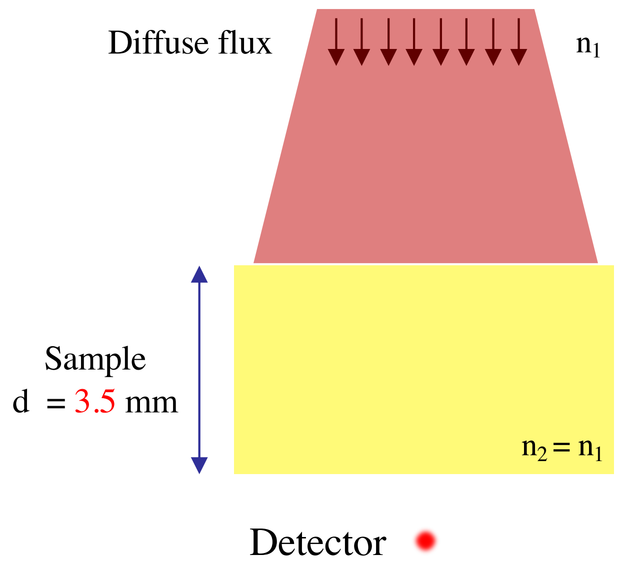
Exercise on the Kubelka-Munk Theory

Exercise for week 10

Consider a semi-infinite scattering and absorbing sample which has a thickness $d = 3.5$ mm placed into an environment which has the same refractive index.
A diffuse and broad "beam" illuminates the sample interface with an irradiance of 12 mW/cm^2. An isotropic detector, which have a "small" diameter, is placed on the other side of the sample (see the figure below). A fraction of the light is transmitted through the sample. This light is also diffuse. The measured fluence rate by the detector is $F_E = 0.5$ mW/cm^2.



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To measure the total reflectance of the same sample, it is placed on the right of an integrating sphere when a laser beam, emitting light at the same wavelength than in the previous experiment, illuminates the inner surface of the sphere (see the figure below). The signal measured at the detector integrated in this sphere is: $S_1 = 0.45$ volts

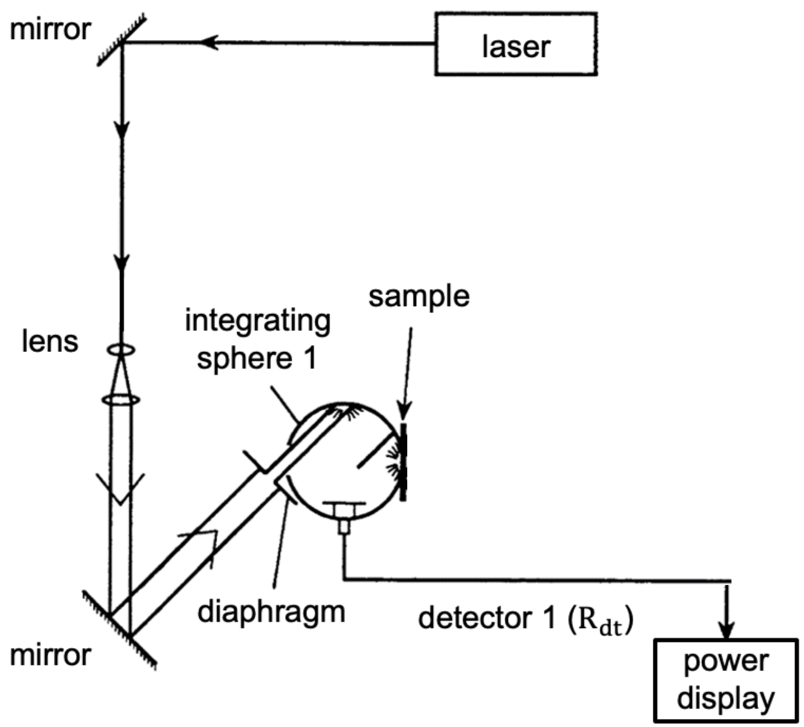
The role of the first sphere is to produce a diffuse light flux on the sample.

The calibration procedure of the detector (S_1) in the sphere is given below:

With a fully reflecting object (mirror) is placed instead of the sample (R = 100 %): $S_1 = 0.70$ volts

With a totally opaque sample is placed instead of the sample (R = 0%): $S_1 = 0.3$ volts.

- Determine the reflectance *R* of the sample?
- Determine the transmittance *T* of the sample.
- Derive the Kubelka Munk coefficients of the sample.
- Determine the value of the fluence rate in the middle of the sample when it is illuminated with a broad diffuse beam with an irradiance of 50 mW/cm^2.



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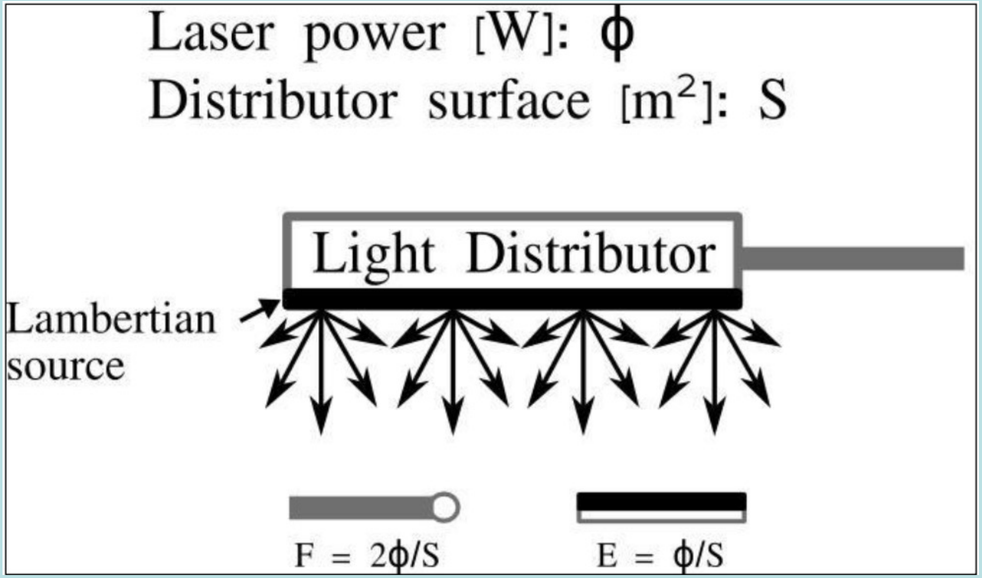
Hint!



$$S = \frac{1}{\sqrt{a^2-1}\cdot d}\cdot \ln\left(\frac{1-R(a-\sqrt{a^2-1})}{T}\right) \text{ and } K = (a-1)\cdot S$$

$$\text{with } a = \frac{K+S}{S} = \frac{1+R^2-T^2}{2R}$$

$$F_+(z) = F(0)\frac{a\cdot\sinh[b\cdot S\cdot(d-z)] + b\cdot\cosh[b\cdot S\cdot(d-z)]}{a\cdot\sinh[b\cdot S\cdot d] + b\cdot\cosh[b\cdot S\cdot d]}$$

$$F_-(z) = F(0)\frac{\sinh[b\cdot S\cdot(d-z)]}{a\cdot\sinh[b\cdot S\cdot d] + b\cdot\cosh[b\cdot S\cdot d]}$$

$$T = \frac{F_+(d)}{F_+(0)}$$

The total fluence rate is:

$$\mathrm{F}(z) = 2\cdot\left(F_+(z) + F_-(z)\right)$$