Professional portrait studio for amateur digital photography

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We describe how to build a professional portable portrait studio that can be used with any consumer camera. The studio allows effortless off-line chroma-key insertion of backgrounds. Digital consumer cameras are designed for delivering acceptable images in typical outdoor or small room situations. The cameras fail when tungsten filament lamps are used. The built-in flash tube is too weak to fill the background in a studio setting and cannot be used to trigger professional electronic-flash lamps because the camera's firmware computes the exposure under the assumption that only the build-in flash tube supplies light to the scene when it is activated. A further problem is the position of the lamps. In the case of digital cameras the position is much more delicate than for silver halide film cameras because the sensor's dynamic range is very small and unwanted shadows are easily created. We present two different lamp set-ups for different size rooms.

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1 Introduction

We have received the task of building a portable indoor portrait studio to produce professional quality portrait images using consumer grade low-cost digital cameras. An additional requirement has been that the studio's backdrop has to have a completely uniform color, so that it is possible to automatically perform chroma-key operations, such as replacing the background with a landscape image. The two main problems have been the selection of a suitable light source and the determination of a lighting geometry that provides a pleasing rendition of the subject's face and concomitantly a uniform background.

Traditional cameras for silver halide (AgX) film can be loaded with film stock for professional photography that is available with emulsions (actually, suspensions) sensitized for a variety of illuminants. Good cameras are equipped with excellent lenses, good exposure meters and auto-focus systems. It is therefore possible to easily achieve professional results, i.e., perfectly exposed and (color) balanced images. Digital consumer cameras are designed for delivering acceptable images in typical outdoor or small room situations. In addition to the low sensitivity of the sensors, a fixed standard illuminant is usually hard-coded in the camera's firmware and due to the low dynamic range of the system aggressive white balancing is performed.

Digital cameras often fail when tungsten filament lamps are used, because their correlated color temperature is too far from the range in which simple white balancing algorithms deliver meaningful results. The built-in electronic-flash lamp is too weak to fill the background in a studio setting, which is typically much larger than a living room. Furthermore, the built-in lamp cannot be used to trigger professional electronic-flash lamps because the camera's firmware computes the exposure under the assumption that only the built-in flash tube supplies light to the scene when it is activated. The solution is to use daylight simulating lamps, which allow the digital camera to operate under simulated outdoor conditions.

In the case of digital cameras, positioning the lamps is much more delicate than for AgX cameras[1] because the sensor's dynamic range is very small and the tone reproduction curves are perfect straight lines, so that unwanted shadows are easily created due to tone clipping. The lamps are not the only light sources in a studio, because the light reflected off the walls and ceiling (the secondary light source) can supply a relatively large proportion of the available light. We present two different lamp set-ups for different size rooms. Finally, we give a number of tips learned by operating such a portrait studio.

2 Light source

The conventional solution is to use photoflood lamps or tungsten halogen lamps and expose a film sensitized for a correlated color temperature of

3400°K (type A film) or 3200°K (type B film). In a consumer level digital camera, it is not possible to change the color filter array on the sensor. We have tried to use a balancing filter in front of the camera lens, specifically a Wratten No. 80A filter[3], but with the camera at hand we obtained unpredictable results. The use of gelatin filters is also questionable in a high pressure situation, where a large numbers of subjects are photographed at the maximal speed allowed by the camera and the digital media has to be changed on the fly between two subjects. Last but not least, under the constraint of portability and the ability to set up the studio in a small space, it is difficult to uniformly illuminate the backdrop with tungsten filament lamps.

Returning to the color temperature problem, at first one might think that digital cameras should be more flexible than AgX cameras, since the digital image can easily be manipulated. However, the white balance algorithms typically implemented in the firmware of digital cameras are not able to make the jump from, for example, D_{65} to illuminant A. Our colleague Paul Hubel has tried to use a number of color appearance models to correct for the difference in illuminant, but this has also produced very discouraging results, probably because today's consumer cameras have only approximately 6 bits of useful information and the transformed images suffer under this radical quantization.

The alternate solution is to use an electronic-flash lamp. In a studio the built-in flash is too weak because reflecting walls are too far away. Even if large reflectors were used, to avoid mixed light the focussing light in the studio would have to be kept very dim, which would have the side effect that the subject’s pupils would be quite dilated, conferring a threatening appearance to the subject’s portrait. We have considered using a studio flash system. To allow for the digital camera’s harsh tone reproduction curve, we would need two lateral lamps for a soft modeling light and two lamps to produce a uniform background for the chroma-key effect. Unfortunately, consumer cameras do not have a connector for an external electronic-flash lamp.

