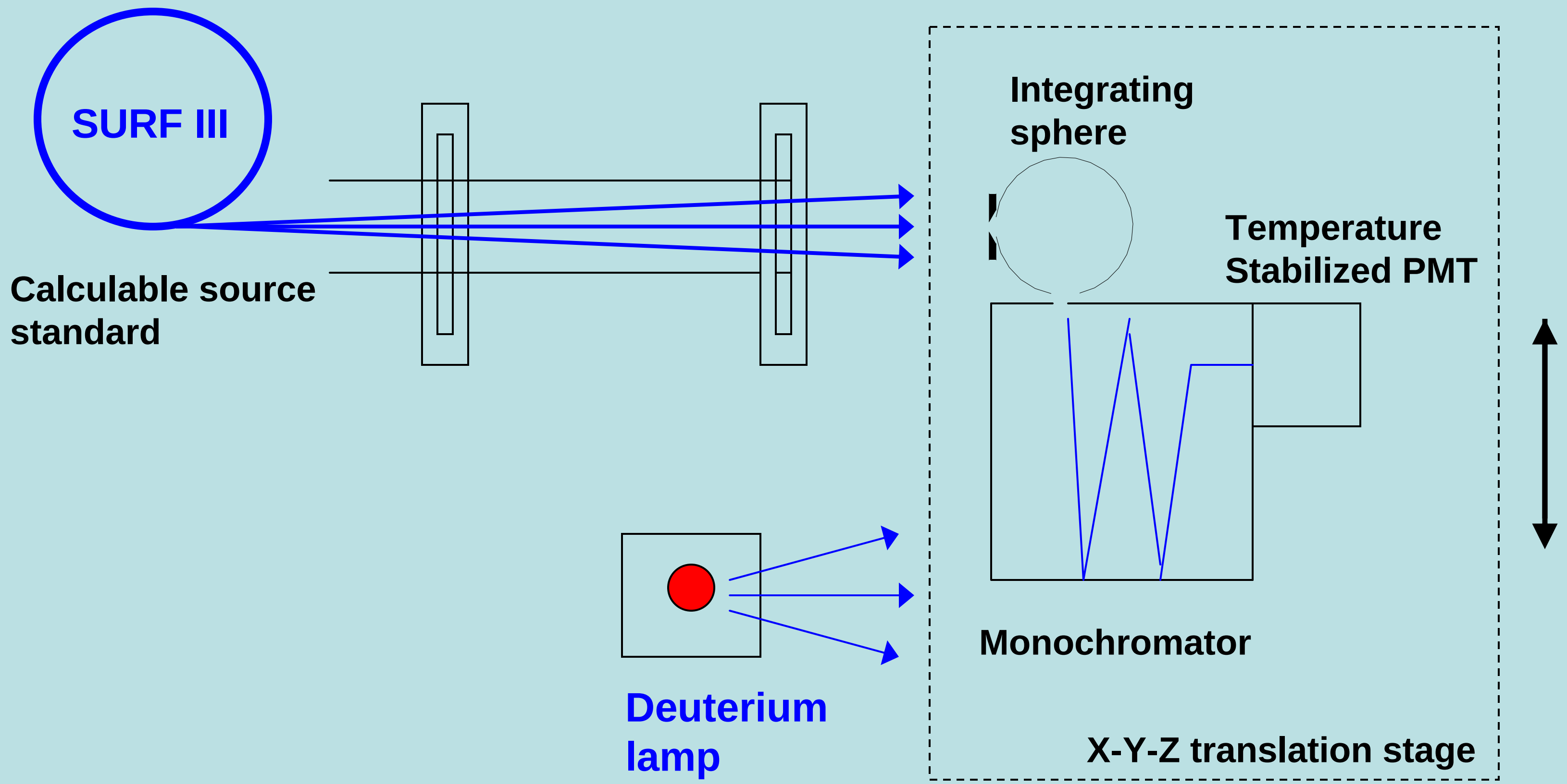
1. UV fluorescence measurement using lasers.

