Introduction to Photography with the Leica M11

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To Lucie, Maël, Margot, Maxime, and Sacha

Forward

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- Bibliographic references are denoted [n] where n is the reference number. For example [30] refers to the M11 instruction manual.
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Introduction to Photography with the Leica M11

Patrick Cousot

Abstract

A short, simple, and illustrated introduction to the fundamental concepts of photography (with a few optional technical explanations), and their practical application with a Leica M11.

1 The Leica M11-P Camera

Leica is a camera maker company that brought to prominence the 35mm film camera in 1925 (Leica A), the rangefinder camera in 1932 (Leica II), the M-mount lenses in 1954 (Leica M3) and their digital versions since 2006 (Leica M8). The Leica M11 first appeared in 2022.

The Leica M11-P (on figure 1) has an upgraded rear screen and quadrupled internal storage compared to the Leica M11 (minus the red Leica logo replaced by a screw on the M11-P).

Traditional Leica M cameras have a viewfinder (for composition/framing, see section 12) and a rangefinder (for manual focussing, see section 22.2 and optional technical details

Figure 1: Leica M11-P (here with a handgrip (doubling as a tripod mount), a finger loop, a thumb support, a soft release button, a carry strap, and a M-mount SUMMILUX-M 1:1.4/35 ASPH lens with UV filter (see section 42) and screwed lens hood).

in section 50). The spare parts of the M11 on figure 2 show the preponderance of electronics in the design of the camera.

The Leica M11 which appeared in 2025 was the first Leica M without rangefinder. Focussing is via the viewfinder (a possibility also offered by the Leica M11 using an external viewfinder, see section 13) or the screen, see section 22.3.

Always carry the camera while holding the strap to avoid falls.

We explain in simple terms how to use the Leica M11 (clicking on dark blue text refers to another section of the e-booklet or to Wikipedia for more detailed and scientific explanations).

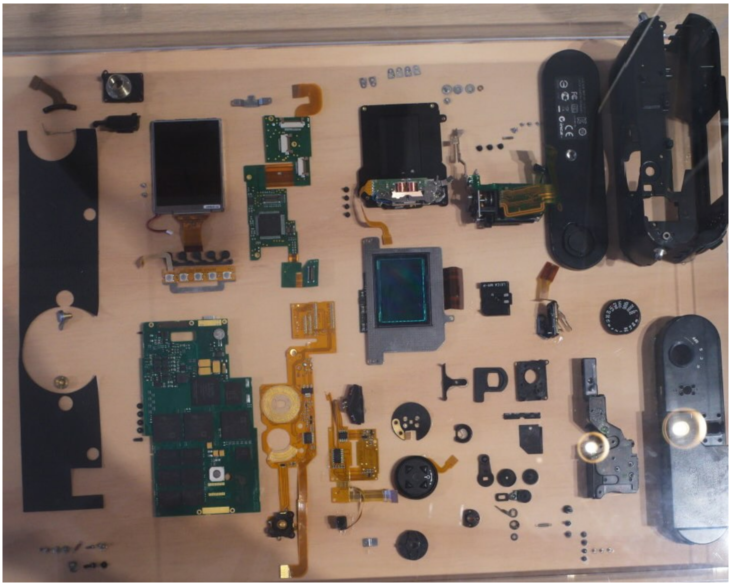


Figure 2: Spare parts of the Leica M11, courtesy Panajou Photo, Bordeaux, France

2 Preparation of the Leica M11

Before taking a photo, the Leica M11 must be prepared by inserting a SD card (Secure Digital card), a battery, initializing the SD card, and mounting a lens.

2.1 Inserting a SD Card and the Battery

- Make sure the camera is off,

  by turning the main switch anti-clockwise;

- Take the bottom cover of the camera off (by unscrewing it, or, with the handgrip, by lifting the rubber cover);
- Insert an new blank SD card;
  - Orient the SD card so as to see the contacts, as shown on the camera battery slot;

- Push the SD card, visible contacts down, into its reader until it clicks.

To unload the SD card, slightly and quickly push the SD card down, and then pull the card out. These two movements required to remove the card prevent an inadvertent fall of the card.

- Charge the battery (Leica BP-SCL7 Lithium-Ion Battery).

which may take 3.5 hours for a full charge, reaching 80% in about 2 hours (when the orange indicator lights up).

- Insert the charged battery,

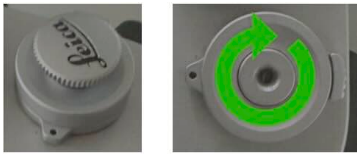
  Push the battery into its compartment until it clicks.

  To unload the battery, turn the battery release lever, so that the battery pushes out slightly, then push down the battery with a brief impulse, and then pull the battery out. Once again this prevents an inadvertent fall of the battery.

- Put back the bottom cover of the camera,

2.2 Initialize your SD card (the first time only)

- Turn the camera on,



  by turning the main switch clockwise;

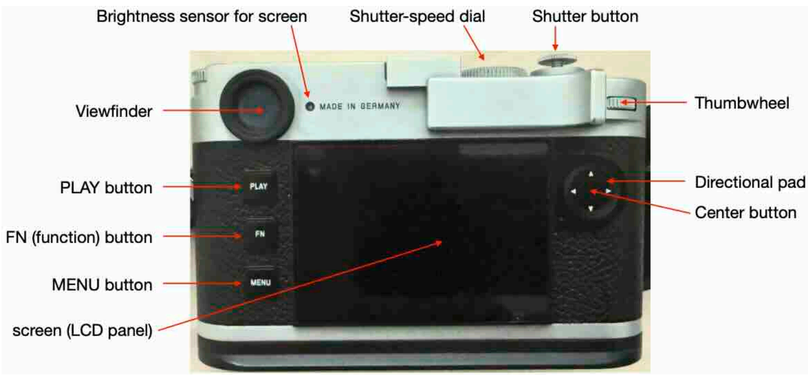


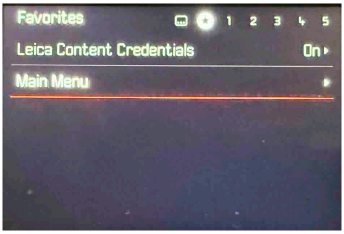
Figure 3: Back of the Leica M11-P

- Look at the back of the camera (see figure 3) and press the PLAY button  to make sure there are no photos on the card. Press PLAY again to exit the photo review mode.

- Press the MENU button ;

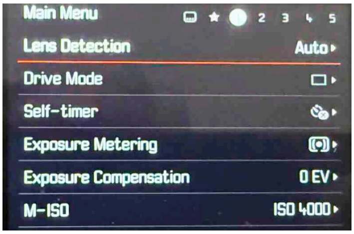
- Press the MENU button again or use the down arrow of the directional pad to select the menu to obtain the following screen:

- Press again the and then press the down arrow to move to Main Menu.

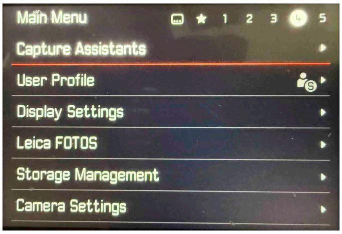


(the Camera Settings may have already been changed so that the Main Menu might be further down on the first or second page of the menu);

- Press the Center button to select the Main Menu and get:

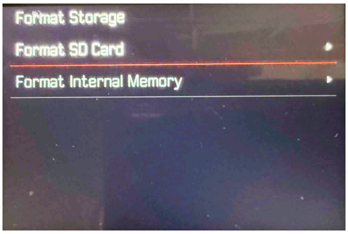


- Press three times the MENU button to select the fourth submenu (marked ④) to get:

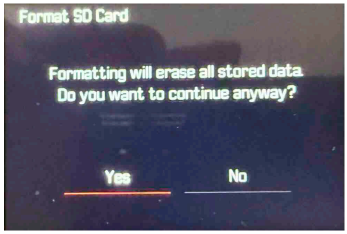


- Press the down arrow on the directional pad to select Storage Management. Then press the Center button to get

- Press the down arrow on the directional pad to select Format Storage and then press the Center button to get



- Push the Center button and then the left arrow to select Yes;



- Push the Center button to start the formatting of the SD card.

  This takes a few seconds and at the end returns to the Format SD Card menu.

- Shut down the camera

2.3 Menus

The previous sequence of actions to navigate the menus of the M11 is traditionally denoted as “ON → MENU → [menu icon] →

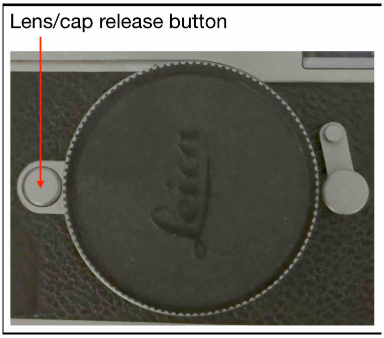
Main Menu → ④ → Format Storage → Format SD Card → Yes → OFF". The selection of the next step by pressing arrows △, ▷, ▽, ◁, the central button, or MENU (to directly get from ① to ④ instead of scrolling down through several pages with ▽) is left implicit. ON, MENU, and OFF are also omitted for brevity. Pressing MENU several consecutive times helps to quickly navigate to the menu pages numbered ① to ⑤.

2.4 Mounting a lens

The Leica M-mount allows many different lenses to be mounted on the M11 camera body.

- First remove the rear cap of the lens by turning it anti-clockwise (here a NOCTILUX-M 1:0.95/50 ASPH) to see the M-mount.

- Then remove the camera cap by maintaining the lens/cap release button pressed down and then turning the cap left.



- Then mount the lens (a SUMMARON-M 1:5.6/28mm in the example)

(by aligning the two red buttons on the camera and the lens and then turning the lens clockwise to the right until hearing a click, which is important to make sure that the lens is correctly fixed on the camera).

To unmount the lens, maintain the lens release button in the front of the camera pushed down and then turn the lens anti-clockwise to the left. Put back the caps/covers on the lens and the camera.