We have tried triggering the external electronic-flash system optically with the built-in flash tube. However, we have quickly learned that digital consumer cameras compute the exposure based on the internal flash. Since on these cameras we cannot set an aperture, we have tried a flash meter and a set of neutral density filters. After we have set up our studio, we have marked where the subjects will be posing and on a gray card measured the built-in's flash illuminance and that of the external electronic-flash system. Finally we have computed the necessary neutral density filter to place in front of our camera's exposure meter sensor.

Unfortunately, in our case this solution has not been viable because the demonstration has required the use of a number of unspecified cameras. Also, in a portable studio it is not possible to predict the environment in which the studio will be set up.

Given all these constraints, we have decided that the only viable solution is to use lamps designed for news broadcasting. These lamps are fluorescent and have a very wide angle, so they can be placed very close to the subject. Current digital cameras use sensors similar to those in television cameras, so a lamp that is tuned for the latter cameras (i.e., no spectral peaks fall in “dangerous zones”) will be well suited also for the former cameras.

We decided to deploy the Balcar Fluxlite 240 lamp. This lamp is a highly energy efficient, fluorescent fixture equipped with 6 daylight fluorescent lamps. The lamp simulates a D_{52} illuminant with a color rendering index of 98. With its optical reflector, the Fluxlite produces 75 foot candles of full-spectrum fluorescent light at 10 feet. The ballast operates at 1 kHz, which is safe for all current CCD sensors and allows their use even in conjunction with scanning digital cameras.

The peak luminous intensity produced by the lamp is 8,000 cd and in the beam center the luminous intensity is 7,500 cd. We have measured the lamp’s stability by monitoring a barium sulphate cake of pressed powder over 45 minutes. The correlated color temperature is completely stable after approximately 20 minutes, during which it raises by 10% to attain 5,200°K. We found the lamp to operate within its specifications after 20 minutes, and since the light bulb’s expected life time is 15,000 hours we leave them on as long as the studio is in operation.

3 Exposure parameters

Unfortunately even with the TV studio illumination, exposure is problematic. Although the illumination is fixed, consumer digital cameras do not have a manual exposure mode. The automatic exposure system will expose each image differently, depending on the lightness of the subject's clothing. While this is not a problem for the portrait per se, it is a problem for the chroma-key algorithm because each image will have a different color background.

Consequently the chroma-key algorithm must accommodate a fair latitude in background lightness. To avoid masking parts of the subject, the background color must be quite different from the potential color of the clothing the subjects will be wearing. This has been a major problem for our studio because we cannot exercise any control on the garments the subjects are wearing. Also the make-up has been outside our control and women wearing eye-liners of a color close to the backdrop color have produced some spooky results.

We have used digital cameras from two vendors and have found that we obtain the best results when over-exposing by half an aperture stop. This correction compensates for the brightly illuminated background.

4 Backdrop

To keep the operating interval of the chroma-key algorithm as small as possible, we have carefully selected the backdrop. In a first step we have measured the spectrum of a number of commercially available background papers that are sold in 9’ rolls containing 12 yards of paper. We have then purchased rolls in those colors that had the most peaked spectral power distribution. In a second step we have used the various backgrounds to shoot portraits of people wearing a variety of garments . We have found that the Studio Blue background paper from Savage causes the least interference with the camera’s white balancing algorithm for a number of different cameras.