2. Determination of the total spectral fluorescence yield of an integrating sphere.

3. Theory of fluorescence from an integrating sphere.

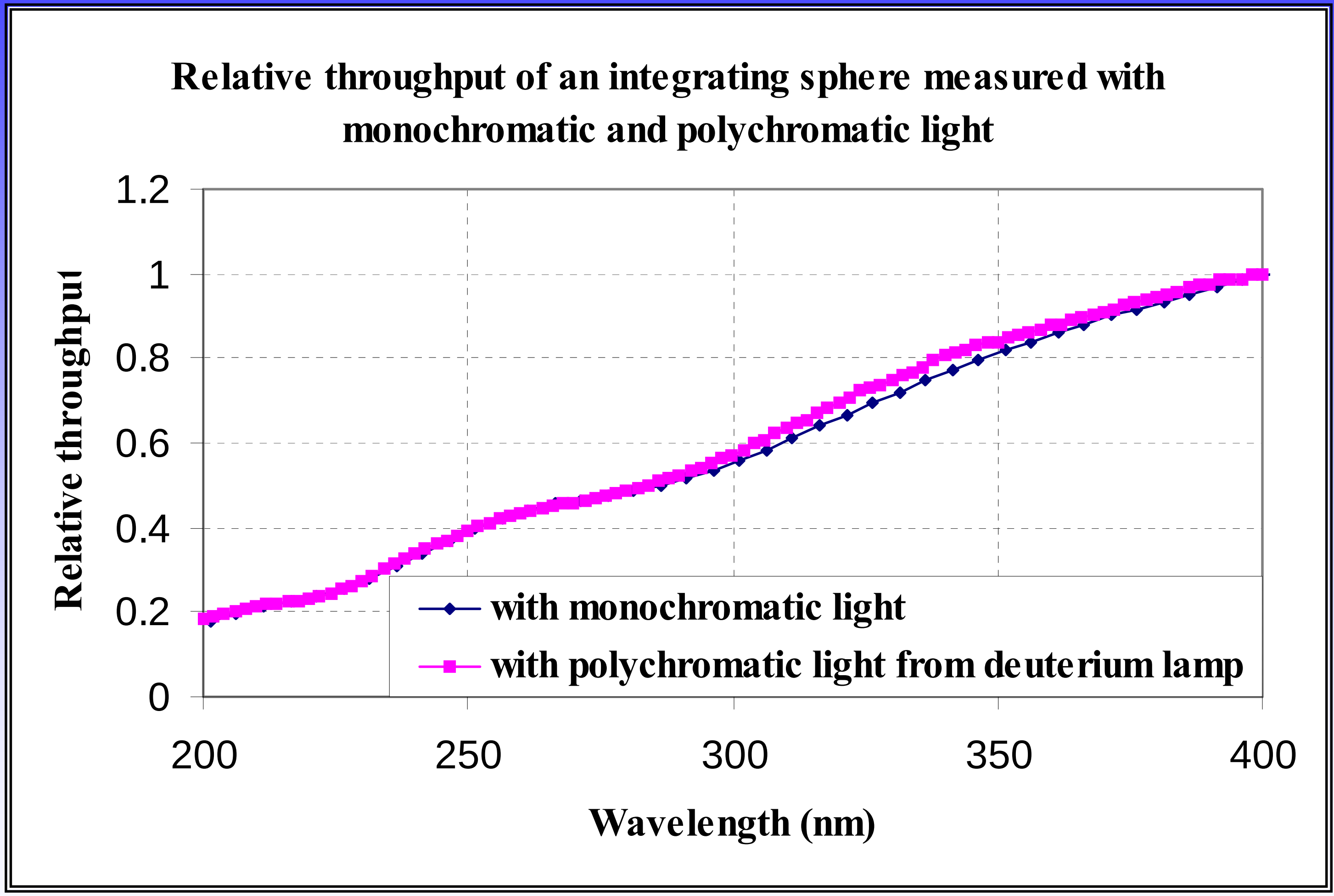
Integrating Sphere for UV Application

- irradiance calibration of deuterium lamps using synchrotron radiation at NIST



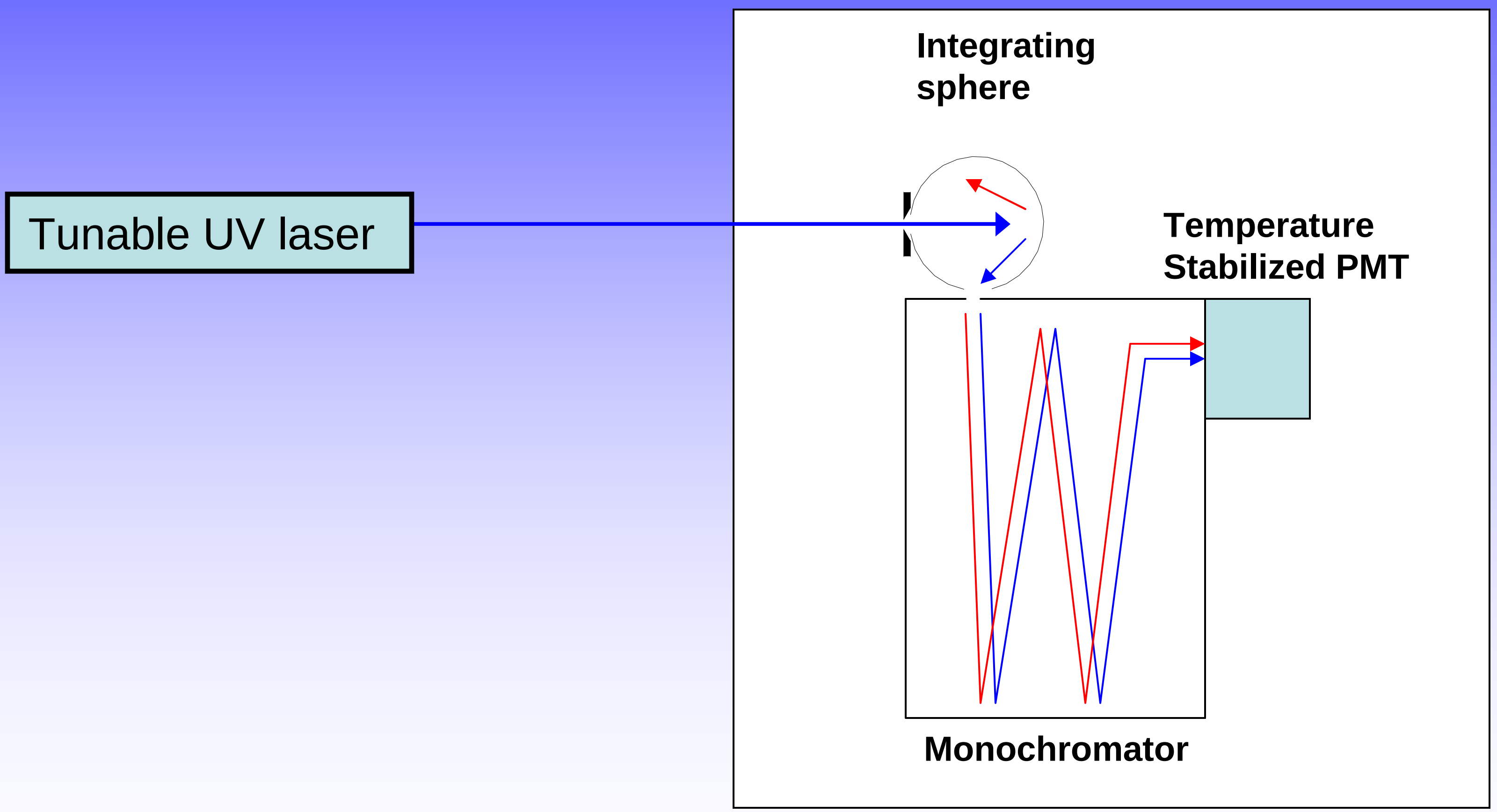
Facility for Irradiance Calibration Using Synchrotrons (FICUS)

Problem with integrating sphere in the UV - fluorescence

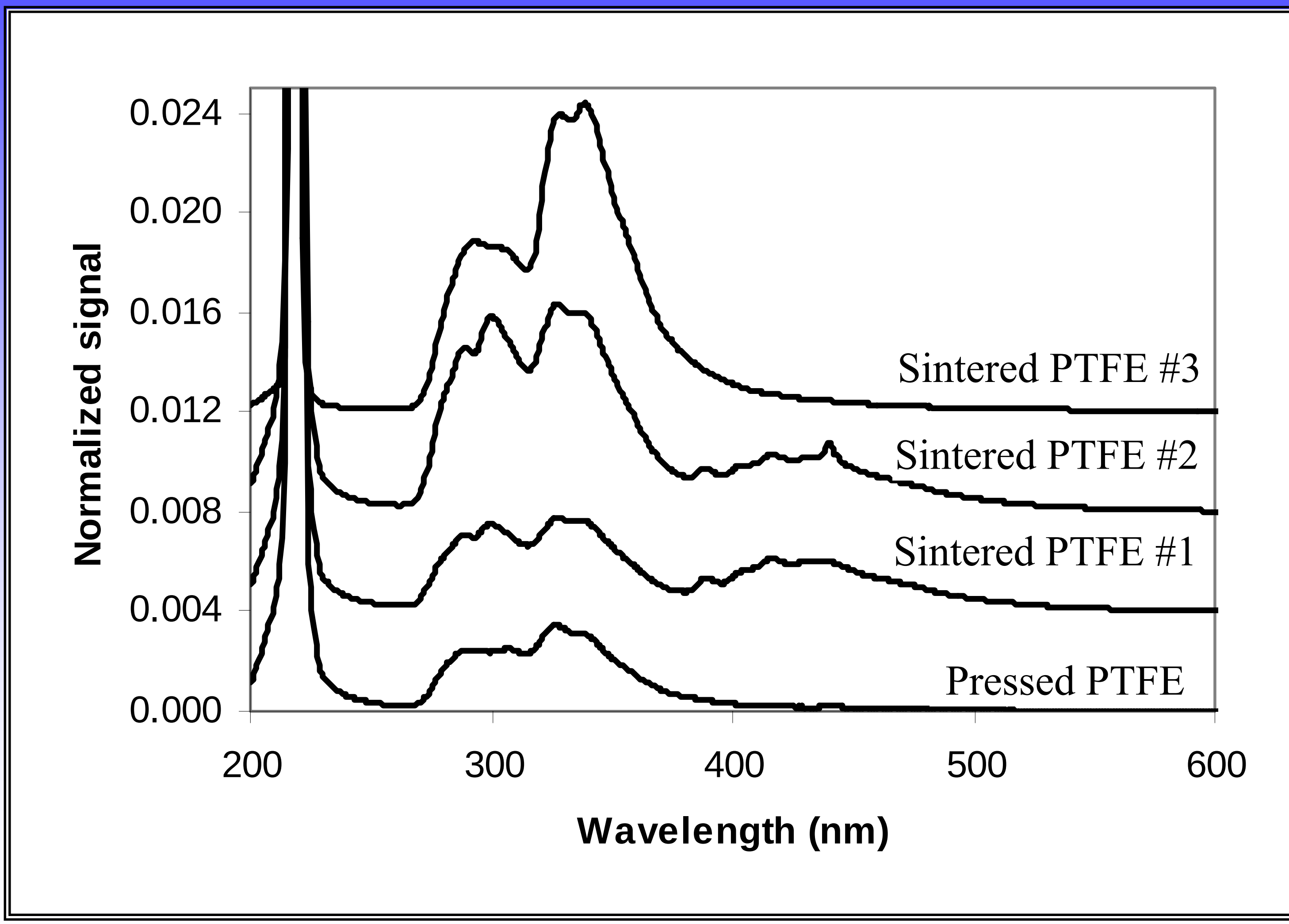


UV Characterization of integrating spheres

Laser Induced Fluorescence (LIF)