3 The First Photo With a Leica M11

- Set the ISO dial to A (automatic), lift the dial, turn it to

Figure 4: ISO dial

  put the A in front of the little index, and push back the dial down.

- Turn the shutter speed to A (automatic);

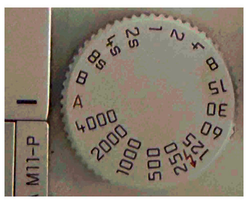
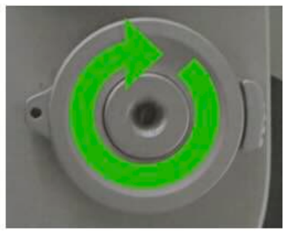


Figure 5: Shutter speed dial

- Turn the aperture on the lens to its maximum (16 or 22), and turn the distance on the lens to ∞;

- Turn the camera on,



  by turning the main switch clockwise.

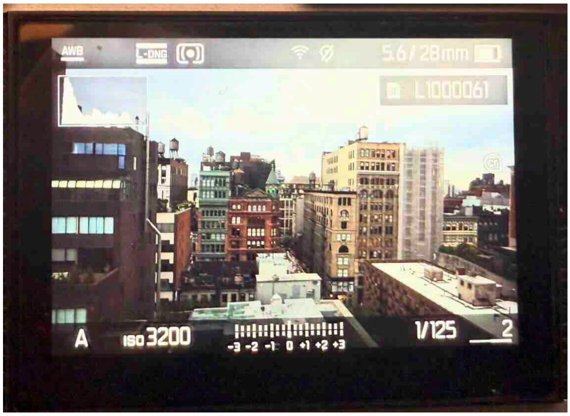
- Get the lens cap off, if any.

- Look to a landscape or a distant subject on the screen (this may require to first press the shutter button half-way if the camera got in standby mode).

The red lines show objects in focus (see section 22.3.2). The camera settings will remain the same as long as the shutter button is pressed halfway. Release and press halfway again if another view is preferred.

- When satisfied with the screen view, press the shutter button down fully to take the photo. A very recognizable sound produced by the mechanical shutter should be audible.

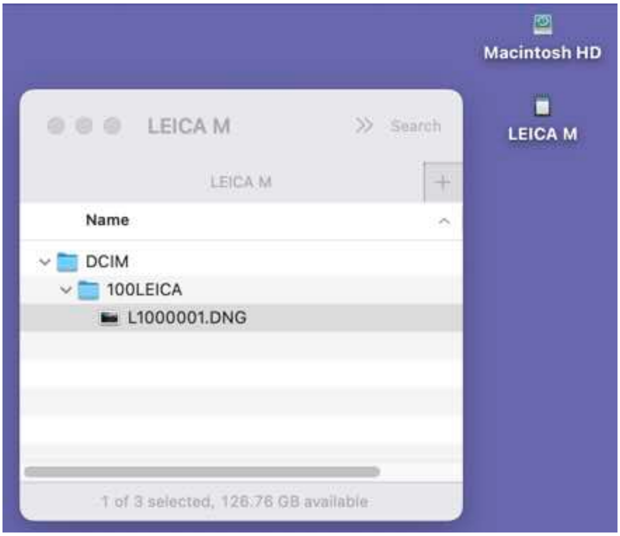
- Look at your photo on the camera screen.



The screen will go black after 30s, push the shutter button halfway to reactivate.

- Transfer the photo
  - to a computer by directly connecting the M11 camera to the computer with a USB-C cable.

  - or, to a computer by removing the battery, then ejecting the SD card, and finally inserting it in your computer slot or a SD card reader.

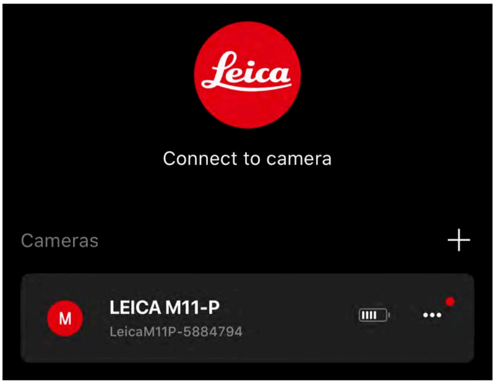


Opening the file L1000001.DNG with Preview or Graphic Converter on MacOS will show the photo enlarged on the computer screen. It can be saved as PDF format and then opened with Adobe Acrobat Reader.

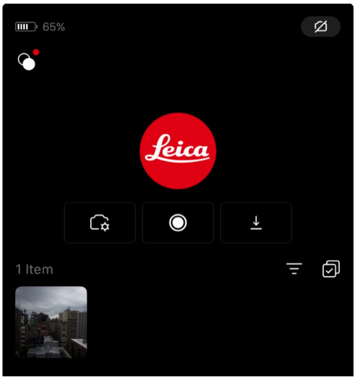
- to an iPhone using the Leica FOTOS app.
  - First pair the iPhone with the camera by opening the Leica FOTOS app on the iPhone,

    selecting Pairing in the Leica FOTOS camera menu, and following the instructions (you might have to re-activate the camera by pushing the shutter button halfway).

- Once the iPhone and camera are paired, open the Leica FOTOS app,



click on LEICA M11-P to connect to the camera (which must be on and active, half-press the shutter button if not) to get the photo



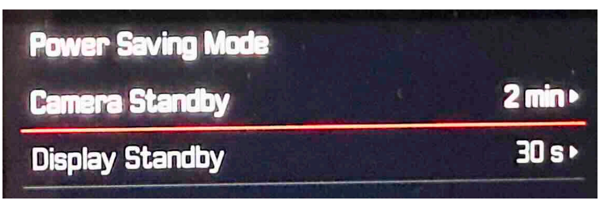
click (or double-click) on the photo to enlarge it and to send it electronically (which may require to turn the camera off to allow the iPhone to chose the destination).

Read what follows to understand what you need to know for your next photos!

4 Silent Deactivation of the Camera and Reactivation

When the camera is on, it automatically goes to inactive mode with a dark screen after some time. This saves energy for the battery. Pressing the shutter button halfway or switching the main switch off and on again will reactivate the camera, as shown by a red Status LED (light-emitting diode) and a visible screen. The silent deactivation time

is 2 min by default and can be chosen by the photographer with MENU → Main Menu → ④ → Camera Settings → Power Saving Modes → Camera Standby to get



Then the desired Camera Standby time can be turned Off or chosen between 30 s and 60 min.

Similarly the display deactivates after 30 s, which can also be modified by MENU → Main Menu → ④ → Camera Settings → Power Saving Modes → Display Standby to be Off or between 30s and 5 min.

Pressing the shutter button halfway or switching the main switch off and on again will reactivate the camera and screen.

5 Light

Photography is the art of fixing visible light on a support. We see and the camera records light from a source (sun, artificial lightning) that reflects on objects.

Light propagates in straight line beams (think to the straight rays of the sun visible through a cloud), of course except for reflexion on a mirror and refraction, for example through a liquid.

Light has an intensity giving an impression of brightness or brilliance (in absence of clouds, the light of the moon is less intense that the light of the sun at sunrise or sunset, which is itself less intense that the light of the sun at noon).

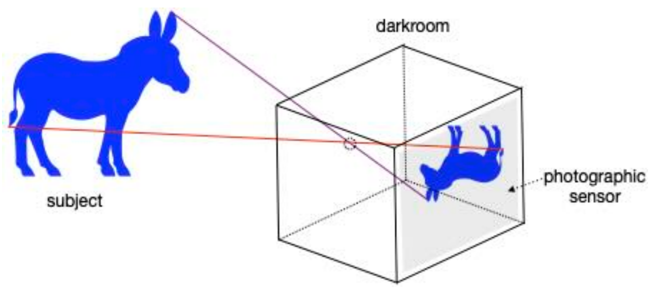
Light is also a quantity (the quantity of light received from the moon for a long time is the same as the quantity of light received from the sun during a very brief instant).

Light can be polarized by reflection on metal or water which alter how the light is transmitted and seen (for example polarization of light allows the glare-reducing effect of polarized sunglasses. Polarizers in photography annihilate light polarization, see section 46).

More scientific details on en.wikipedia.org/wiki/Light, en.wikipedia.org/wiki/Polarization_(waves), or [51].

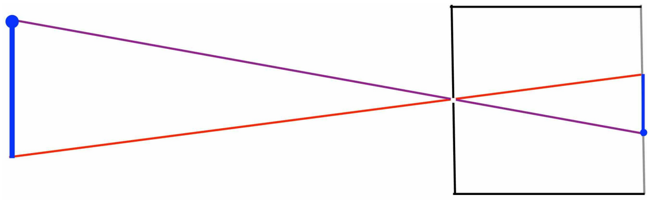
6 Darkroom

The darkroom has been known for centuries and is at the origin of photography. A darkroom is a box with a small pinhole in one face and a image sensor on the opposite face. This sensor was originally made of frosted glass or thin paper. The light beams going through the tiny pinhole reach the image sensor. Of course if the light outside the box is intense one sees nothing on the image sensor. But if the image sensor is seen in the dark (by looking at the image sensor while covered by a black cover), one can see an inverted image of the subject (flipped horizontally and vertically, that is, turned 180°).



This is because a ray of light from the top left of the subject goes through the pinhole and arrives at the bottom right of the image sensor. The same way, a ray of light from the bottom right of the subject goes through the pinhole and arrives at the top left of the image sensor. Of course cameras flip the image to see it right side up on the viewfinder and screen.

Instead of reasoning in three dimensions, one can use a simpler representation of the darkroom in two dimensions, valid in the two horizontal and vertical planes, as follows.



Originally artists painted directly over the frosted glass or thin paper serving as image sensor to reproduce the subject. Nowadays some artists like Arnulf Rainer and Philippe Cognée, use a similar idea and paint over photographs.

