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THE BASIC CONCEPTS ABOUT LIGHT AND ITS PRACTICAL APPLICATION IN FILMING

Abstract: *The article resents the basic concepts and methodologies of practical application of light in filming. The main attention is paid to the data on the values of the ranges of visible spectrums, terminology, and also units of measurement. Examples for calculating the lighting during the filming are given.*

Key words: *light, spectrum, lighting, Weber-Fechner law, filming*

Language: *English*

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I. Introduction

Correctly selected lighting allows to fully convey the emotional character of the scene, aspects of the characters in action, their environment. Due to the lighting we perceive space and objects as three dimensional on a flat screen. Specialists who ensure illumination for filming the video and television, play an important role as an audio operator in the preparation of radio programs, since it is their skill that determines the quality of the image.

The artistic expressiveness of video production (especially in HDTV/DTV technologies) and films that shot on film is considerably determined by the creative attitude to the formulation of lighting. In order to learn correctly control the light, knowing its main characteristics, quality, color temperature and light intensity is needed**.**

In lighting on television, in the cinema or in the theatre, one should consider how people see changes in brightness on the scene, which is called the logarithmic law of perception of the image by our eye and brain, conditioned by nature itself.

II. Main part

According to the Weber-Fechner law, the intensity of the sensation is proportional to the logarithm of stimulus intensity, in most cases the human perception of brightness occurs logarithmically; for example, changes in the pitch of the sound tone, in the volume level, and also changes in the brightness of the subjects are estimated in this way [1].

This means that a logarithmic change, or a logarithmic progression, occurs when each subsequent number in a series of numbers is a multiple of the previous number.

Returning to the human perception, it should be noted that our eye and brain have a different sensitivity to changes in the level of influence (from areas with different brightness). They are more sensitive to changes in a weakly lighted scene than in a brightly lighted one. Another way to deal with this issue is to evaluate this phenomenon with reference to the conditions for the reproduction of brightness in a television process. The control and management of the level of black, which is installed on the camera, are arranged in such way that they are extremely sensitive to setup, and even a small error in the video signal level will result in either too dark images, with "**notches**" in the shadows, or with "**thin**", low-saturated images without black tones. While at the white level, in the peaks of the television dynamic range, the same percentage change in the signal level will not have a noticeable effect on the tonality of the image.

Whenever trying to evaluate the uniformity of lighting, it is easier to use a "**monochrome**" glass with a transmittance coefficient of 1%, which is an optical filter for viewing, as it were, "**compressing the maximum brightness**", which are visible to the eye, so that in the scene it can be seen with a significant decrease in its brightness. In this case, the differences in brightness between light and dark objects will be seen most clearly.

The purpose of logarithmic control over exposure is that when the aperture of the lens opens or closes on f-stop values, the brightness of the image will **change equally** between the two neighboring values of an aperture, i.e., this will create the same increment when perceiving such image. The increase in brightness of the image in logarithmic dependence is used in the tables of gray scales, which are used to adjust the television path. For our eye and brain, to see changes in the brightness of adjacent gray fields in equal amounts of increments, the changes in the reflection coefficients of these fields must follow the logarithmic law.

Light is a part of the spectrum of electromagnetic oscillations, inclusively to microwaves and radio waves, which limits the visible spectrum of waves on the right. Figure 1 illustrates the state of the visible part of the spectrum within the full electromagnetic spectrum and its color, perceived differentially by our vision, depending on the wavelength of the radiation.