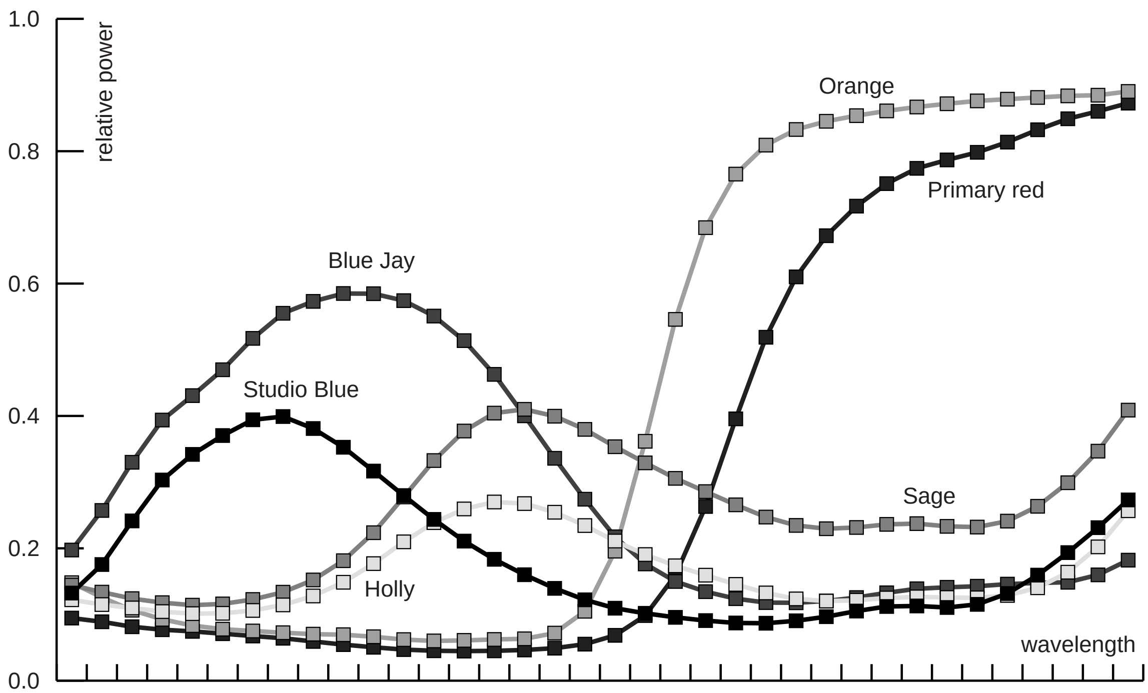

FIGURE 1. Relative spectral power distribution of some Savage background papers. The measurement conditions are the CIE standard illuminant D_{50} for the CIE 1964 supplementary standard observer.

This result has been somewhat counterintuitive, because the orange background has the most peaked spectral power distribution and is easiest to identify with the chroma-key algorithm. However, the orange background causes the largest errors in the white balance depending on the subject garment’s color. It appears that the number of pixels receiving a reddish orange signal plays a large role in the algorithms incorporated in the considered cameras.

As mentioned earlier, the Studio Blue backdrop’s color is close to certain eye liners and in one case even to the iris color of one of our subjects (this problem has been severe with the Blue Jay background paper). We invest a considerable amount of time in assuring a uniform illumination of the backdrop so that we can operate the chroma-key algorithm with a very tight tolerance. We place the lamps so that when we scan the backdrop with a spot meter, the maximum exposure deviation is half an aperture stop.

5 Lamp placement

The selected Balcar Fluxlite 240 lamps project at a quite large angle, namely 55° vertically and 60° horizontally. While this is convenient when a large area has to be illuminated uniformly in a limited space, it has the disadvantage that the illuminance drops off quite rapidly with the distance from the lamp, requiring a very precise positioning of the lamps. Tab. 1 shows the performance of the lamp.

Distance [ft.]	5	6.5	10	13	16.5	20
Height [ft.]	4.3	5.6	8.4	11.2	14	17
Width [ft.]	5.7	7.5	11	14	18	22
Illuminance [lux]	3300	1840	810	490	325	215

TABLE 1. Light projected from a Fluxlite 240 lamp

5.1 Small room

We have started our studio in a small room 18’ long, 16’-6” wide, and 8’-3” high, with a bluish gray carpet and whitish walls and ceiling. Fig. 2 shows the layout. Note that the camera is extremely close to the subject. In a professional environment, the camera would be at least 7’ from the subject and a 105 mm or at least 80 mm lens would be used.

For the convenience of a quick set-up, we indicate all distances from the studio’s perimeter. Of course, the relevant distances are those from the subject or object to be photographed. First we have placed the main subject lamp so that no reflections are visible in glasses worn by subjects. Then we have placed the auxiliary lamp so that shadows are filled in but no double shadows are visible; the low ceiling providing ample reflection allows us to place the auxiliary lamp relatively far away. Both lamps are aimed at the subjects eyes; with all lamps on and considering the reflections in the room, the total approximate illuminance from the main lamp is 5,500 lx and that from the auxiliary lamp is approximately 1,400 lx. The lamps illuminating the backdrop are placed last and in a way that the background paper is illuminated with a uniformity below half aperture stop. With the map Fig. 2, the complete studio can be set up in about half an hour.