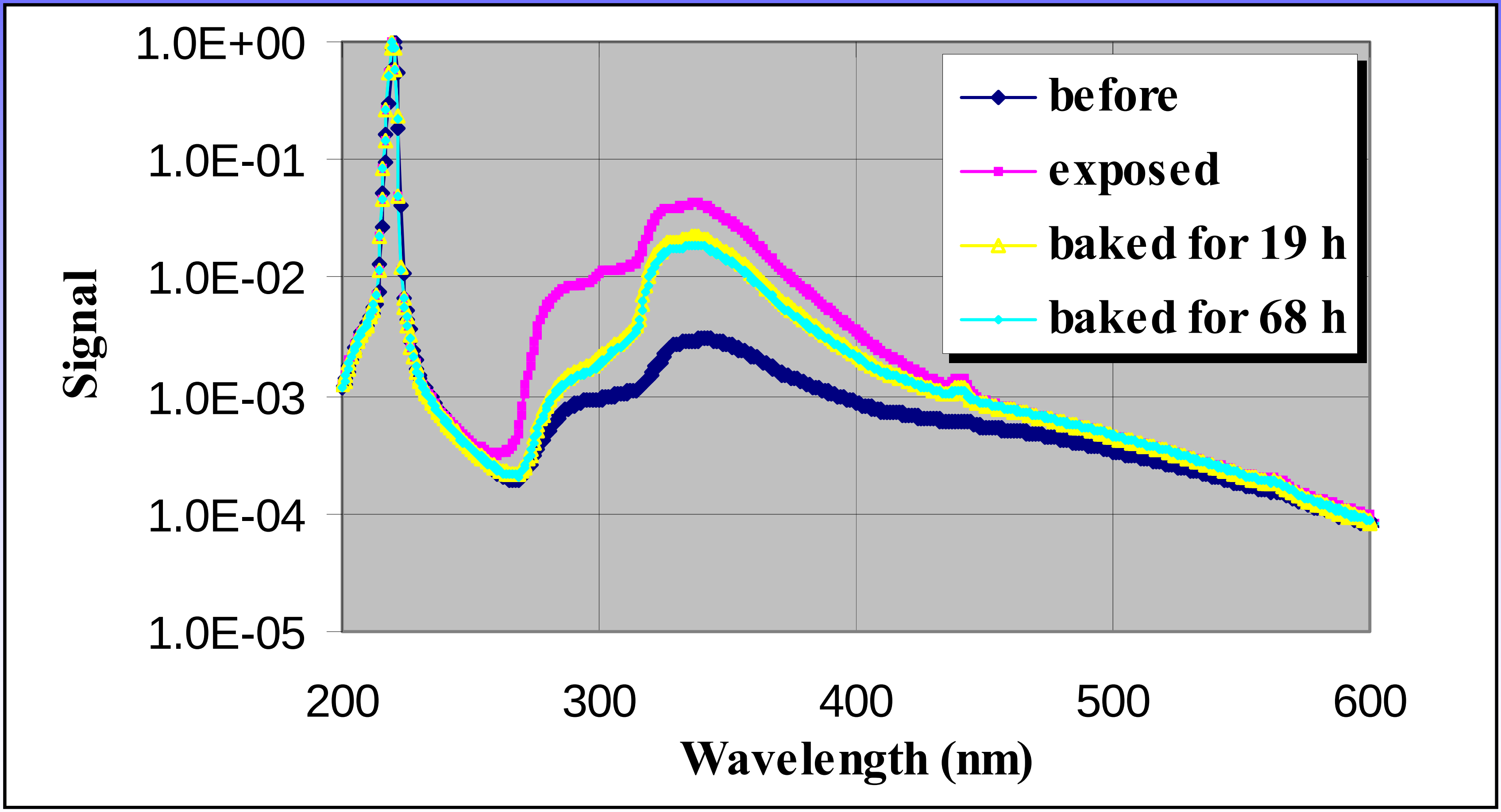
UV induced fluorescence from typical PTFE integrating spheres excited by 220 nm laser



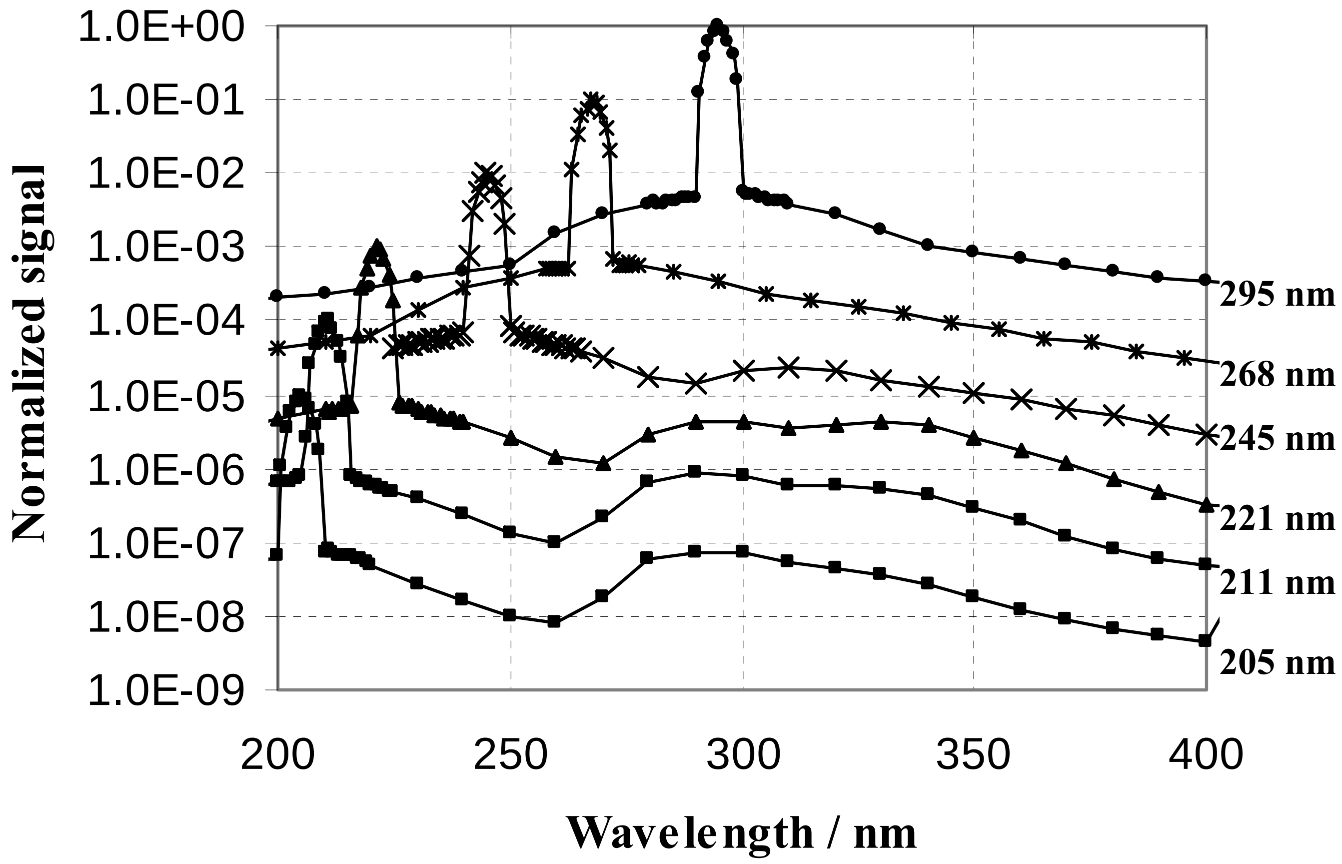

U.S. Government

Sintered PTFE integrating spheres exposed to diesel gas exhaust

With 220nm excitation laser



Raw data from laser induced fluorescence measurement of integrating sphere



P.S. Shaw, Z. Li, U. Arp, and K.R. Lykke Applied Optics, Vol. 46, p. 5119 (2007)