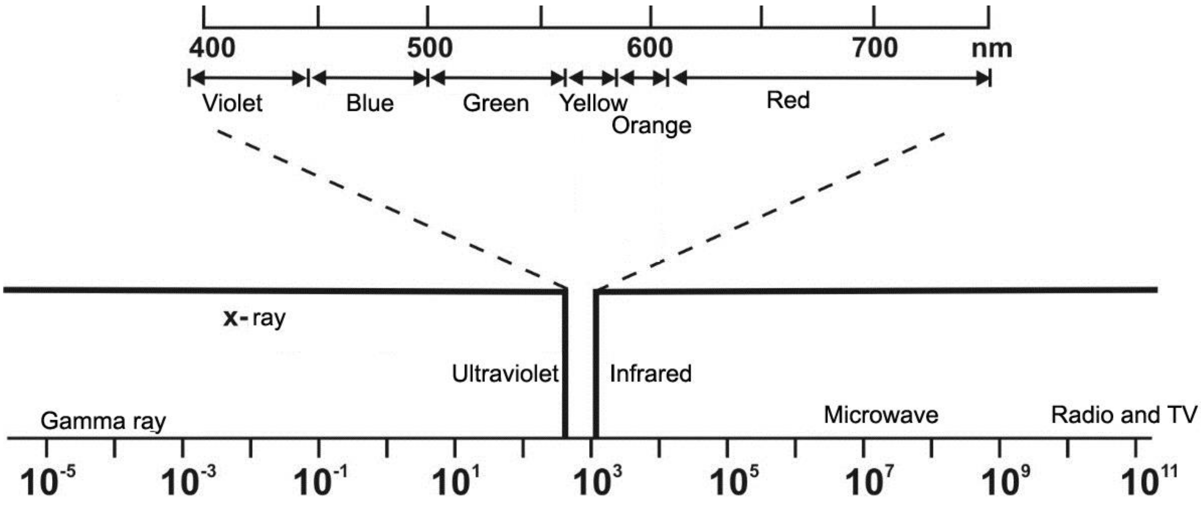

Figure 1 - State of the visible spectrum.

Light is usually characterized by a wavelength (do not confuse with frequency) and expressed in nanometers (nm), where 1 nm = 10^{-9}m. The visible spectrum ranges from about 400 nm (blue) to about 700 nm (red). The reaction of the human eye and brain is inhomogeneous, falling to any direction from the maximum sensitivity at a wavelength of 555 nm.

The average response of the eye and brain is called the photopic curve (or the visibility curve) (Figure 2). It is important that any measurements of light are consistent with the way we see, that is, all instruments that measure lighting should have a corresponding photopic characteristic [2].

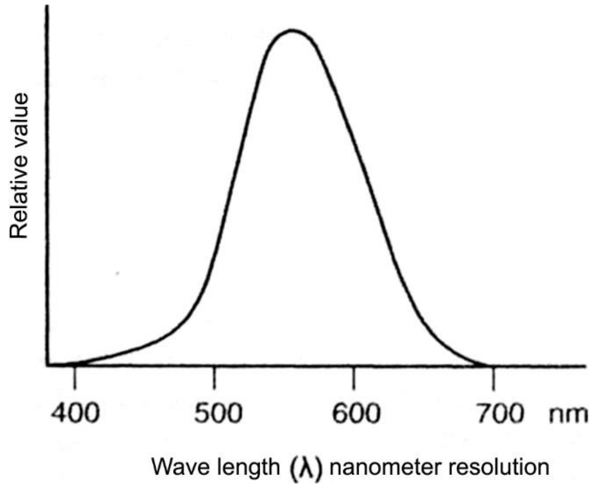

Figure 2 - Visibility curve – average value of eye reaction to the light.

Light units are based on comparison with the visual standard. Figure 3 illustrates the various lighting parameters that we must and can measure.

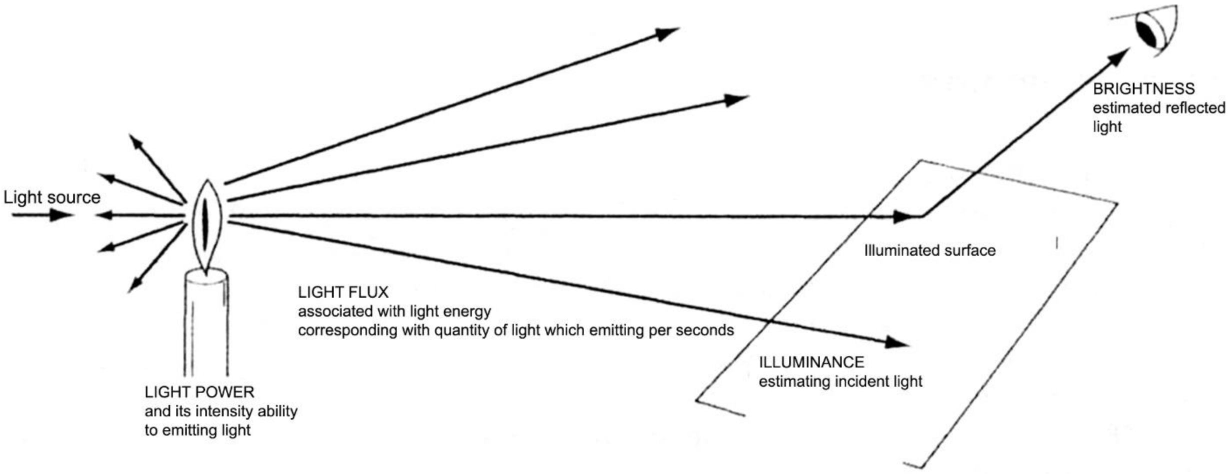

Figure 3 - Light. Estimated parameters.