To obtain a better distance from the subject and allow for a personal comfort zone, we have first tried to use a focal length doubler as they are used on camcorder and tried to keep the camera at 7’ from the subject. Unfortunately the focal length doubler confuses the auto-focus mechanism and the resulting

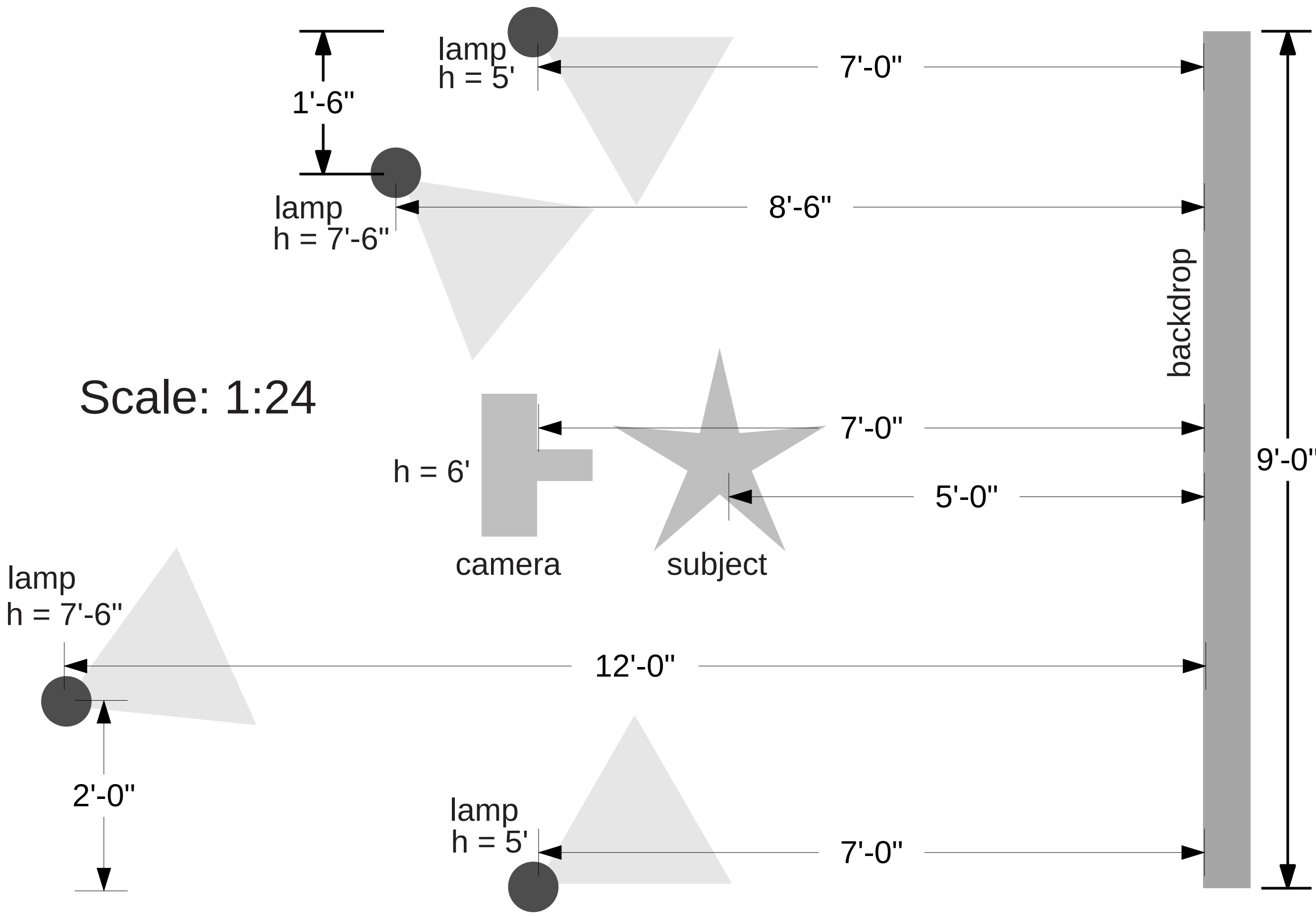

FIGURE 2. Portrait studio layout for a small room and buil-in camera lens.

image is visibly blurred. We have finally compromised on an attachment that increases the focal length by a factor of 1.4. This allows us to compromise between distance to the subject (3'-6" instead of 2'-0" as shown in Fig. 2) and slight blur that hides small imperfections in the subject's skin.