Here is an improvised darkroom made of a cardboard carton with a pinhole in it and a image sensor made of plant-based plastic frosted with a mirror fine sandpaper of grit size 1000. The photo of the sensor under a black sheet shows that the luminous cone is inverted.

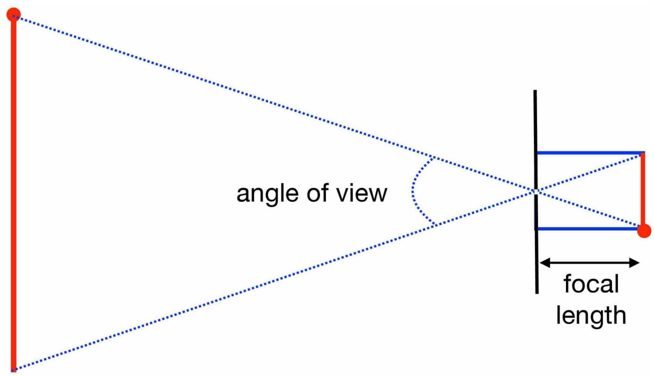
The history of photography [60] is a long search of (sometimes dangerous) chemicals able to capture the light on the image sensor of the darkroom and then fix it using a developer and then a fixer, to be able to see the photo in plain light without further modifications by exposure of the photo to light. Film photography appeared in the 1900's while digital photography appeared in the 1990's, replacing film by a digital image sensor.

7 Lenses of Different Focal Lengths

The darkroom also allows us to understand why a camera like the M-A has several lenses (objectives) of different "focal lengths" 18 mm (millimeters), 21 mm, 24 mm, 28 mm, 35 mm, 50 mm, 75 mm, 90 mm, and 135 mm, some with adjustable focal lengths 16-18-21 mm and the older 28-35-50 mm. Some vintage focal lenses such as the Leica Summicron-C 40mm, the Konica (M-Hexagon 21-35, 28, 90 mm lenses), Minolta (24, 40, and 90 mm), or the french Boyer f. Leica M 2,8/45mm Topaz, are no longer produced (the Établissements Boyer founded in 1895 disappeared in the '70s). Light Lens Lab produces copies of old lenses (28, 35, 50 mm). Other companies also produce M-mount lenses such as 7Artisans (28, 35, 75 mm), Lomography (17 mm), Meyer-Optik Görlitz (58 mm), Voigtländer (10 mm, 15 mm, 40mm), TTArtisan (35, 50, 100 mm), and Zeiss (15, 21, 25, 28, 35, 50 mm).

8 Definition of the Focal Length

The focal length is the depth of the darkroom. It determines the angle of view and the magnification of a lens.



Old-style bellows cameras had an extendable part that allowed the focal length to be adjusted.

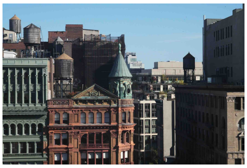
Courtesy Camera Doctor NYC

Modern lenses have a focus ring (see section 22) that allows for focusing by varying the focal length (which is called focus breathing). Turning the focus ring changes the lens's effective focal length and angle of view to a small degree thus making the subject appear to zoom in or out very slightly.

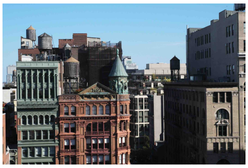
The lens focal length is defined as its effective focal length when focussing at infinity ∞.

The larger the focal length is, the smaller the (horizontal and vertical) angle of view and the larger the magnification are. This is clear on the following pictures all taken from the same shooting point and centered on the copper-covered (green) cupola of the former MSI (Manhattan Savings Institution) building in New York, now called the Bleecker Tower.

135mm



90mm



75mm

50mm

40mm

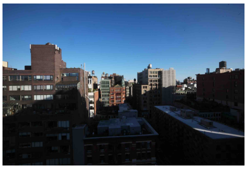
35mm

28mm

24mm

21mm

18mm



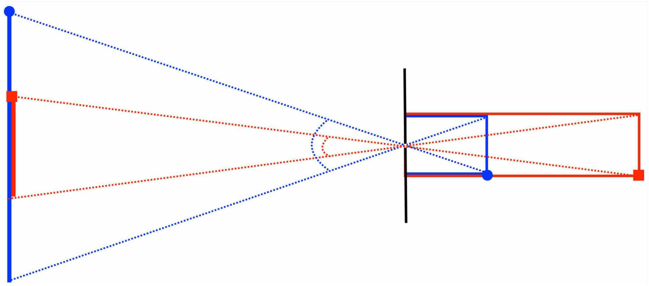
16mm

15mm

Observe the water tank (in the background on top right of the picture) appearing proportionally smaller than the cupola with small focal lengths. Let us explain why.

9 Comparing Lenses with Different Focal Lengths

Different focal lengths correspond to different depths of the darkroom box.



The two darkrooms, the small in blue and the large in red, have exactly the same image sensor size in their back but different depths, that is, focal lengths. The blue darkroom has a small focal length and records a large part of the subject (in blue). The red darkroom has a large focal length and records a small part of the subject (in red).

Notice that because the image sensors of the two darkrooms are of the same size, the red darkroom with large focal length has a smaller angle of view and can record more details of the visible subject part thanks to a larger magnification. On the contrary, the blue darkroom with smaller focal length has a larger angle of view but can record less details of the subject because of the smaller magnification.

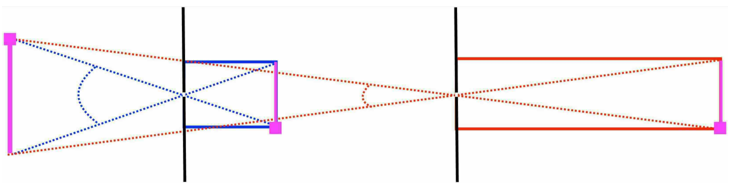
When choosing a lens, its focal length determines which part of the subject will be captured (as determined by the angle of view). This part of the subject recorded by the camera is called the "frame". This frame is visible in the viewfinder and on the screen (see section 12).

Spatial telescopes have huge focal lengths such as 57.6 meters (189 ft) for the Hubble Space Telescope and 131.4 meters (431 ft) for the James Webb Space Telescope (JWST). Photo lenses have much shorter focal lenses, typically between 10 mm and 800 mm,

10 Most Common Focal Lengths of Lenses

The most common Leica M lenses have focal lengths of 28, 35, or 50 mm. The 28 mm, with large angle of view (approximately 75 degrees horizontally), is typically used for a landscape, the 35 mm with a smaller angle of view (54 degrees) is better fitted for a group of persons, while the 50 mm with even smaller angle of view (47 degrees) will be used for an individual (although, obviously, these lenses can be used in all circumstances but produce different photos).

To take a picture of a subject of a given size with a lens of smaller angle of view, one can get farther from the subject. Symmetrically, to take a picture of a subject of a given size with a lens of larger angle of view, one can get closer from the subject.



In both cases the subject will be captured with exactly the same size on the image sensor.

But the pictures will be different! For example[1], The

28mm 50mm 120mm

Figure 6: Perspective distortion

background appears farther for lenses of small focal lengths and closer with lenses of larger focal lengths, the 50 mm being very similar to the human eye. Notice also that the green glass[2] in the background is much more blurry with the 120 mm that it is with the 28 mm. The explanation is given in section 23 (depth of field).

11 Perspective Distortion

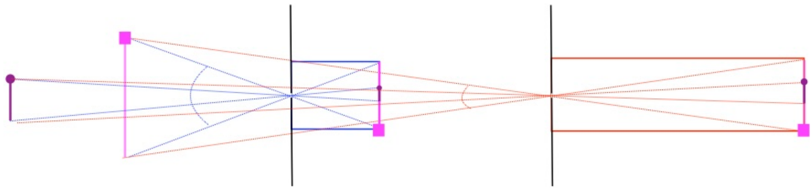
The backgrounds in the pictures of figure 6 look quite different because of the different perspective distortions, that is, what is in front and behind the subject is different on the three pictures.

[1]The pictures have been taken with the Leica LUX app on an iPhone, there is no Leica 120 mm M-mount lens.

[2]Couleur menthe à l'eau, Eddy Mitchell.

For example with a 28 mm, what is behind the subject looks very far since it will be small. With 50 mm what is behind the subject will be larger and look similar to what we see with human eyes. With the 120 mm focal length, the background is larger so looks closer.

This perspective distortion becomes clear on the following schema.



The subject (in magenta) appears to be of the same size on the image sensor of both darkrooms. But the purple object in a distance behind the subject is smaller on the image sensor of the blue camera with short focal length and larger on the image sensor of the red camera with longer focal length.

The further is an object, the smaller it looks like. Therefore, in the picture of the blue camera the brown object will look farther (since it is smaller) and it will look closer on the red camera (since it is larger).

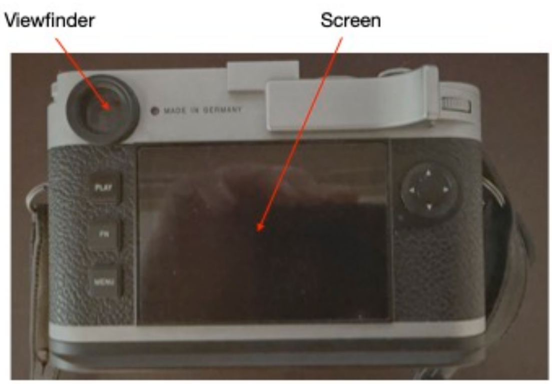
It follows that the three 28 mm, 35 mm, and 50 mm lenses can all be used to take pictures of the subject at a given size (provided enough space is available for the photographer to move farther or closer to the subject) but, unless there is no distant background, the three pictures will look quite different.

12 Viewfinder and Screen

In darkrooms the inverted picture appears directly on the translucent sensor. In Leica M cameras, the picture (in fact the inverted image straighten) can be seen through the viewfinder or on the screen (called LCD panel) for recent cameras (since the M8 but not for the M11-D which has no screen). The luminosity of the screen is automatically adjusted by the M11 using the front brightness sensor shown on figure 7.