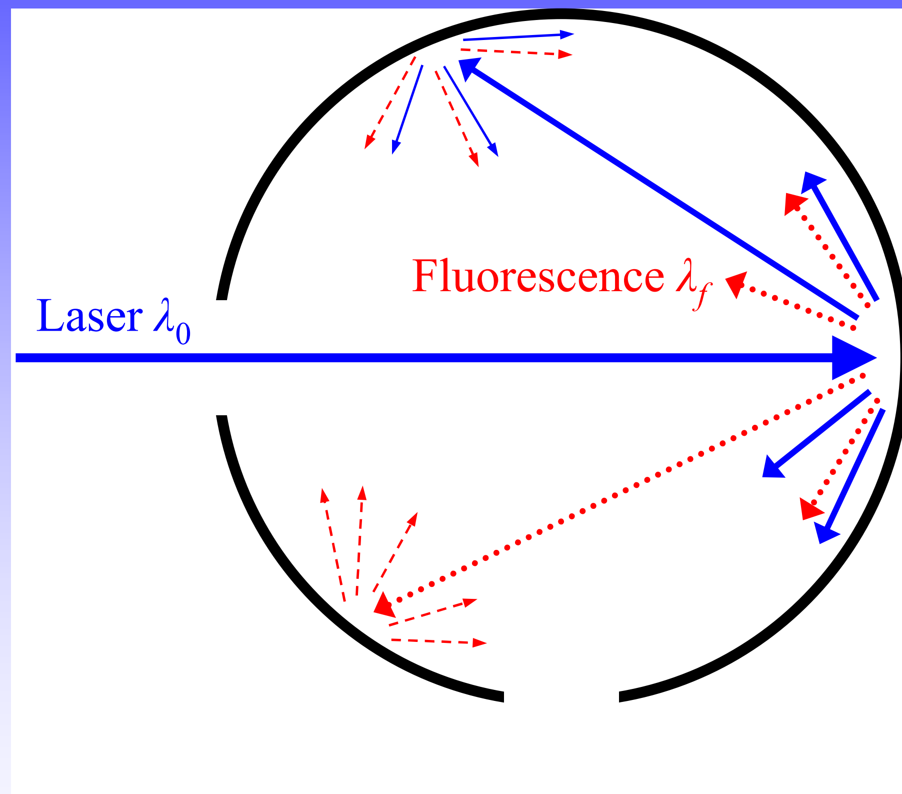
The total spectral fluorescence yield

Define the total spectral fluorescence yield of an integrating sphere as

$$f_{\lambda,total}(\lambda_f, \lambda_0) = \frac{\Phi_{\lambda,fl}(\lambda_f, \lambda_0)}{\Phi^0}$$

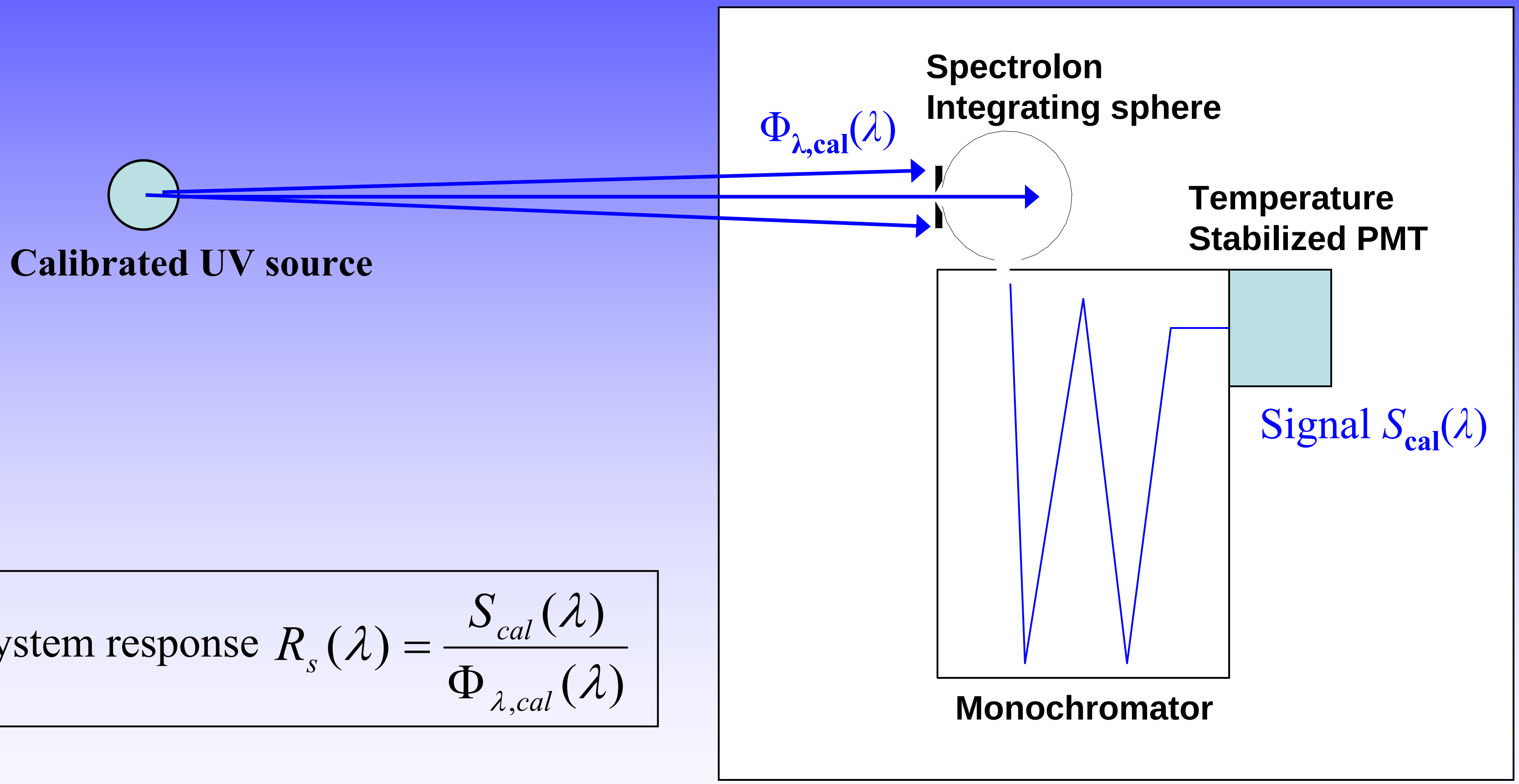
Φ^0 : power of the primary radiation λ_0 entering the integrating sphere.

$\Phi_{\lambda,fl}(\lambda_f, \lambda_0)$: the total spectral power of fluorescence excited.



Measuring total spectral fluorescence yield

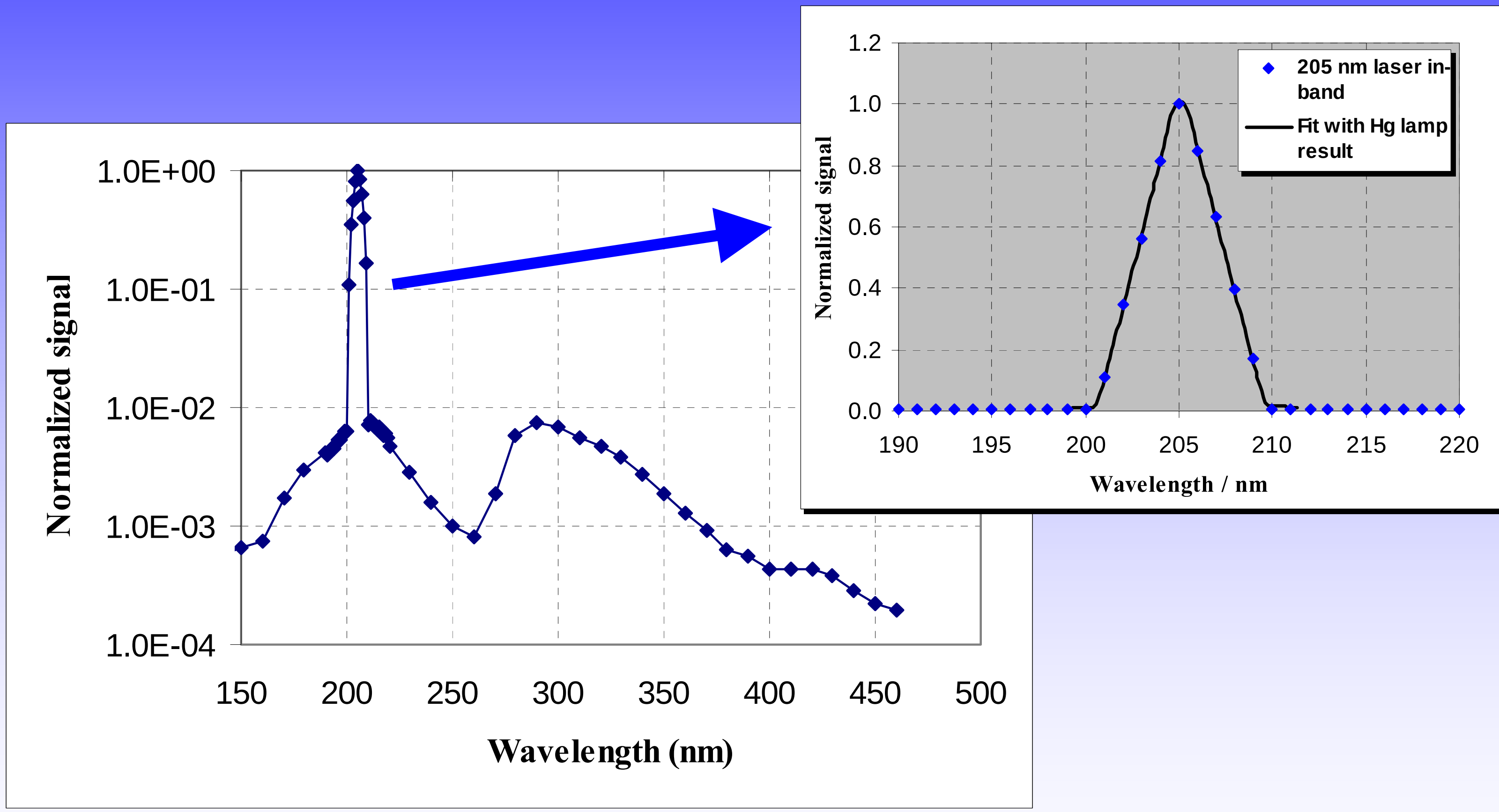
1. System response calibration



System response $R_s(\lambda) = \dfrac{S_{cal}(\lambda)}{\Phi_{\lambda,cal}(\lambda)}$