Luminous intensity (*I*) - evaluates the source's ability to emit light, expressed in candela (formerly called candlepower).

Luminous flux (*F*) - estimates the light energy emitted by the source in every second, expressed in lumens.

Illuminance (*E*) - estimates the light energy falling on the surface, expressed in lux ($\frac{lumen}{m^2}$) or $\frac{foot}{candela}$ - ($\frac{lumen}{ft^2}$).

Luminance (*L*) - estimates the light energy reflected from the surface, expressed in apostilb (reflected $\frac{lumen}{m^2}$) or foot/lambert (reflected $\frac{lumen}{ft^2}$).

Note. There is a term - "brightness", which refers to how brightly we see the objects. This is a subjective effect that depends on the environment and the background. Our eyes and brain adapt to the prevalent visual lighting conditions. In everyday practice, the term "brightness" is often used when the term "luminance" has to be used.

In the dictionary, the term "luminance" is translated into russian in the same way as the term "brightness" [3]. In the SI system, the brightness is estimated in $\frac{cd}{m^2}$ [4-10].

Light intensity (I). This is the estimation of light energy based on a **visual** comparison with known standard sources. Originally it was a standard candle, which was called the ***candlepower***. For example, the light intensity of 15,000 candles has a 1-kilowatt spotlight with a Fresnel lens in the operating mode. Subsequently, in the international SI system, the candlepower standard was replaced by a modern candela standard, which is scientifically a more precisely established standard. However, for practical purposes, the terms candlepower and candela can be evaluated as similar.

Light flux (F). This is an estimate of the light energy, expressed in lumens and can be determined, as shown in Figure 4. This is the amount of light energy emitted per unit solid angle from a point source by the light intensity into one candle. Clearly, an element of time should be introduced here, and in this case the definition will be: a light flux is the amount of light energy emitted every second in a unit solid angle from a point source by the light intensity into one candela. The light flux is the energy seen by the human eye, that is, its magnitude is determined through the visibility curve (photopic curve).

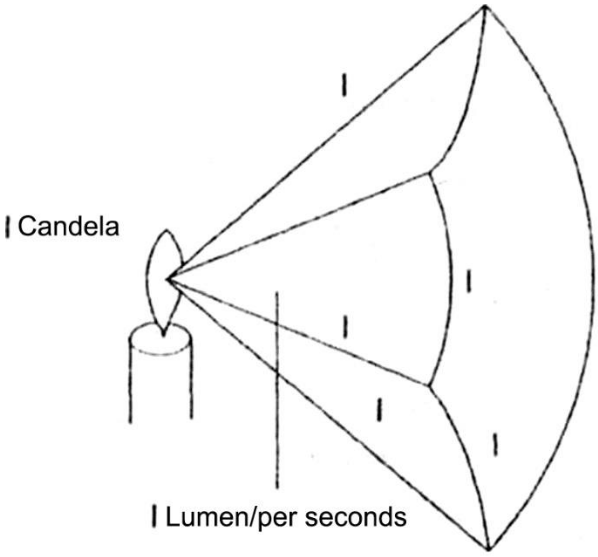

Figure 4 - Light flow is determined in lumens.

Illumination. This is a measure of the light flux falling to the surface, measured in lumens per unit area, that is, in $\frac{lumen}{m^2}$ or $\frac{lumen}{ft^2}$ (see Table 1).

Figure 5 illustrates the relationship of basic units.

Table 1

Typical values of illuminance

	Illuminance, ***lx.***
Sun light with bright sunny day. Cloudless	100 000
Day light. Cloudy	6500 (2000-10 000)
Day light. Cloudy. Winter	500
Interior with natural lighting. Day	400
Interior with artificial lighting.	200-300
Illuminance of an office (horizontal side of the table)	300-500
Office with computer	300
Drawing department	750
Typical Supermarket	600-700
Sunrise/Sunset	<200
Street lighting	4-20
Moon light in full moon position	0,1

Lux - is the most preferable term for the world television (except for the US), but the term foot-candela has been in use since the very first filming and is still used by many cinematographers.

As a result, many light meters that measure falling light are calibrated in foot-candelas.

Ratio of units: To convert foot-candelas into lux, multiply the numerical value of foot-candelas by 10.76, that is, 1 foot-candela = 10.76 lux (10.76 is the number of square foots in square meters).