At the time of film photography, the photographer could not immediately see the result and had to wait a few days until development of the photographic film in an amateur darkroom or a specialized commercial laboratory.

The viewfinder and LCD liquid crystal screen both allow the photographer to anticipate what will appear in the pictures taken by the camera.



(the camera is off on this picture). The screen shows the subject as seen through the lens (plus other informations to be discussed later). The viewfinder shows a different view of the subject (putting a hand or a cap in front of the lens blackens the screen but leaves the viewfinder unchanged). This is because the image in the viewfinder comes from the viewfinder window in front of the camera (see figure 7). If

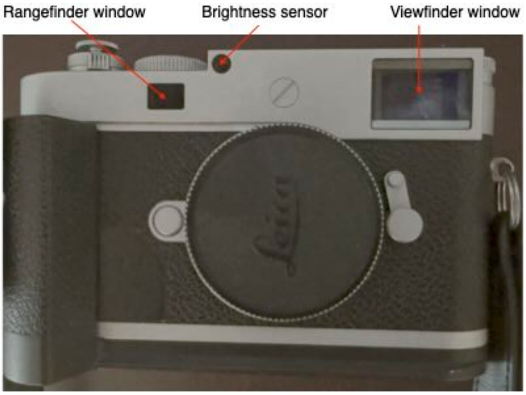


Figure 7: Front of the Leica M11-P camera (with no lens)

the camera is equipped with a lens, putting an hand on the viewfinder window blackens it but leaves the screen unchanged. This shows that the viewfinder and screen are independent.

In particular if a cap is forgotten on the lens, this is not visible through the viewfinder, but the black photo will be visible on the screen, maybe after a few dozens of seconds of processing by the camera software to denoise the black photo.

The viewfinder view is the same for all lenses and the part in the viewfinder frame for the mounted lens shows what is seen on the screen. So the viewfinder shows the photo in its context, while the screen only shows the photo. This explains while photographers may prefer the viewfinder to the screen for framing.

A question is whether to take a picture using the viewfinder or the screen? The screen shows only the photo to be taken (which depends on the lens and focussing). The view inside the viewfinder is always the same and the photo to be taken appears inside a rectangle within that view (which size depends on the lens). So with the viewfinder you see the photo plus what is around the photo (so as to find the good view). To do the same with the screen only, you have to move the camera in front of you and move it around to find the right view. Another possible solution is to use the viewfinder for focussing and framing (decide on which part of the subject should appear on the photo), take the photo, and look at the result on the screen.

Finally, note that observing the sun through the viewfinder, in particular during eclipses, can damage the eyes.

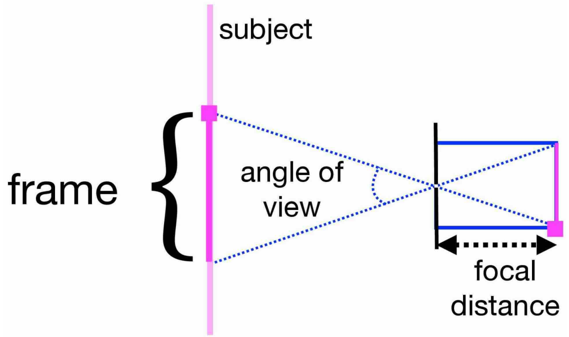
13 Electronic Viewfinder (Leica Visoflex 2)

An electronic viewfinder (called Leica Visoflex 2) can be mounted on the accessory shoe of the Leica M11 cameras. It exactly reproduces the screen but can be oriented in three different positions to provide an eye-level alternative for the screen. To save battery, the Visoflex 2 has a sensor to activate it only when you look through it.

(The former Leica electronic viewfinders other than the Visoflex 2 are incompatible and should not be mounted and used on the M11.)

14 Frame

The frame is the part of the subject reflected on the electronic image sensor. Only this frame part of the subject will appear on the photo.



The frame depends on the focal length of the lens. This frame can be viewed as a rectangle in the Leica M11 viewfinder when the lens is mounted (see figure 8). The part of the view inside the frame also appears exactly on the digital screen.

Moving the Frame selector lever

Frame selector lever

(on the right of the lens when facing the camera) will show six different possibilities. Other ones can be seen using external viewfinders to be fixed on the accessory shoe.

When fixing the lens, the current frame is shown in the viewfinder. Moving the Frame selector lever shows two other possible frames, either 35 mm + 135 mm, 28 mm + 90 mm, or 50 mm + 75 mm. These two frames are represented as two rectangles, as seen on figure 8. (By the way, the little white rectangle in the middle, shows what is seen through the rangefinder window (see figure 7) in superposition of

Figure 8: Viewfinder frames

what is seen through the viewfinder window. This is used for manual focussing, as explained later in section 22.2.)

If the frame produced by a lens is not satisfactory, moving the frame selector will show which lens provides the desired frame.

The luminosity of the bright lines is adjusted automatically by the M11 using the front brightness sensor shown on figure 7.

15 Framing With External Viewfinders

For other focal lenses, external viewfinders, to be mounted on the accessory shoe, provide the corresponding frame. Here are a few examples.

M11-P with 18mm lens and viewfinder

M11-P with 21mm lens and viewfinder

M11-P with 24mm lens and viewfinder

M11-P with 16-18-21mm lens and
universal wide-angle viewfinder

(the lens is equipped with a 67 mm UV filter (see section 42) with an 49-67 mm adapter since a smaller one creates vignetting (see section 40) at 16 mm).

These external viewfinders are for framing only. Focussing must still be done with the camera viewfinder (or using the screen or the electronic viewfinder reproducing this screen introduced at the end of section 12).

16 Camera

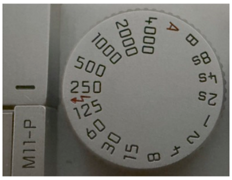
A camera is a darkroom with a image sensor capturing light like a metal plaque covered by silver salts darkening with light (which yields a negative). The darkroom image sensor was originally prepared by the photographer in the dark and then covered to be protected from light. The pinhole of the darkroom is closed, the image sensor is introduced in the back of the darkroom and uncovered. It is now sensitive to light. The photographer then opens the pinhole for long enough for the image sensor to capture enough light. This time is called the "exposure time". In the early days of photography it was hours, later seconds, and nowadays can be fractions of milliseconds.

The first Leica cameras used photographic films, nowadays electronic image sensors.

17 Exposure Time (or Shutter Speed)

Originally, the exposure time was very long, a few hours, since the image sensor was not very sensitive to light. Photography was for immobile subjects only, such as landscapes. A person traversing the landscape would not appear on the photo since it did not produce a large enough quantity of light to impress the image sensor. Over time, sensitivity of image sensors improved and it became possible to take pictures of persons, provided they did not move for a few dozen of seconds. Photographers used supports of the head and body to prevent movements so that the photographed persons often looked tense, rigid, and cramped!

On the Leica M11, the exposure time (or shutter speed) can be chosen thanks to the shutter speed dial on top right of the camera.



The shutter speed dial can be turned left or right and set to be 1/4000 s (second), 1/2000 s, 1/1000 s, 1/500 s, 1/250 s, a red lightning ⚡ (1/180 s) for photos taken with a flash, 1/125 s, 1/60 s, 1/30 s, 1/15 s, 1/8 s, 1/4 s, 1/2 s, 1 s, 2s, 4s, or 8s, each time doubling the exposure time. There is also a `B` meaning that the exposure takes place as long as the shutter button remains pressed down. Finally the `A` means that the exposure time will be automatically chosen by the camera image sensor and software.

If a photo is overexposed, that is, too bright, with too much light captured, this will be indicated by ◀ in the viewfinder. A solution is to increase the speed, by turning the shutter speed dial left, as shown by ◀, in order to increase the speed.

Else, if a photo is well-exposed, a disk ● appears in the viewfinder.

Otherwise, the photo is underexposed, that is, too dark, with not enough light captured, as indicated by ▶ in the viewfinder. A solution is to increase the exposure time, by turning the shutter speed dial right, as shown by ▶, in order to decrease the speed.

In addition to the viewfinder, the exposure measurement is also visible at the bottom of the screen

- 

is underexposed (the speed is too fast),
- 

is well exposed, and
- 

is overexposed (the speed is too slow).

18 Camera Stand

However, beyond 1/250 s to 1/60 s, the photographer will possibly slightly move the camera and the photo will be blurry. A solution is to use a monopod, a tripod or minipod,

tripod

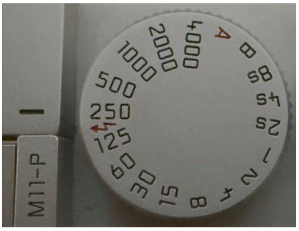
minipod

and even a mechanical shutter release cable to avoid any movement of the camera on the tripod when pressing the trigger.

The shutter release cable has a wheel to block it in down position for the `B` long exposure time.

19 Shutter Speed

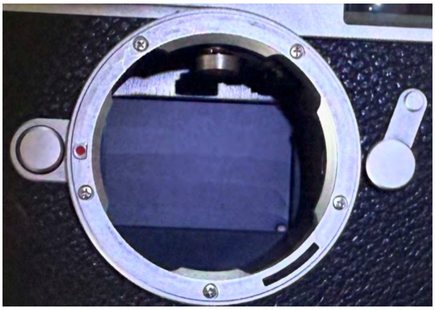
The shutter is the physical device on the camera that opens and closes to control the exposure time of the electronic sensor as determined by the shutter speed dial on top right of the camera (that can be moved by half increments).



The faster (respectively slower) is the shutter speed the smaller (resp. larger) is the exposure time so less (resp. more) light touches the camera electronic sensor.

The exposure time is a time measured in seconds. Calling it shutter speed is somewhat a confusing misunderstanding, since a speed is measured in meters per second (m/s or fractions of these). But obviously, the faster the shutter moves (in m/s), the shorter the exposure time (in s). Calling the shutter speed the exposure time avoids the confusion.