Measuring total spectral fluorescence yield

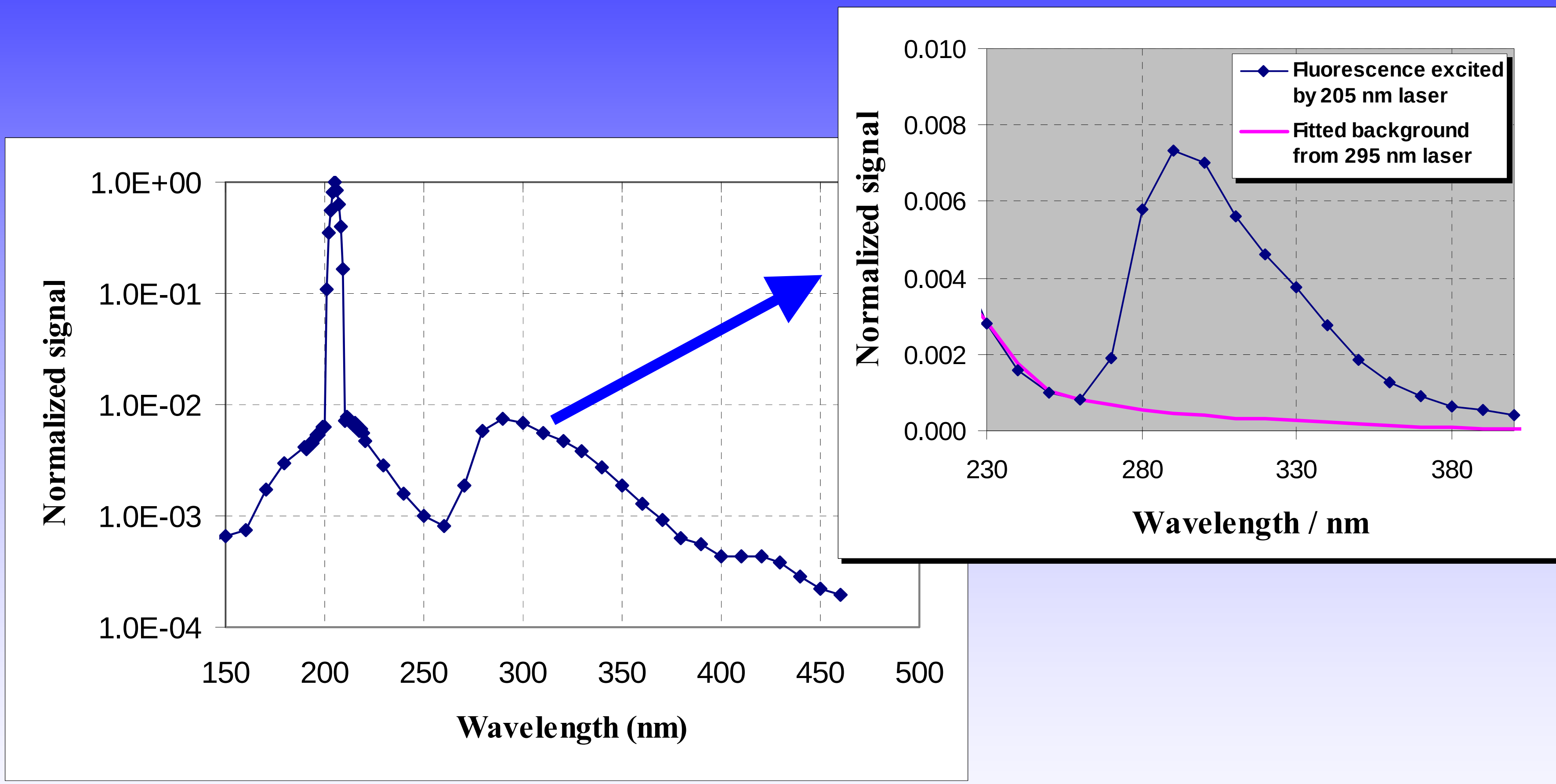
2. Relative laser power determination from in-band slit scattering function



Relative laser power $\Phi^0 = \frac{\int_{in-band} S(\lambda) d\lambda}{R_s(\lambda_0)}$

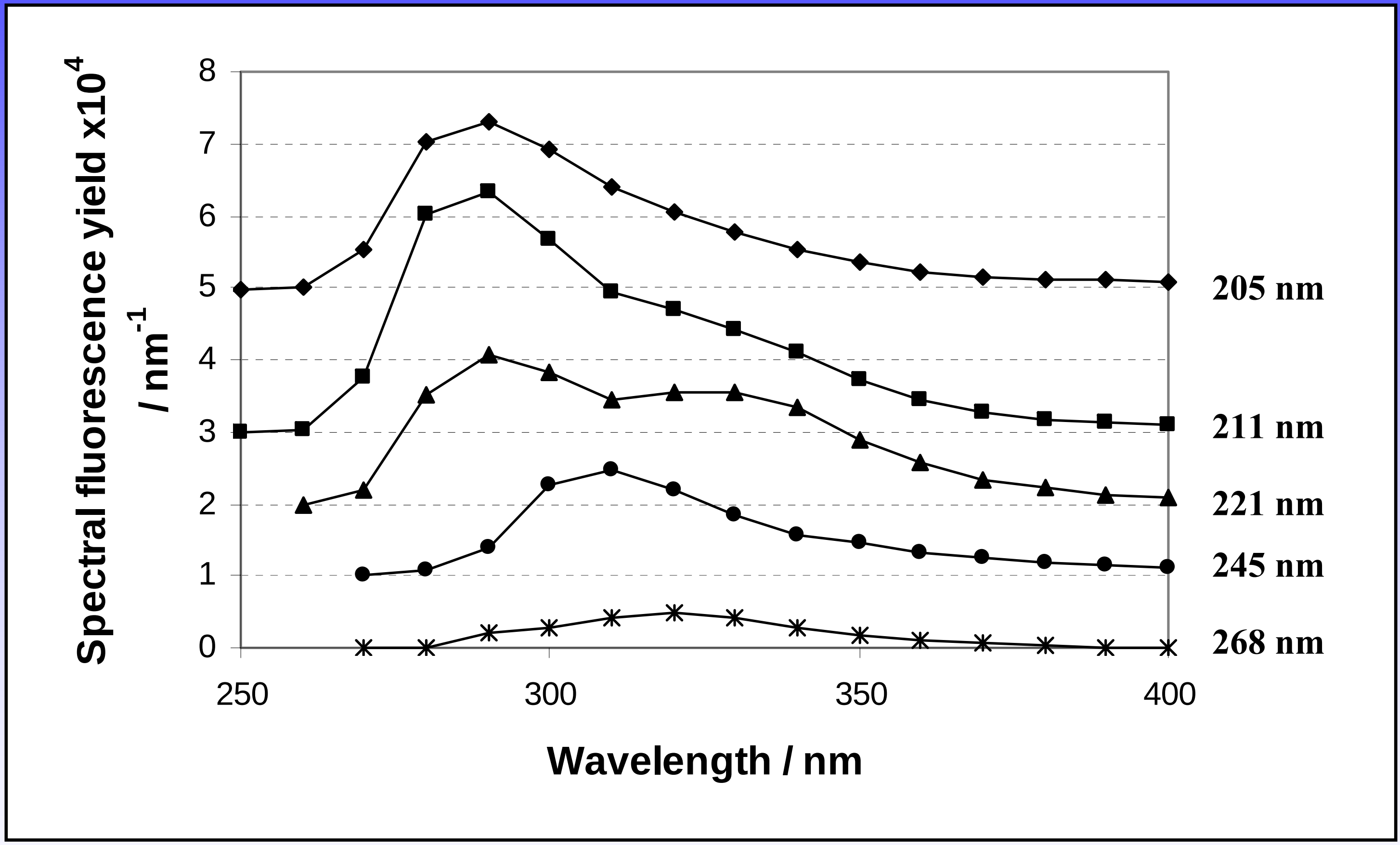
Measuring total spectral fluorescence yield