For most practical purposes, it is quite simple: the original number must be multiplied by 10 (when converting foot-candelas into lux) or divided by 10 (when converting lux into foot-candelas).

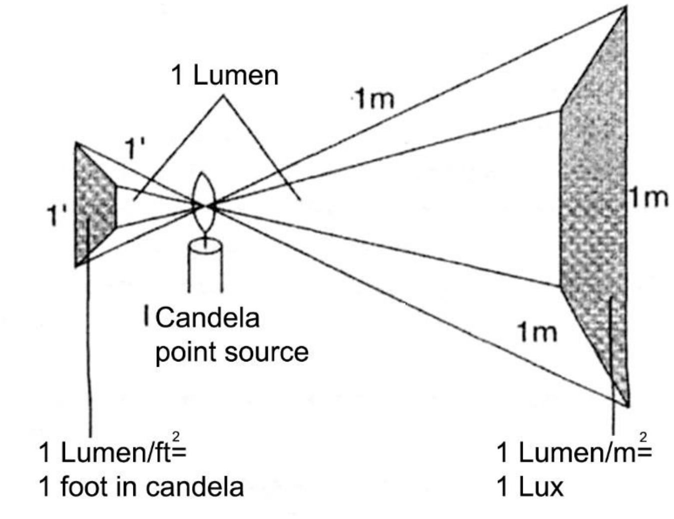

Figure 5 - Determining the units of illuminance.

Exponometers, measuring falling light usually have a very wide coverage angle. To measure the illumination, it is necessary to put a diffusion disk (lumidisk) on the photocell. However, it is more common to use a diffuse hemisphere mounted on the photoexponometer before the photocell. This hemisphere integrates all the light that illuminates the subject, and gives a better result than the lumidisk when measuring the total light on the subject.

Brightness (L). This is a measure of light energy, estimates the amount of light reflected from the surface. When the surface reflects the total light flux of 1 $\frac{lumen}{m^2}$, it is said that this surface has a brightness of 1 apostilb. (Similarly, if the surface reflects the total light flux of 1 $\frac{lumen}{ft^2}$, then it is about the brightness in 1 foot-lambert). These terms are not generally accepted, and therefore the brightness on the sienna is ultimately "measured" by the television camera.

The amount of light reflected from the surface depends on the coefficient of its reflection or on its reflectivity.

$$Brightness = (\rho \cdot illuminance) = apostilb.$$

For example, if the illuminance is 600 lux, then what is the brightness of the peak for the TV white surface with c = 0.6 (60% reflectivity)?

$$Brightness = (\rho \cdot illuminance) = 0.6 \cdot 100\, apostilb.$$

The brightness meters have very narrow measuring angles, usually 1^0, for example, such as the "Pentax" spot meter or "Minolta". Most spot meters are calibrated in exposure values (EV), where the exposure value increases by one value when the brightness is doubled. Often the exposure numbers are expressed in terms of f-stop. For example, if the peak white indicates 9 EV and black indicates 4 EV (see Table 2), then this is the contrast in 5 EV or 5 f-stops, or the contrast between these surfaces is 2^5:1 = 32:1**.**

The ratio of units: *1 apostilb = 0.318 cd / m^2; 1 cd / m^2 = 3.14 apostilb; 1 foot-lambert = 10.76 apostilb; 1 apostilb = 0.0929 foot-lambert.*

Table 2

Typical EV (Expositional values)

	EV
Blue	13-14
White clouds	15-16
Continuous cloudiness	10-11
Typical tone of the face in sunny day (Caucasian skin)	14-15
Typical tone of the face in overcast day	8-9
Typical tone of the face in the room (day)	7
Typical tone of the face in the room (artificial light)	6
TV monitor peak	7,0

Inverse square law. The light from the point source will be distributed by a divergent beam of rays, and consequently, the farther from the light source, the larger the area will be illuminated (Fig. 6), and the illuminance level will correspondingly decrease.