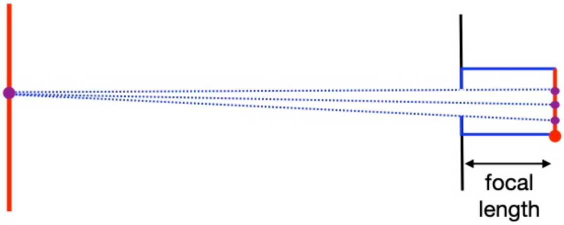
The shutter can be seen in closed position on a camera with no lense.



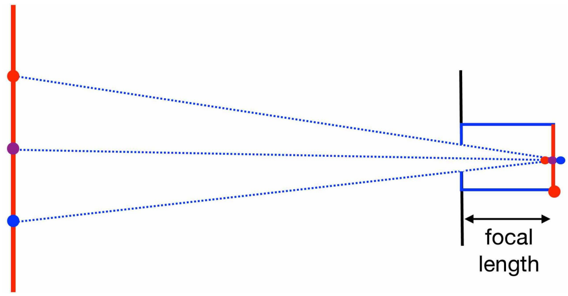
The mechanical shutter consists of light metal blades moving very quickly (in up to 1/4000 s). The shutter is very fragile and should not be touched or blown on (with one's breath or a rubber dust blower ball). The M11 has also an electronic shutter to control the light exposure of the sensor electronically allowing exposure times up to 1/16000 s. Electronic shutter are not perfect so that the M11 offers, by default, an hybrid mode, using the mechanical shutter up to 1/4000 s exposure time and the electronic shutter beyond.

20 Lenses

An obvious solution for a darkroom to capture more light is to have a larger hole. But then a point of the subject will send light rays to different points of the image sensor.

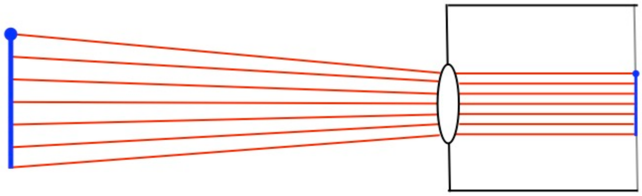


Symmetrically, a point of the image sensor will receive light from different points of the subject.

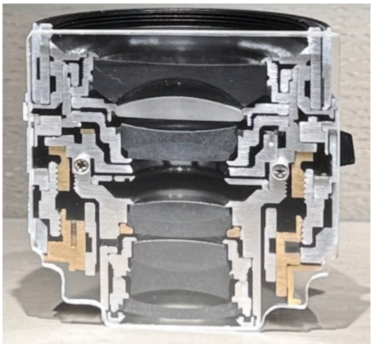


The result is that the photo will be blurry.

To allow a larger hole in a darkroom without blurring the image sensor, photographers invented lenses (that they also call objectives or glasses in slang). Ideally, a lens would project exactly the subject in reduced size on the image sensor.



In practice it is impossible to achieve this ideal goal [51, section 4.3.1, page 50] and lenses have a much more complicated design, always with some limitations [23].



(courtesy Leica Store, New York)

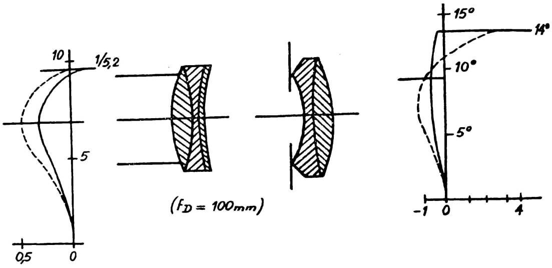


Fig. 225.- Objectif "Dialyt" de Petzval

[23, page 542]

There are usually several lenses in the lens[3] and some mechanism to move them within the lens for focussing, as well as a second mechanism, called a diaphragm, to determine the aperture to modify the size of the hole through which the light beams reach the image sensor, so called entrance pupil (as well as a third related one for the rangefinder, see sections 22.2 and 50).

[3]In french the lenses inside the lens are "lentilles" inside the "objectif" without ambiguity. Photographic objective is rarely used by photographers in English.

21 Aperture

Lenses have an adjustable iris diaphragm allowing for different apertures with large holes (called entrance pupil) having small numbers while small holes/entrance pupils have large numbers. Typical apertures are $f/$ 0.95, $f/$ 1.4, $f/$ 2, $f/$ 2.8, $f/$ 4, $f/$ 5.6, $f/$ 8, $f/$ 11, $f/$ 16, $f/$ 22. Small f-numbers (also called focal ratio, f-ratio, or f-stop) correspond to large apertures through which a large quantity of light goes through while large f-numbers correspond to small apertures through which a small quantity of light goes through. The desired aperture is chosen by turning the focus ring marked with these f-numbers. Looking through the lens clearly shows the various apertures (which exact size depends on the lens)

A lens with a small f-number is called fast because when wide opened it captures a lot of light so that the exposure time can be small (or shutter speed very fast). The fastest Leica lens is the NOCTILUX-M 1:f/0.95 50mm ASPH (which first appeared in 2008).

22 Focussing

Ideally whatever is the distance of the subject to the lens, the subject should appear sharp on the photo. Unfortunately, this is not possible in practice. Lenses must be focussed on the subject for this subject to appear clear, sharp, in focus on the photo.

On Leica M cameras, focussing is manual. A particular case is when the subject is far enough (usually more than 15/20 m), in which case the distance is set to ∞ (infinity,

$f/16$

$f/11$

$f/8$

$f/5.6$

$f/4$

$f/2.8$

$f/2$

Figure 9: Entrance pupil of the SUMMICRON-M 1:2/28 ASPH lens with UV filter and no hood nor rear cap at apertures f / 16, f / 11, f / 8, f / 5.6, f / 4, f / 2.8 and f / 2. Half increments are also possible but not shown.

math for very far!).

Taking pictures of landscapes is always easy since focussing is trivially set to ∞! Otherwise, the focus must be made manually to the distance to the subject.

The focussing distance in photography is measured from the camera's electronic sensor plane to the subject, not from the front of the lens. This sensor plane is about 1/3 in the back of the M11 camera.

22.1 Focussing by Measuring (Optional)

The focussing distance can be measured by a tape measure or a laser distance meter or rangefinder (0.947 m in our example) and the focus ring turned to be positioned at that distance (1 m in the example), with some tolerance since the measure is often more precise than necessary.

Although most photographers do not use this measuring method, it is very precise when extremely sharp image quality is required.

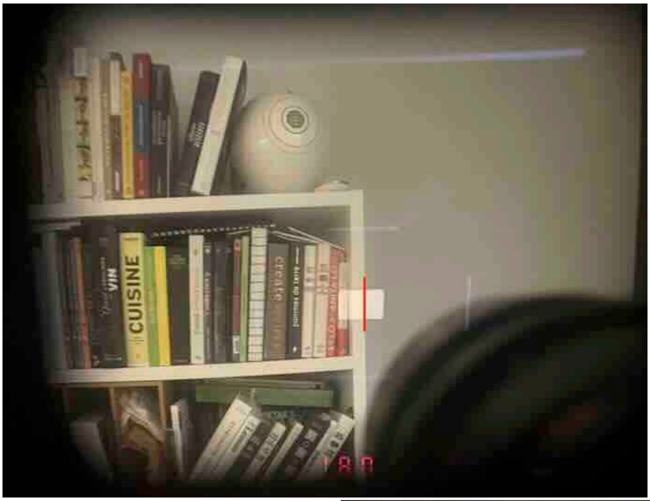
22.2 Focussing with the Viewfinder

The M11 is a rangefinder camera. This means that a coincidence rangefinder (also called telemeter) is incorporated in the M11 and used to determine the distance to a subject. The image taken through the viewfinder must be aligned vertically with the small center rangefinder image taken through the rangefinder window (see figure 7). This alignment is made by turning manually, left or right, the focussing ring (marked in meters (and feet) on the lens). If you want to always turn the focussing ring in the same direction, preset it to ∞, and then turn it right to focus.

The alignment of the viewfinder and rangefinder views by turning the focus ring requires a mechanical linkage between the lens and the viewfinder (described in section 50).

Here is an example with an APO-SUMMICRON-M 1:2/90 ASPH lens at an $f\,/\,2$ aperture (which require a precise focussing as explained subsequently).

- When the lens and rangefinder images are vertically aligned (because the focussing ring is on 1.3 m in this example), the lens is focussed and the image on the screen and the photo are clear. The red line on the picture has been added a posteriori to show the perfect alignment.



- When the lens and rangefinder images are not perfectly aligned vertically (because the focussing ring is on ∞ in this example), the image is blurry. The broken red line on the picture has been added a posteriori to make the misalignment clear.

If the subject has no clear vertical line, it is usually possible to move the camera to focus on a vertical line somewhere else at the same distance, then maintain the shutter button half-pressed to keep this distance setting, and come back to the subject to take the photo by fully pressing the shutter down.

Another solution in case of absence of clear vertical line is to turn the camera by 90°, in portrait position, and to focus on an horizontal line.

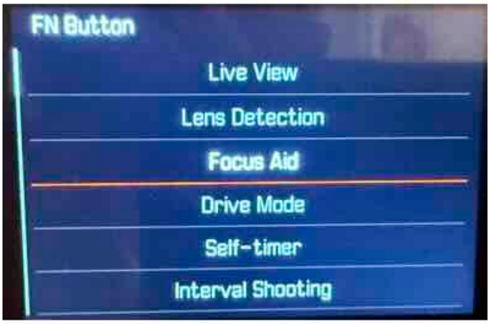
For very short distances the rangefinder can be imprecise in which case focussing can be done on the screen (or empirically, like 60 cm (centimeter) if you can touch the subject with your arm while holding the camera).

22.3 Focussing with the Screen

It is possible to focus with the screen, turning slowly, left or right, the focussing ring until the image is clear on the screen. Two settings of the camera do help.