3. Relative spectral fluorescence power determination



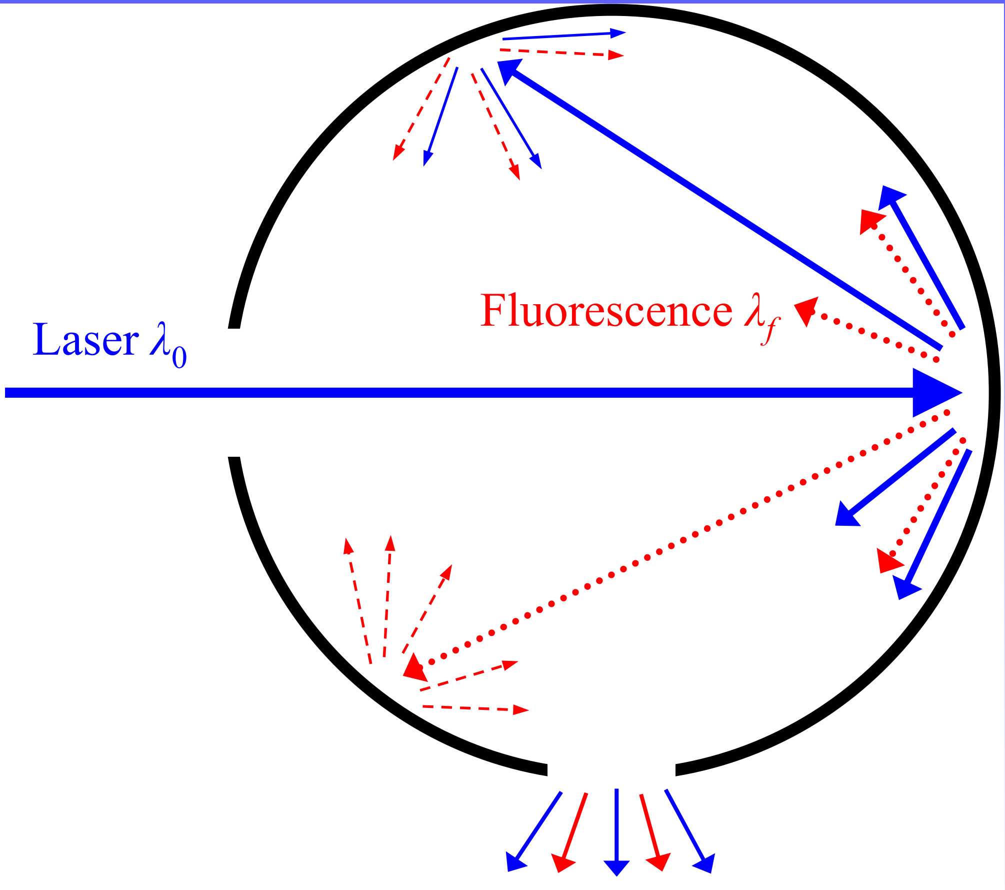
Spectral fluorescence yield $f_{\lambda,total}(\lambda,\lambda_0) = \dfrac{[S(\lambda) - S_{bg}(\lambda)]}{R_s(\lambda)} \Bigg/ \dfrac{\int_{in-band} S(\lambda_i) d\lambda_i}{R_s(\lambda_0)}$

Total spectral fluorescence yield of an integrating sphere



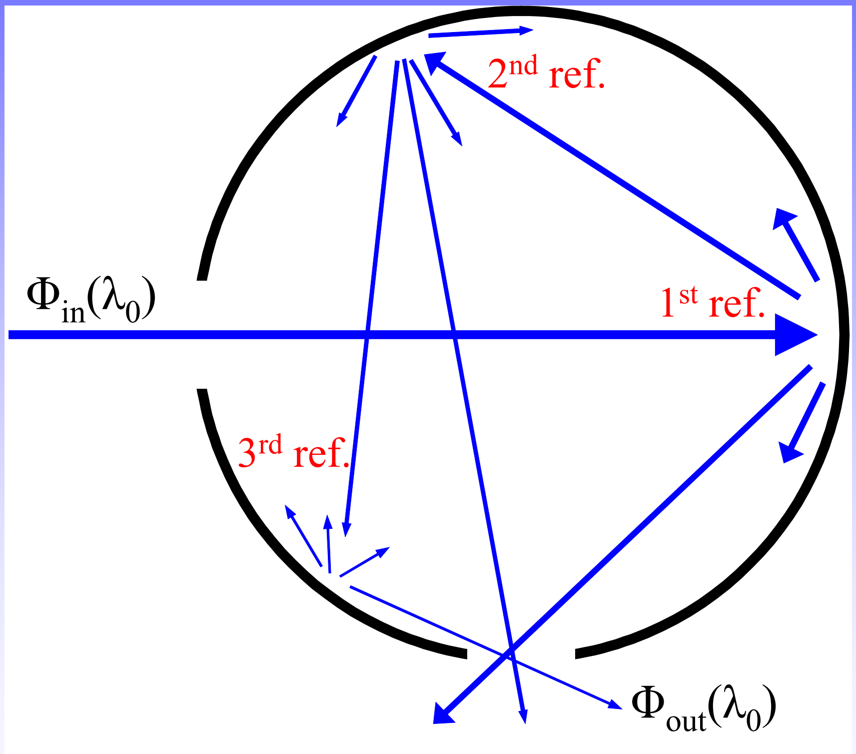
P.S. Shaw U. Arp and K.R. Lykke, to be published in Metrologia

Theory of fluorescence from integrating spheres



P.S. Shaw and Z. Li, Applied Optics, Vol. 47, page 3962 (2008)

Basic integrating sphere throughput formula



Throughput of an integrating sphere can be calculated by summing contribution from all reflections inside the sphere as

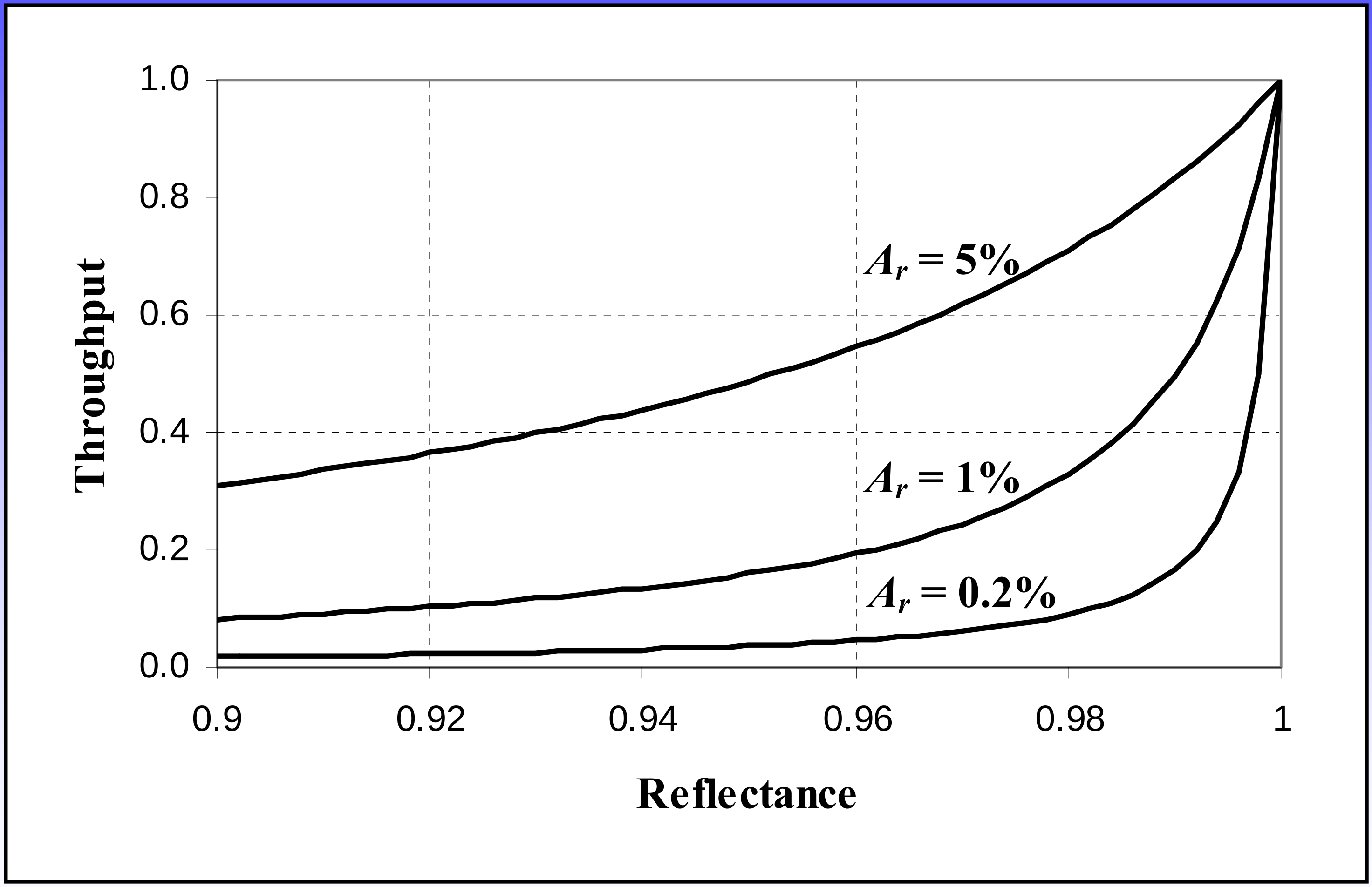
$$\frac{\Phi_{out}(\lambda_0)}{\Phi_{in}(\lambda_0)} = \frac{\rho(\lambda_0)\alpha A_r}{1-\rho(\lambda_0)(1-A_r)}$$