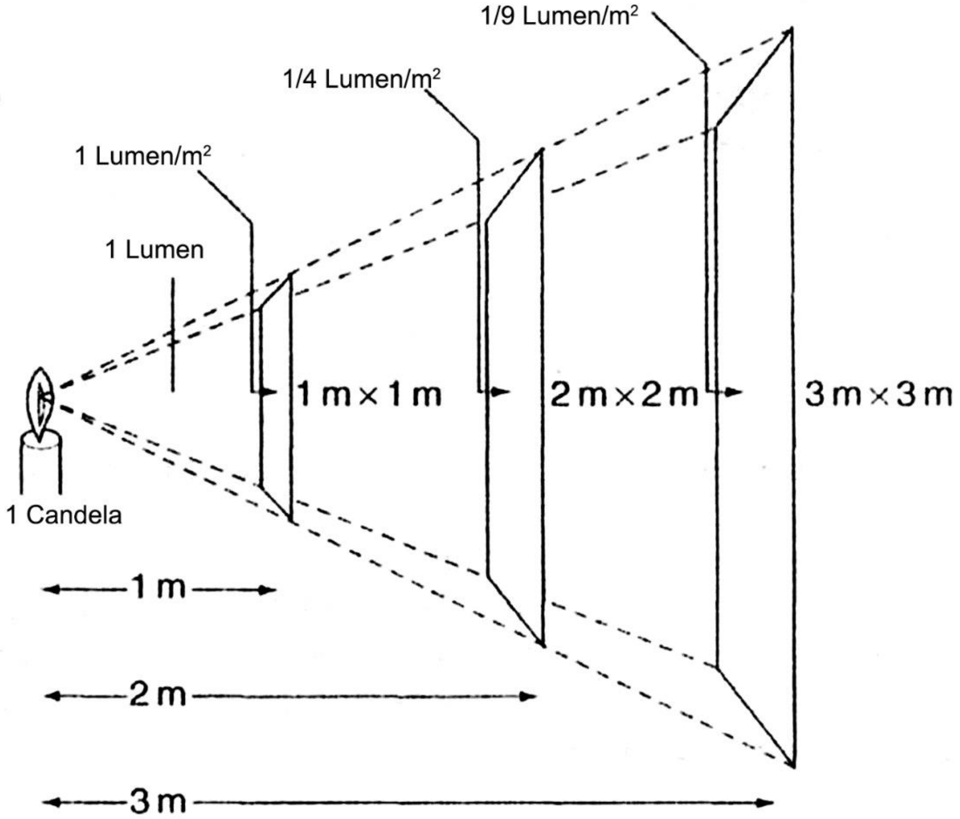

Figure 6 - Inverse square law.

In 1 m distance from the light source with 1 lumen it creates 1 lux illuminance on 1m^2 surface. In 2 m from the light source this light flux creates the ¼ lux illuminance on the 4m^2 surface. In 3 m from the light source it creates 1/9 illuminance on 9m^2.

When the distance is doubled the illuminance does not decrease for ½ lux, it decreases for ¼, just illuminance decreases proportionally (1/2)^2.

$$Illuminance(E)\alpha\frac{1}{distance^2}lux.$$

When the distance is tripled, then illuminance decreases not for 1/3 times, it decreases for 1/9 times, or (1/3)^2. If light intensity is doubled then the illuminance will also be doubled. Similarly, if we had a light source of 1000 candelas, then the illuminance would be x1000. Therefore the general equation for the values of illuminance will be:

$$Illuminance(E)=\frac{Light\,intesity}{distance^2}lux.$$

Example:

1) What illuminance will be at a distance of 5 m from a 1.2-kilowatt HMI=spotlight with a Fresnel lens with a light intensity of 50,000 candelas?

$$Illuminance(E)=\frac{light\,intensity}{distance^2}=\frac{50\,000}{5^2}=2\,000\,lux$$

2) What kind of illuminance will be from a 650-watt spotlight with a Fresnel lens with a light intensity of 9000 candelas at a distance of 3 m?

$$Illuminance(E)=\frac{light\,intensity}{distance^2}=\frac{9000}{3^2}=1\,000\,lux$$

3) What is the maximum distance to install a 5-kilowatt spotlight with a Fresnel lens of 100,000 candelas, if it is necessary to get an illuminance of 500 lux?

$$Illuminance(E) = \frac{candela}{distance^2}$$

Thus,

$$Distance^2 = \frac{candela}{Illuminance(E)} = \frac{100\ 000}{500} = 200$$

Distance = $\sqrt{200} = 14{,}14$ m, i.e. about 14 metres.

These examples illustrate how easy to determine illumination at any distance if the effective luminous intensity is known (the effective luminous intensity usually refers to the central ray).

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III. Conclusion

Thus, in this article we have considered the basic concepts of light, the representation of light flows and units of measurement. The main laws influencing the lighting during the filming, including light intensity and distance based on the law of inverse squares, were presented. Versions of application of light in the filming are reflected in the corresponding illustrations. Also a number of examples are given how easy it is to determine the illumination at any distance if the effective luminous intensity is known.

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