22.3.1 Magnification

- Pressing down the FN (function button, see figure 3) long enough, a menu appears on the screen



  Using up or down arrows of the directional pad, select Focus Aid and then press the Center button to select this option.

- Afterwards, shortly pressing the FN (function button) will magnify the middle of the screen, which is helpful for focussing. Pressing again will go back to the full image on the screen.

22.3.2 Focus peaking

Focus peaking highlights the edges of in focus subject elements in red.

On the left screen the parts of the plant in focus have a red border. On the right screen no part appears in red since the camera focus is incorrect.

If not set by default, focus peaking is enabled by MENU → [≡] → ④ → Capture Assistants → Info Profiles → Info Profile 1 → Focus Peaking → On (the Color is red and Sensitivity is High in our examples).

23 Depth of Field

For each of its possible apertures and focus distances, a lens has a corresponding depth of field, that is a zone where the photo is clear, sharp, in focus. Subjects outside that this field will appear blurry on the photo (see figure 10). Of course the transition from sharp to blurry is progressive. The closer in front or farther behind the subject, the more blurry the photo will be. Photographers appreciate a smooth transition. Depending on the lens and aperture, the depth of field can be very large or tiny. Each lens has a

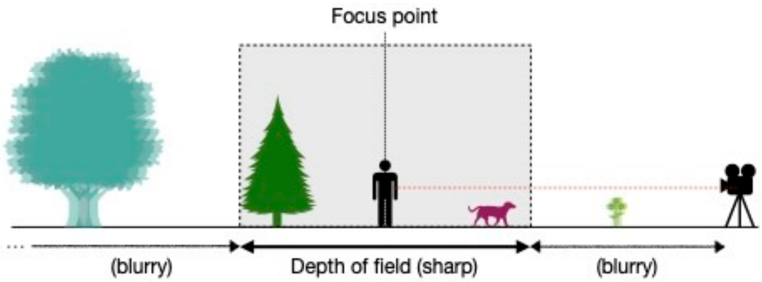
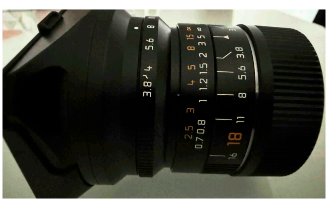


Figure 10: Depth of field

different depth of field which depends on the aperture and is engraved on the unmovable depth of field ring of the lens.

Depth of field ring of the SUMMILUX-M 1:1.4/35 ASPH

Lenses with small focal length have the largest depth of field. Here is the depth of field of the SUPER-ELMAR-M 1:3.8/18 ASPH with focal length of 18mm.



As shown on the middle picture, the aperture is set to f / 8 and the focus distance to the subject to 5 m (15 feet for the British Imperial System). The depth of field starts at 1.1 m and is sharp up to infinity ∞ (and beyond :). If the aperture is set to 16, then the depth of field for a focus distance of 5m goes from 0.7 m (on the left picture) to ∞ (and beyond on the right picture). This means that, with this lens, choosing an aperture of 16 and a focus distance of 5 m, all pictures will be in focus.

Lenses with large focal length have the smallest depth of field. Here is the depth of field of the APO-TELYT-M 1:3.4/135 of focal length 135mm with focus distance of 5 m.

For the smallest aperture of 22, the depth of field has a minimum of 4.3 m and a maximum of 6.3 m, which means that the sharp zone, in gray in figure 10, is only two meters deep. At the maximal aperture of 3.4 the depth of field is very small, a few decimeters. Nevertheless this lens is no problem for photographing objects at a long distance such as the summit of a mountain in a landscape or the top of a skyscraper.

Small depths of field have been used in portraiture. For example with an APO-SUMMICRON-M 1:2/90 lens of focal length 90mm at maximum aperture of 2 and a distance to the subject of 1 m

the depth of field is tiny (and not much larger with aperture 16). Therefore, the subject will be sharp but its background blurry, the farther, the blurriest.

In summary,

depth of field:	small	large
aperture:	large (small f-number)	small (large f-number)
focal length:	large	small

A shallow depth of field is in general suitable for a close subject while a greater depth of field may be necessary for a distant subject.

24 Hyperfocal distance (hyperfocus)

The hyperfocal distance (or hyperfocus) is the focussing distance that maximizes the depth of field for a given lens and aperture. When focussing at the hyperfocal distance, the depth of field extends from half that distance to infinity. This is mainly used in landscape photography to ensure that both the foreground and background are sharp, in focus.

On Leica M lenses, the hyperfocus is obtained by turning the focus ring so that the ∞ symbol is positioned in front of the aperture on the depth of field marking.

Hyperfocus at 2.5m on the ELMARIT-M 1:2.8/24 ASPH at aperture $f\,/\,8$ (∞ is set in front of the depth of field marking 8). The depth of field is from 1.2 m to ∞ (both under marking 8).

25 24 × 36 mm Film Cameras

The original photography techniques (the heliography by Nicéphore Niépce in 1826, the hysautotype in 1832 by Niépce and Daguerre, and the daguerreotype named after its inventor Louis Daguerre in 1839) produced only one picture at a time. The invention of the photographic film by George Eastman at Kodak, first in black and white (monochrome) and then in color allowed for several photos to be taken in succession and exactly reproduced on photographic paper as many times as desired (now on printers). The film had perforations and the camera used a film advance lever or knob to advance to the next photo. The photographic films could have different sizes and numbers of photos (so called exposures). The 24 × 36 mm format, designated as 35 mm, was adopted by the Leica M1 in 1959 and this 2 × 3 ratio of height × width is still used in the Leica M11 (which, moreover allows for thousands of photos on SD cards). The purely mechanical Leica M-A camera and the Leica M6 incorporating an electronic light meter are the most popular recent Leica film cameras.

26 ISO (Sensitivity)

The films had different sensitivities (improperly called "film speed")[4], the more sensitive films requiring a smaller quantity of light, therefore allowing for faster shutter speeds.

A standardized method of sensitometry was introduced in 1934 and internationalized in the 1974 by the ISO (International Organization for Standardization) to measure film speed.

Popular film ISOs are 100, 200 and 400 but one can also find films at ISO 25, 50, 64, 160, 800, 1600 and 3200. A doubling of film sensitivity is represented by a doubling of the numerical film speed value.

A small ISO produces the best quality photos while the quality may degrade at high ISOs with the appearance of noise, such as unwanted grain, dots, and lines.

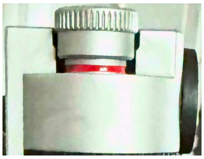
Compare, for example, the following cropped and zoomed photos of a white wall.

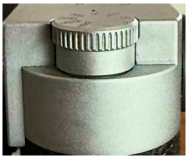
ISO 64 at 0.60 s

ISO 50000 at 1/1500 s

[4]The obsession with "speed" dates back to the origin of photography where exposure times were extremely long.

The ISO sensitivity of the camera electronic sensor can be chosen with the ISO dial on top left of the M11. Lift it, select the desired ISO (400 in the example), and push it back down.





The base ISO of the M11 is 60. This is the lowest ISO setting on the M11, which provides the highest image quality with the least amount of noise. The traditional film sensitivities of 100, 200, 400, even 800 are also popular. Beyond 3200/4000 ISO the quality may slightly degrade.

When the ISO dial is on A, the ISO is automatically chosen by the camera and can be upper limited to avoid noise (by MENU → ☰ → Main Menu → ② → Auto ISO Settings → Maximum ISO → ISO 3200, for example).

27 Automatic Mode

As discussed in section 3, the Camera Settings can be chosen automatically by the M11. Just select the ISO A, the shutter speed A, the aperture according to the ambient luminosity and desired depth of field (for example 5.6 inside and 16 outside), and select the subject distance manually using the screen, knowing that ∞ will always work for landscapes. The M11 will automatically select the ISO and shutter speed. The algorithm used by the M11 for this selection is sketched in section 34.3, optionally, for interested readers only. See section 33 on exposure compensation to manually adjust the automatic settings.

28 Manual Settings of the Camera

To take a photo, the manual settings of the M11 are

1. **Lens:** The choice of the lens, which determines the frame, that is the part of the subject appearing on the photo, and the magnification.

   Moving closer or further from the subject with any lens may be possible, but this will affect the perspective, as discussed in section 11;

2. **ISO:** The sensitivity of the electronic sensor measured in ISOs. The lower the better to get better photo quality (64 offering the best quality, 400 is often chosen as equivalent to a good quality film sensitivity).

3. **Aperture:** The aperture of the lens, the smaller the better (that is, the larger f-number the better) to allow for a deep depth of field (unless bokeh is desired, see section 41);

4. **Shutter speed:** For the shutter speed, the faster is the better to avoid blurring with hand held cameras (but blurred photos by moving the camera or choosing low shutter speed is also popular to get off the beaten track [46, page 76]);

5. **Focussing:** Finally the manual focussing on the subject.

One can start with a standard choice like (ISO 400, aperture $f/$ 5.6 or $f/$ 8 inside and $f/$ 16 or $f/$ 22 outside, and a shutter speed of 1/250). Then one can either use the information in the viewfinder or screen to adjust the speed as explained in section 32 or take the picture, and adjust these settings empirically from the photo on the screen (this is one reason for photographers to look at the screen after shooting).

Another solution is to take a first picture in automatic mode, look at the setting chosen by the camera, adjust if necessary, and retake the photo with the adjusted settings. Of course this will work well for architectural photography but probably not for street photography.

Taking several shots is recommended since failed pictures cost nothing and are easy to erase by PLAY → MENU → Delete Single → FN (marked with a trash), moving to other pictures with ◁ and ▷ arrows, and terminating with PLAY (marked ↩).

The M11 can also be instructed to take several pictures (3 or 5) for a shot at different exposures and speeds. See *exposure bracketing* in the manual [30, page 119].