5.2 Large room

The main effect of a large room is the absence of reflections, especially from the ceiling, so there are only primary light sources. We compensate for the lack of secondary light sources by placing the main and auxiliary lamps at almost the same distance from the subject and by lowering them to the subject's eye level. Because now the photographer would cast a shadow on the subject, the use of a 1.4 focal length extender is imperative. Fig. 3 shows the final set-up for large rooms.

6 Useful tips

As mentioned earlier, the studio can easily be assembled in half an hour. The background paper roll and the lamps are heavy, so the use of air damped

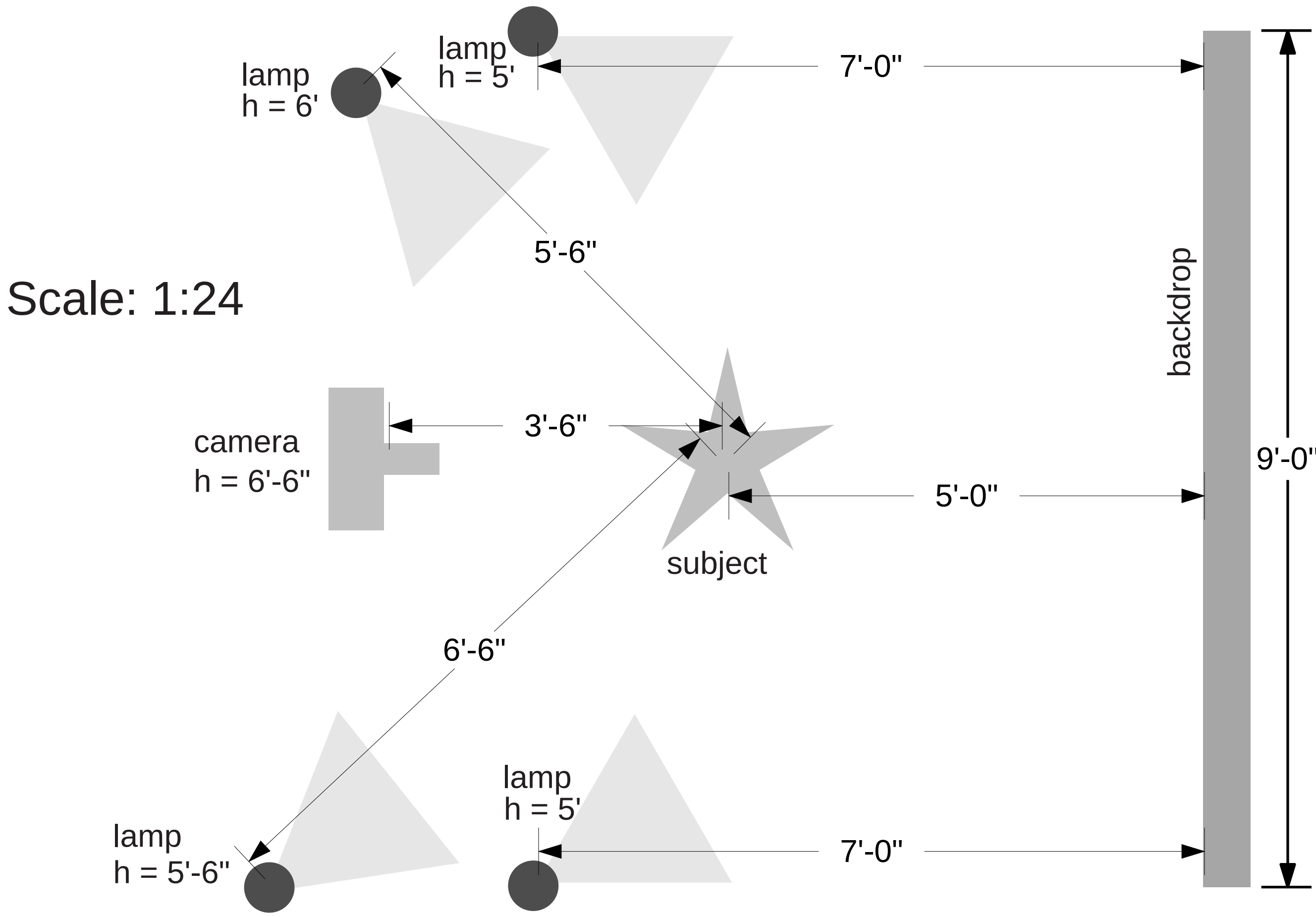

FIGURE 3. Portrait studio layout for a large room. In this case the camera is equipped with a 1.4 focal length extender, which modifies the lens from a wide angle to a normal lens.

stands is highly recommended. Operating a digital portrait studio requires more human skills than operating a conventional portrait studio. This has two reasons, the exposure delay and the time required to download the images to the host computer.