A_r : total port area

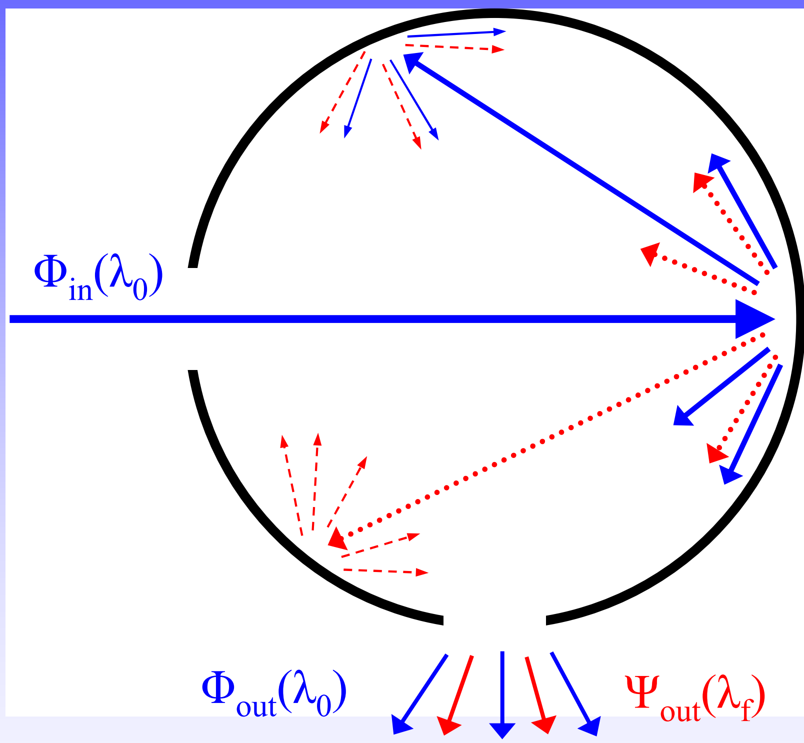
α : exit port area / total port area

$\rho(\lambda)$: diffuse reflectance of the inner coating in hemispherical illumination geometry.

Calculated integrating sphere throughput as a function of reflectance



Calculation of the fluorescence excited by multiple reflection of the incident radiation



By summing fluorescence from all reflections inside the sphere, the fluorescence yield is

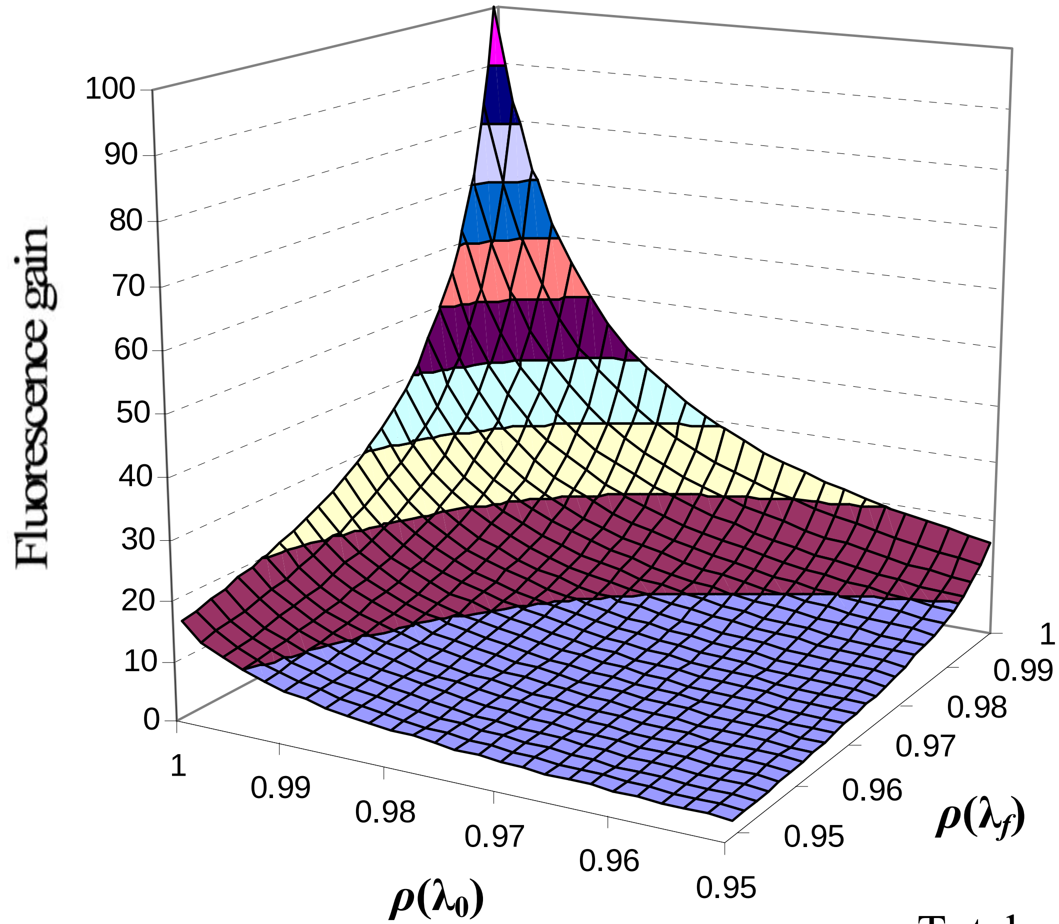
$$\frac{\Psi_{out}(\lambda_f)}{\Phi_{in}(\lambda_0)} = f(\lambda_f, \lambda_0)\frac{\rho(\lambda_f)\alpha A_r}{[(1-\rho(\lambda_f)(1-A_r)][1-\rho(\lambda_0)(1-A_r)]}$$

$f(\lambda_f, \lambda_0)$: fluorescence yield at λ_f for a plaque excited by λ_0.

