LELEC2811
Photodiode Comparison

In this document, we present the two systems of units used for light power characterization, namely radiometric and photometric units, and explain how to convert values from one system to the other. This first section summarizes the presentation of W.-C. Wang in [1]. Then, we explain and discuss the important characteristics of a photodiode.

1 Radiometric and Photometric Units

On the one hand, **radiometric** units are related to the *detection and measurement of the power of the light in a given portion of the electromagnetic spectrum* and are sometimes referred to as **energetic** units. They are more intuitive to understand as they are expressed in the International System of Units (SI). On the other hand, **photometric** units are related to the radiometric ones, but *take into account the response of the human eye to different wavelengths of light* illustrated in Fig. 1a. They are sometimes referred to as **visual** units, and are less intuitive to understand yet widely used when referring to light in the context of human vision. A summary of the different quantities, together with their symbol and units, is proposed in Table 1.

Radiometric			Photometric		
Radiant power	Φ_e	W	Luminous flux	Φ_v	lumens (lm)
Radiant intensity	I_e	W/sr	Luminous intensity	I_v	lm/sr or cd
Irradiance	E_e	W/m^2	Illuminance	E_v	lm/m^2 or lx
Radiance	L_e	W/(m^2·sr)	Luminance	L_v	lm/(m^2·sr)

Table 1: Summary of the quantities, symbols and units in the radiometric and photometric systems, adapted from [1].

Two elements of this table deserve an explanation. First, the **lumen (lm)** is the photometric equivalent of the Watt (W), and corresponds to the radiometric power weighted by the response of the human eye to different wavelengths of light. This curve is depicted in Fig. 1a and has a maximum at a 555-nm wavelength for the day vision (photopic). This maximum corresponds to green light and to a conversion factor of **1 W = 683 lm**. Note that this fixed conversion factor is only valid at this specific wavelength. Besides, the photometric unit used for luminous intensity is referred to as a **candela (cd)** with 1 cd = 1 lm/sr. At 555 nm and given the conversion factor defined earlier, **1 lm/sr = 1.46 mW/sr**. Finally, the unit for illuminance is referred to as a **lux (lx)** with 1 lx = 1 lm/m^2.

Second, the units in Table 1 rely on the concept of **solid angle**, denoted as Ω and expressed in steradians (sr). It is similar to the concept of angle in 2D, but extended to 3D, as shown in Fig. 1b. The solid angle is defined as the ratio between the area A on the surface of a sphere of radius R, divided by the radius squared, i.e.,

$$\Omega = \frac{A}{R^2} \text{ sr.} \tag{1}$$

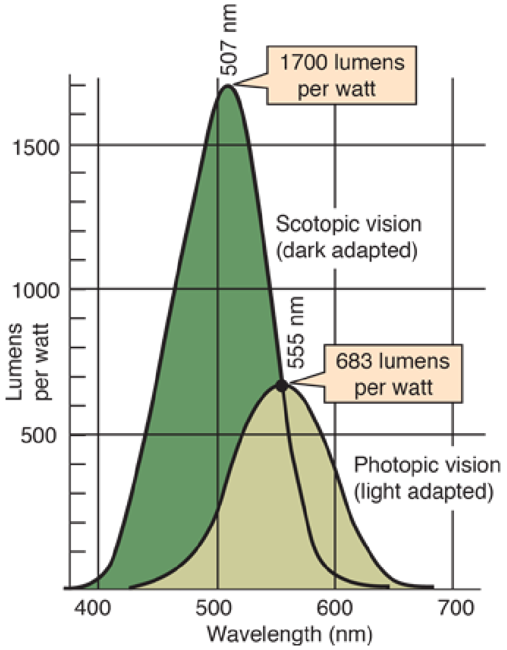
As a reminder, the surface of a sphere of radius R is equal to $4\pi R^2$, so the solid angle can be at most 4π. In addition, a useful result is the surface intercepted by a cone of half angle θ, or angle of aperture 2θ, on a sphere of radius R. It corresponds to a surface of $2\pi R^2(1 - \cos(\theta))$ and thus to a solid angle of $2\pi(1 - \cos(\theta))$.

2 Photodiode Characteristics

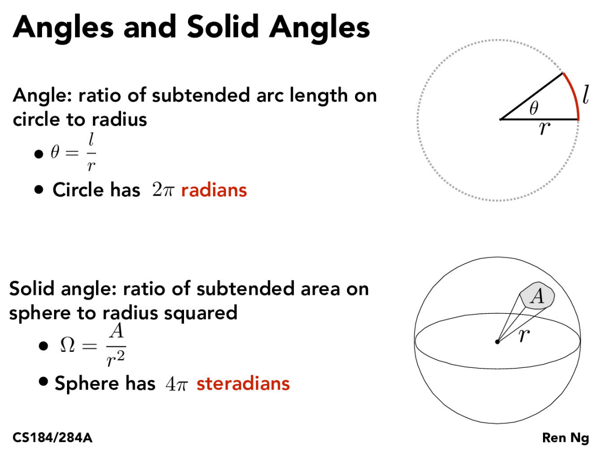
A photodiode is an electronic device that converts light into an electrical current, with the photocurrent flowing from the negative to the positive terminal. It can be characterized by three main features:

1. The **dark current**, i.e., the reverse leakage current flowing through the photodiode in the absence of light;
2. The **photocurrent**, i.e., the current generated by the light to which the photodiode is exposed. It is the current that we want to sense and that will consequently be used and processed in the instrumentation chain;
3. The sensitivity to light, i.e., the ratio between the photocurrent and the light irradiance (in W/m^2) or illuminance (in lx or lm/m^2).

One should note that the dark current is usually what sets the limit of detection (LoD) in a sensing application, as it is not possible to measure a photocurrent which is lower than the dark current.



(a)



(b)

Figure 1: (a) Response of the human eye to different wavelengths of light for the day vision (photopic) and night vision (scotopic), with the courtesy of [2]. (b) Illustration of the concepts of angle and solid angle based on [3].

References

[1] W.-C. Wang, "Radiometry and Photometry", *National Tsing Hua University*. [Online]. Available: https://depts.washington.edu/mictech/optics/me557/Radiometry.pdf. [Accessed Oct. 24, 2022].

[2] T. Beaulieu and R. Nave, "Luminous Efficacy, Photopic Vision and Scotopic Vision". [Online]. Available: http://hyperphysics.phy-astr.gsu.edu/hbase/vision/bright.html. [Accessed Oct. 24, 2022].

[3] R. Ng, "Measuring Light: Radiometry and Photometry", *UC Berkeley*, 2022. [Online]. Available: https://cs184.eecs.berkeley.edu/sp19/lecture/11-0/radiometry. [Accessed Oct. 25, 2022].