29 Histogram

When pressing the shutter bottom halfway, the M11 displays a preview of the photo together with other informations in transparent superposition, such as an image histogram[5].

---

[5]If there is no histogram set MENU → Main Menu → ④ → Capture Assistants → Info Profiles → Info Profile 1 → and set Histogram to On. The Grids and Level Gauge (to check the camera horizontality and verticality)

The image histogram represents the number of pixels in the image for each color brightness in the picture, darker colors on the left and lighter colors on the right.

- The image details may be lost due to blown-out highlights. For example, the sky may look white with no cloud visible. In this case, the histogram has a peak on the right;
- On the opposite, the image details may be lost due to blacked-out shadows. For example the shadow of a building looks black with nothing visible within the shadow. In this case, the histogram has a peak on the left;

Both phenomena appear on the following picture so that the histogram (appearing superimposed on the screen preview) has two peaks,

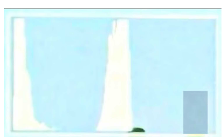
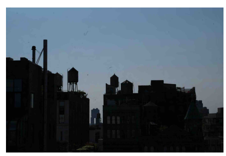



Photo histograms may have different shapes but peaks and biases to the left or right always show an excess in some color brightness, which, in general, is undesirable.

30 Stops: Aperture versus Exposure Time versus ISO

Cameras, films, and lenses are all designed so that the settings to receive the appropriate quantity of light needed to

---

may also be useful.

make a well-exposed photo are always the same (in a given luminosity situation). In particular the settings will be the same for all lenses of the Leica M-A. To achieve this, the basic notion is that of *stop* (or *exposure value*, EV).

If, for a given amount of light, a photo is too bright/overexposed (respectively dark/underexposed), the photographer must decrease (respectively increase) the exposure, that is the quantity of light received by the camera electronic sensor. There are three possibilities (often, somewhat improperly, called the "exposure triangle", except that a triangle has three sides).

- **Aperture**: decrease (respectively increase) the aperture (that is increase (respectively decrease) the f-number);
- **Shutter speed**: decrease (respectively increase) the exposure time, that is, increase (respectively decrease) the shutter speed;
- **ISO**: The ISO modification was listed last since it was not available with film photography. This fixed ISO was a limitation which disappeared with digital cameras. **ISO**: decrease (respectively increase) the ISO of the image sensor.

The increment or decrement in these cases are called "f-stops" or simply "stops" by photographers. For example stopping down goes down by one stop (for example from 11 to 8) while stopping up goes up by one stop (for example going up from 4 to 5.6).

Most lenses allow to stop the aperture up or down by a half-stop. Some lenses like the Carl Zeiss Distagon 2.8/15 ZM even offer 1/3 stops (that is 19 possibilities between 2.6 and 22).

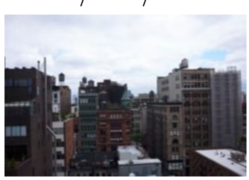
Cameras and lenses are designed so that an aperture stop, a shutter speed stop, and an ISO stop allow for the same change of the quantity of light received (up by doubling it, down by dividing it by 2). For math fans, this will be explained in detail in optional section 34.

Assume we have used the lens SUMMILUX 1:1.4/35 ASPH to take the following picture

16/250/200

at aperture 16, speed 250, and ISO 200. If we think that is is too dark (a question of taste), we can make the following corrections (on top is the camera screen and below the photo).

11/250/200 16/125/200 16/250/400

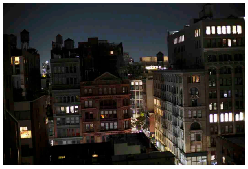


The photos look pretty the same since in each case the change was by 1 stop.

So photographers have to look for a compromise since increasing the aperture (decreasing the f-number) may restrict the depth of field, decreasing the speed may yield blurring, and increasing the ISO may introduce noise.

Moreover the results of the camera and lens settings depend slightly on the lens. Figure 11 is an example of two photos taken during the night with the SUMMILUX-M 1:1.4/50 ASPH and the NOCTILUX-M 1:0.95/50 ASPH lenses, both at aperture f / 1.4, speed 1/30 s, and ISO 3200 focussed at ∞. Although the settings are the same, the NOCTILUX-M 1:0.95/50 ASPH photo looks brighter. The lens brightness depends on its design (number and type of elements), coating, and handling of optical aberrations (like chromatic and spherical aberrations) but also on its "speed" (minimal aperture f-number), see sections 34.9 and 34.10.

SUMMILUX-M 1:1.4/50 ASPH



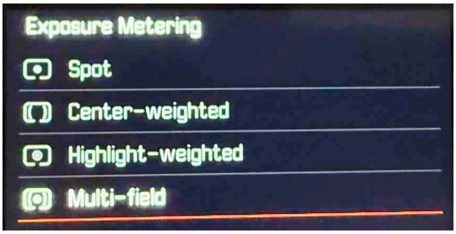
NOCTILUX-M 1:0.95/50 ASPH

Figure 11: Different brightness for same settings

31 Exposure Metering With the Camera

To decide automatically of the correct camera settings for a photo, the M11 determines the exposure, that is the quantity of light per unit area reaching the surface of the electronic image sensor (and then showing its estimation on the screen or viewfinder to help the photographer get the correct exposure as previously explained in section 28).

The M11 lets the user choose how the exposure is computed, by MENU → ≡ → Main Menu → Exposure Metering showing the following alternatives



- The Multi-field default option determines the exposure by looking at the whole frame;

- The Center-weighted option determines the exposure by looking around the middle of the frame;

- The Highlight-weighted option determines the exposure by prioritizing the bright areas (to prevent them to be overexposed and appear white);

- The Spot option determines the exposure by looking at a small disk in the middle of the frame.

  This may be useful for example to take a picture of the moon in the dark. With the Multi-field option, most of the picture is dark, which requires a high sensitivity, so that the moon will be very over exposed. But with the Spot option pointing at the moon, its exposure will be correct, while the rest will remain dark, more precisely under exposed dark, which does not make much difference.

Recall that observing the sun through the viewfinder can damage the eyes, in particular during eclipses.

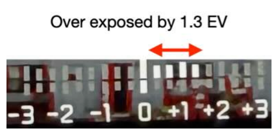
32 EVs (Exposure Values)

An EV (Exposure Value) is a measure of the quantity of light that must be captured by the camera sensor (film or electronic), as defined by given ISO, apertures, and exposure time, according to the light brightness reflected by the subject. The stops as discussed in the previous section 30 correspond to 1 EV.

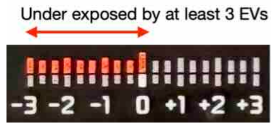
A scale in EVs is shown on the screen to indicate whether a photo is well exposed (EV of 0), overexposed (positive EV, too much light captured by the electronic image sensor) or underexposed (negative EV, not enough light captured by the electronic image sensor).

- This scale shows the *difference* between the expected brilliance according to the camera settings (ISO, aperture, and shutter speed) and the actual brilliance of the subject (as measured by the image sensor), both expressed in EVs, that is stops.

Over exposed



Under exposed



When the exposure is correct, the scale is on 0 EV

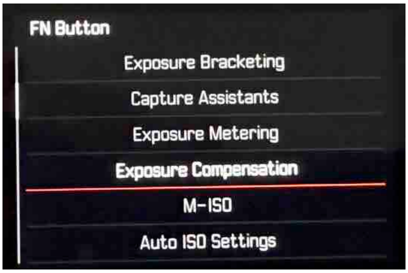
- In the viewfinder, an over exposure is indicated by a red left arrow ◀ (showing the direction for the shutter speed button to be turned for correction by decreasing the exposure time), a correct exposure is shown by a red disk ●, and an under exposure is indicated by a red right arrow ▶ (showing the direction for the shutter speed button to be turned for correction by increasing the exposure time).

EVs are further explained in next section 34 (for the math nerds only).

33 EV Compensation (or Correction)

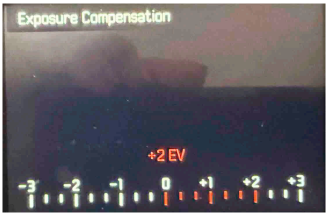
In automatic mode the aperture is chosen by the photographer (to get an appropriate depth of field) and the exposure (shutter speed, and ISO) is chosen by the camera software. The camera choice may not be that desired by the photographer, being too dark or too bright. An instruction can be given to the M11 to go brighter (by a positive number of (thirds of) EVs) or darker (by a negative number of (thirds of) EVs). Since this correction may depend on each photo taken, it is useful to make this correction easily accessible, as follows:

- Press down the toothed thumbwheel (on top right of the back of the camera), a menu will appear



  and select the Exposure Compensation to assign the exposure compensation selection to the thumbwheel.

- Afterwards, pressing the thumbwheel and turning it left or right *while taking a picture* will select an exposure compensation measured in thirds of EVs.



  This will be added to the exposure selected by the camera or photographer (hence subtracted, that is darker, for negative values).

- Notice that the exposure compensation will remain the same until reset manually to a different value, and this, including when the camera is shut off and then on. It is a good practice to always reset it to 0.

34 A (Long) Digression on the EV Formula for Math Lovers (*Optional*)

If you are resistant to mathematics, just skip this section 34 and go directly to the next section 35, with one click, with a light heart and no regret. A definitely more ambitious solution would be to first refresh your knowledge in mathematics by reading [9].

34.1 The EV Formula

But if you like formulas, here is one

$$EV = \log_2\left(\frac{100 \times f^2}{I \times s}\right) \text{ where } \begin{array}{rl} EV & : \text{Exposure Value} \\ I & : \text{ISO} \\ f & : \text{lens aperture} \\ s & : \text{shutter speed} \\ & \text{in seconds} \end{array} \quad (1)$$

An EV is a number representing the ISO I, aperture f, and exposure time (or shutter speed) s to be set on a camera for the camera sensor (film or electronic) to capture a given quantity of light during s seconds. Lower EV numbers indicate low light (so more light is needed for the photo) while higher EVs indicate more light (so less light is needed for the photo). This means that an EV is also a measurement of the subject brightness based on camera

In a dark, unlit room Pointing at lit light bulb

Figure 12: EV measurement

settings (different from but related to luminance based on photometry in optics). In a dark, unlit room, the exposure time with ISO 100, during 1 s, with aperture of $f/1.0$ of the camera is $EV = \log_2 1 = 0$ (see figure 12). If the quantity of light captured by the camera sensor and the subject brightness coincide, the photo is well-exposed.