Define a fluorescence gain factor, κ, as the ratio of the fluorescence emerging from an integrating sphere to that of a flat sample excited by the same incident beam.

$$\kappa = \frac{\rho(\lambda_f)\alpha A_r}{[1-\rho(\lambda_f)(1-A_r)][(1-\rho(\lambda_0)(1-A_r)]}$$

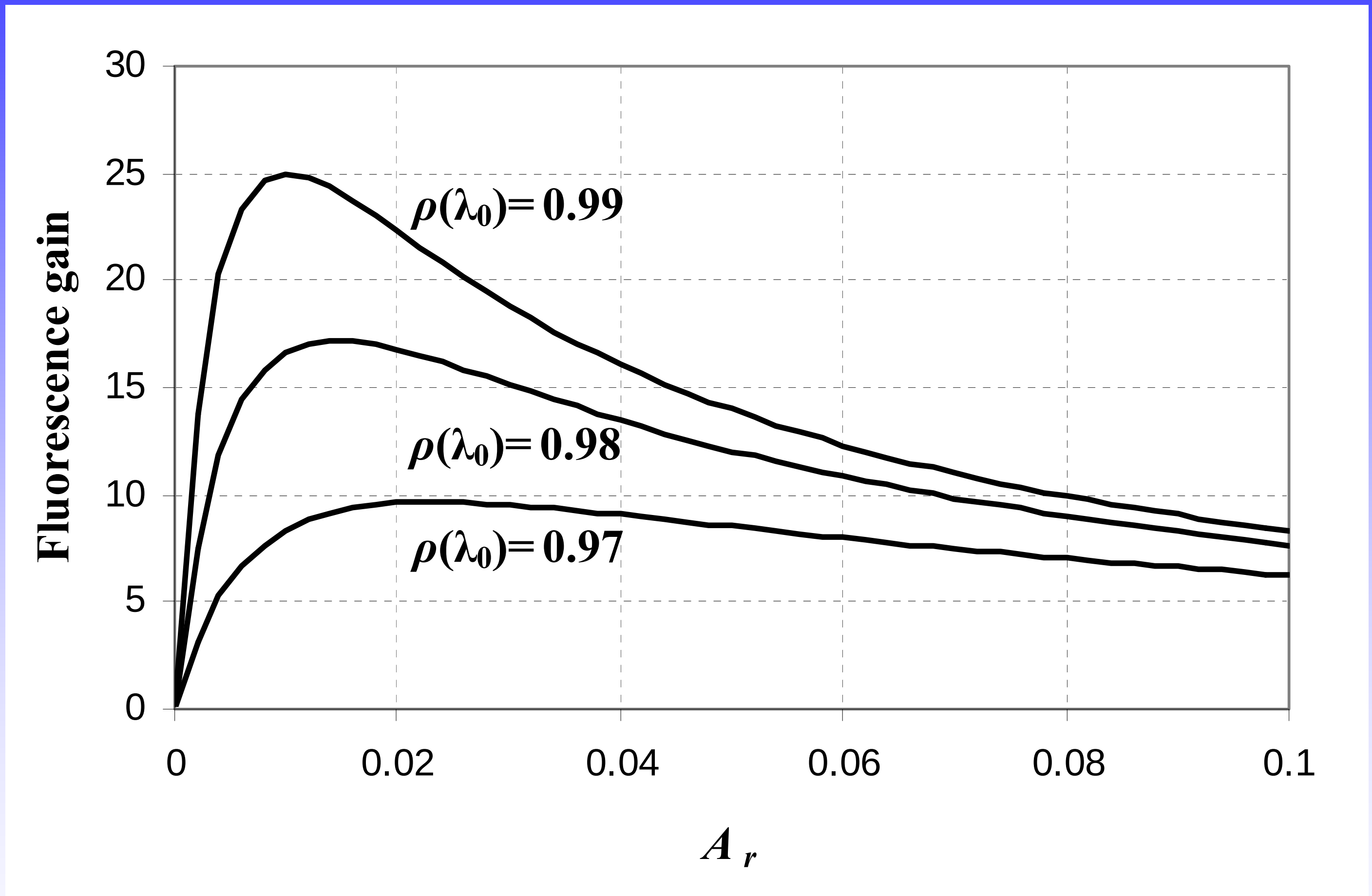
Calculated fluorescence gain of an integrating sphere



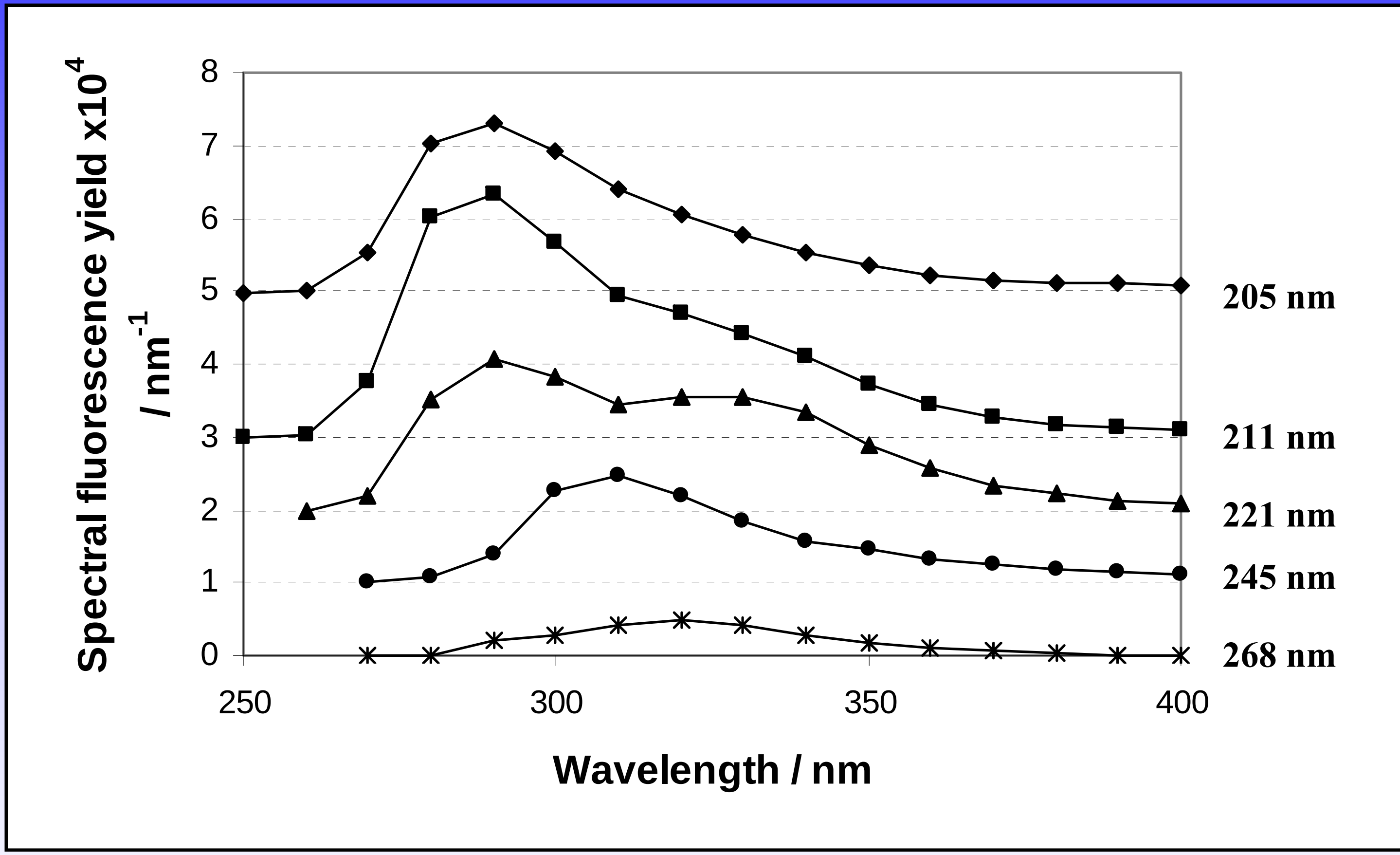
Total port area = 1%

High fluorescence gain of an integrating sphere caused by multiple reflection of exciting radiation

Calculated fluorescence gain as a function of port area



Theoretical expression for the measured total spectral fluorescence yield of an integrating sphere



Total spectral fluorescence yield $f_{\lambda,total}(\lambda_f, \lambda_0) = f(\lambda_f, \lambda_0) \dfrac{1}{[1-\rho(\lambda_0)(1-A_r)]}$

Conclusion

- Integrating sphere fluorescence is mainly caused by contamination of the wall coating.
- Total fluorescence yield of an integrating sphere can be derived from the measurement result of laser induced fluorescence.
- Integrating sphere fluorescence has been modeled theoretically.
- Fluorescence from an integrating sphere is enhanced because of multiple reflection of the incident beam.
- Integrating spheres can potentially be used as sensitive contamination detection devices.