Unfortunately, when the exposure release button is pressed on a digital consumer camera, there is a certain variable delay of several seconds until the image is actually captured. The most important skill of professional portrait photographers is the ability to capture the moment when the subject assumes the most characteristic pose. To this purpose the photographer coaches the subjects and then shoots the picture within the fraction of a second. With a digital camera, the photographer has to influence the subjects so that they maintain their pose for six or seven seconds, until the image is recorded.

When a number of portraits are taken in sequence, the following workflow has given good results.

1. A master of ceremonies receives the subjects and keeps them in the queue. The subjects are ushered in proximity to the studio, so their visual system adapts to the lights and squinting due to glare is avoided.
2. When a subject's turn comes up, the photographer's assistant prepares the subject, which consists in removing lint, straightening glasses and garments, and relaxing the subject for the procedure.
3. While the subject is being prepared, the photographer must quickly determine the viewing angle that shows the subject in the "best light." The photographer then must build up a pose that the subject can assume for the several seconds it takes to expose the image, while keeping the subject relaxed.
4. Depending on the number of portraits to be taken per hour, a number of assistants is necessary to down-load the images from the memory cards. In our set-up we have used three memory cards and two down-loading stations each staffed by an assistant.

7 Glossary

For clarity, we repeat the standard terminology in a brief glossary. We follow the CIE recommendation[2].

(Perceived) light. Universal and essential attribute of all perceptions and sensations that are peculiar to the visual system.

Luminous intensity. Quotient of the luminous flux leaving a source and propagated in the element of a solid angle containing the given direction, by the element of solid angle. Unit: candela (cd).

Illuminance (at a point of a surface). Quotient of the luminous flux incident on an element of the surface containing the point, by the area of that element. Unit: lux (lx).

Brightness. Attribute of a visual sensation according to which an area appears to emit more or less light.

Glare. Condition of vision in which there is discomfort or a reduction in the ability to see details or objects, caused by an unsuitable distribution or range of luminance, or to extreme contrasts.

Illuminant. Radiation with a relative spectral power distribution defined over the wavelength range that influences object color perception.

CIE Standard illuminant. The illuminants A, B, C, D_{65} and other illuminants D, defined by the CIE in terms of relative spectral power distributions. (A: Plankian radiation at a temperature of approximately 2856°K; B, C: obsolete, D_{65}: daylight including the ultraviolet region).

Correlated color temperature. The temperature of the Plankian radiator whose perceived color most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions. Unit: degree Kelvin (°K).

Primary light source. Surface or object emitting light produced by a transformation of energy.

Secondary light source. Surface or object which is not self emitting but receives light and re-directs it, at least in part, by reflection or transmission.

Lamp. Source made to produce an optical radiation, usually visible.

Incandescent lamp. Lamp in which light is produced by means of an element heated to incandescence by the passage of an electric current.

Tungsten filament lamp. Incandescent lamp whose luminous element is a filament of tungsten.

Discharge lamp. Lamp in which the light is produced directly on indirectly by an electric discharge through a gas, a metal vapor or a mixture of several gases and vapors.

Fluorescent lamp. A discharge lamp of the low pressure mercury type in which most of the light is emitted by one or several layers of phosphors excited by the ultraviolet radiation from the discharge.

Photoflood lamp. Incandescent lamp of especially high color temperature, often of the reflector type, for lighting objects to be photographed.

Tungsten halogen lamp. Gas-filled lamp containing halogens or halogen compounds, the filament being tungsten.

Photoflash lamp. Lamp emitting, by combustion within a bulb, a large quantity of light in a single flash of very short duration, for lighting objects to be photographed.

Flash tube; electronic-flash lamp. Discharge lamp to be operated with an electronic equipment in order to give a high light output for a very brief period, capable of repetition.

Daylight lamp. Lamp giving light with a spectral energy distribution approximating that of a specified daylight.

Color rendering index. Measure of the degree to which the psychophysical color of an object illuminated by the test illuminant conforms to that of the same object illuminated by the reference illuminant, suitable allowance having been made for the state of chromatic adaptation.

8 Acknowledgments

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