Notes on power and units

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Power

 "Power" can commonly mean three things:

1. How much **electrical power** does a source use?

2. How much **radiant power** is emitted by the source?

3. How powerful does a human observer believe the source to be (**luminous power**)?

For the most part, we'll be concerned with the second type of power (called "radiometric power"). Light sources turn electrical power (the first kind of "power" above) into radiant power with a conversion efficiency dictated by the physics of the light source. The "radiant power" of the source is measured in watts (a "radiometric" unit). If we wanted to know how bright the source appeared to a human observer, we could scale the radiant power of the source by a curve that reflects the sensitivity of the eye at different wavelengths. The result is called "luminous power" and is measured in lumens (a photometric, rather than radiometric, unit). For example, a deep red light source and a green light source might have the same radiometric power, but since the human eye is less sensitive to red light, the green source has higher luminous power than the red source.

Question: When we are calculating the exposure of holographic or black and white photographic film, should we use radiometric or photometric units? Explain why.

Units

The **radiant power** of a light source (in our case, usually a laser), is measured in watts (or milliwatts, or microwatts). A watt is a Joule/sec. A laser is a great source because it delivers all of its power in a small beam that we can direct and manipulate. In general, though, we are most concerned with the light delivered to a surface such a holographic/photographic plate, not the total power output of the source. This value is called correctly called **irradiance**, but commonly called **intensity**, and it's measured in watts per square meter (μW/cm^2, or mW/cm^2, etc).

Let's now add the time axis. Total **radiant energy** (Joules or ergs, which are 10^{-7} Joules) is radiant power delivered over time. Power is proportional to the number of photons per second leaving a source, while energy is proportional to the total number of photons leaving the source over a given interval.

When we expose a piece of holographic/photographic film, we have to apply energy (power over time) at a given density (over an area for film sheets) to cause a chemical process to occur in the film itself and turn it black. **Energy density** is measured in watt-seconds per square meter or, for us, μW-sec/cm^2, or ergs/cm^2. Ergs are CGS units and 1 μW-sec = 1μJ = 10 ergs.

In Practice

Here's how to use these units in practice. A light meter measures total power received on its sensor area. The sensor also has varying sensitivities to different wavelengths of light. First, the light meter must be calibrated to compensate for its wavelength sensitivity and the size of its sensor. When the calibration is done, the meter will read out in a unit such as uW/cm^2.

The film you are using will have some given target exposure that depends on its chemical composition and the processing it will undergo. This number will be given to you. For Agfa 8E75 film, a good target exposure is 600 ergs/cm^2, or 60 μW-sec/cm^2. Note this value is just intensity times time. Given this value, just divide by the light meter reading (intensity) to find time, which is the exposure time for the film.

(Note that the relationship between exposure time and film density (how dark the exposed and processed film is) isn't completely linear – very long exposure to low intensities or very short exposures to high intensities might produce less density than predicted.)

So:

1. Make sure light meter is calibrated to the wavelength you are using.

2. Find out the required exposure (the sensitivity) of the photosensitive material. Convert to μW-sec/cm^2 or mW-sec/cm^2.

3. Measure the intensity of the light at the point of exposure.

4. Divide the desired exposure by the intensity to get the exposure time.

Stops

Sometimes you'll see the term "stop" used in connection to photographic or holographic exposure. One stop is a change in brightness of a factor or two: "one stop more" means twice the exposure, "one stop less" means half. This change can be made in either intensity ("one stop brighter" or "one stop dimmer") or time ("two stops longer" is four times the exposure time, while "three stops shorter" is eight times less exposure). Since the human visual system has a somewhat logarithmic sensitivity, stop-by-stop changes in brightness appear to be roughly equally perceivable.

The word "stop" comes from the mechanical stops on a camera lens that permit the lens opening to be set to different sizes. The numbers applied to these "f-stops" are ratios of the diameter of the lens opening to the lens' focal length. To change the area by a factor of two (and let twice or half as much light in), the diameter must be changed by the square root of two. That's why the numbers on a 35mm camera lens are the peculiar sequence 4, 5.6, 8, 11, 16, and 22.