All camera combinations of the ISO, f-number, and shutter speed that yield the same exposure have the same EV. An incrementation of the EV by 1 corresponds to 1 stop (either on the ISO, aperture, or shutter speed), as explained in section 30 and proved in section 34.16.

As shown in figure 12, a subject brightness EV can be measured by an external light meter (see section 49 for more details).

For example an exposure $EV = 14$ can be achieved by ISO $=$ 100, $f = 22$, and $t = \frac{1}{30}$ since $\log_2(22^2 \times 30) = 13.8257538329 \simeq 14$ (among other solutions).

An external exposure value measurement is not necessary since the Leica M-11 can measure the EV of the light reflected by the subject with its image sensor. Given a measured EV, formula (1) provides the possible ISO I, aperture f, and shutter speed s, that can be chosen to have the correct exposure for that measured EV.

Notice that the camera can read the exposure time thanks to the position of the shutter speed dial (see section 17), the ISO thanks to the position of ISO dial (see section 26), and the aperture f-number thanks to a mechanical connection of the interchangeable lenses and the camera described in section 50.5.

34.2 Use of the EV Formula in Manual Mode

In manual mode, the Leica M11 measures the EV of the light reflected by the subject with its image sensor (depending on the Multi-Field, Center-Weighted, and Spot metering mode, see section 31), reads the f-number, ISO, and shutter speed that the photographer has chosen on the lens and camera, computes the right-hand side of formula (1), and compares it with the EV measured with its image sensor. The result of this comparison is shown in the viewfinder with arrows ◀ and ▶ and a 1/3 EV graded scale on the screen, for example  (and ▶ in the viewfinder) means underexposed by 2 EVs.

34.3 Use of the EV Formula in Automatic Mode

In ISO and shutter speed automatic mode `A`, the Leica M11 measures the EV of the light reflected by the subject with its image sensor (depending on the metering mode), get the

f-number from the lens aperture, and uses formula (1) to determine the ISO and shutter speed (which are shown on the screen, the speed only in the viewfinder). The balance between ISO and shutter speed is influenced by MENU → ② → Auto ISO Settings allowing to set up limits on the ISO and shutter speed

- The Maximum ISO (for example ISO 4000), and
- The slower Shutter Speed Limit (for example 1/(4f) s (which is a rule of thumb for setting the minimum shutter speed to avoid motion blur caused by handheld camera shake, a bit more tolerant that the traditional "1/focal length" rule) or 1/60 s (a simplification of the old $s \leqslant$ 1/f second rule of thumb to avoid blurring for focal length $f/50$ which isn't on the speed dial, so the next fastest option of 1/60 is chosen).

Starting from the base ISO 64 for the M11 and maximum speed (1/4000), the camera evaluates formula (1) and terminate with these settings in case of equality with the measured EV. Otherwise, because of low light, the camera will successively increase the shutter speed by one stop (1/4000 → 1/2000 → 1/1000 → 1/500 → …) until a solution is found or the Shutter Speed Limit is reached. Then the ISO is increased by one stop, and the procedure is repeated.

If no solution is found with maximal ISO and minimal speed, the camera software will try harder, by bypassing the user settings and going to the camera limits. But if the photo is ultimately too dark (for example because you forgot the lens cap) you get 

and a black photo. The only solution is to remove the cap or to illuminate the subject. If the photo is too bright, you get

and the photo is white. A solution is to use a ND filter (see section 43) and move to the electronic shutter allowing higher shutter speeds by MENU → ③ → Shutter Type → Electronic.

This mode of operation allows the photographers to use the formula without having to know it, since, given the selected aperture f, the ISO and shutter speed are selected automatically to get the right settings, if any. The settings will chose the lowest possible ISO and fastest possible shutter speed.

34.4 Use of the EV Formula in ISO Manual Mode

The camera ISO dial may also be set to M and the shutter speed to A. In this ISO manual mode, the ISO can be chosen by the photographer at ISO values not appearing on the ISO dial by MENU → ① → M-ISO. For example, one can chose ISO 80 which is not possible with the ISO dial since the half-increment between 64 and 200 is 100. Then the shutter speed will automatically determined using formula (1) for the chosen M-ISO. So this is the same as choosing the ISO with the camera ISO dial, except that intermediate values are allowed. (One can also choose Auto-ISO but this is equivalent to setting the camera ISO dial to A.)

34.5 Apertures of a Lens

To understand formula (1), let us first understand the magic aperture numbers 1.4, 2. 2.8, 4, 5.6, 8, 11, 16, 22 appearing on the aperture ring of lenses, already discussed in section 21.

The powers of the square root of 2 are [9, page 122]

- $\sqrt{2}^1 = \sqrt{2} = 2^{\frac{1}{2}} = 1.41421356 \simeq 1.4$ and $1.41421356 \times 1.41421356 = 1.99999999 \simeq 2$ (by $\sqrt{a} \times \sqrt{a} = a^{\frac{1}{2}} \times a^{\frac{1}{2}} = a^{\frac{1}{2}+\frac{1}{2}} = a^1 = a$ since $\sqrt{a} = a^{\frac{1}{2}}$ and $a^m \times a^n = a^{m+n}$);
- $\sqrt{2}^2 = (2^{\frac{1}{2}})^2 = 2^{\frac{1}{2}\times 2} = 2^1 = 2$ (by $((a^m)^n) = a^{mn}$);
- $\sqrt{2}^3 = 2.82842712 \simeq 2.8$;
- $\sqrt{2}^4 = \sqrt{2}^2 \times \sqrt{2}^2 = 2 \times 2 = 4$;
- $\sqrt{2}^5 = 5.65685425 \simeq 5.6$;
- $\sqrt{2}^6 = 8$;
- $\sqrt{2}^7 = 11.3137085 \simeq 11$;
- $\sqrt{2}^8 = 16$;
- $\sqrt{2}^9 = 22.627417 \simeq 22$.

So the apertures engraved on the lens are the rounded powers of $\sqrt{2}$.

34.6 Effect of the Aperture Diameter on the Quantity of Light Captured by the Sensor Per Second

Lenses have an aperture ring marked by different f-numbers, such as 1.4, 2. 2.8, 4, 5.6, 8, 11 or 16 for the SUMMILUX-M 1:1.4/50 ASPH. The lens has a mechanism, called a diaphragm, that will change the diameter d of the aperture (also called entrance pupil) when turning the aperture ring to different

f-numbers (see figure 9). This changes the size of the entrance pupil hence the quantity of light reaching the image sensor during a shot (say of 1 second).

The entrance pupil is a disk (or very close to be a disk). Therefore, the surface of the entrance pupil is πr^2 where r is the radius of the entrance pupil set by the diaphragm when turning the aperture ring, that is $\pi(\frac{d}{2})^2 = \pi\frac{d^2}{4}$ for the diameter $d = 2r$.

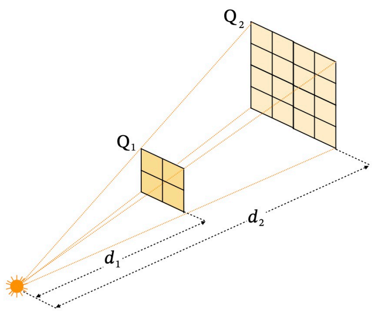
Increasing aperture by one stop, will decrease the diameter by a factor $\sqrt{2}$ so the surface of the aperture disk is now $\pi(\frac{d}{2\times\sqrt{2}})^2 = \pi\frac{d^2}{(2\times\sqrt{2})^2} = \pi\frac{d^2}{2^2\times\sqrt{2}^2} = \pi\frac{d^2}{4\times\sqrt{2}^2} = \pi\frac{d^2}{8} = \frac{1}{2}\pi\frac{d^2}{4}$. Therefore increasing the aperture by one stop divides the surface $\pi\frac{d^2}{4}$ of the aperture by 2, hence divides by 2 the quantity of light received per second.

Decreasing aperture by one stop, will increase the diameter by a factor $\sqrt{2}$ so the surface of the aperture disk is now $\pi(\frac{d\times\sqrt{2}}{2})^2 = \pi\frac{(d\times\sqrt{2})^2}{2^2} = \pi\frac{(d^2\times\sqrt{2}^2)}{4} = \pi\frac{(d^2\times 2)}{4} = 2\times\pi\frac{(d^2)}{4}$ Therefore decreasing the aperture by one stop multiplies the surface of the aperture by 2, that is, doubles the quantity of light received per second.

We remember from this section that the quantity of light received by the image sensor from a lens with entrance pupil diameter d is proportional to $\pi\frac{d^2}{4}$ that is of the form $c_a d^2$ where c_a is a constant coefficient that depends only on the lens/objective (for example the quality of the glass and coating of the lenses in the objective). Because a stop changes d by a factor $\sqrt{2}$, $c_a d^2$ is changed by a factor 2.

34.7 Effect of the Focal Length on the Quantity of Light Captured by the Sensor Per Second

The inverse square law of distance in optics is a law of physics, that is a mathematical formulation of an immutable observation of a natural phenomenon. This inverse square law of distance states that the intensity of light from a point source is inversely proportional to the square of the distance from the source. For example doubling the distance reduces the quantity of light received to one quarter. This is clearly visible when using a flash, since close subjects are much brighter than distant ones on the photos.



$$Q_1 \times (d_2)^2 = Q_2 \times (d_1)^2$$

Figure 13: Inverse square law of distance in optics

If a subject reflects the same quantity of light through lenses of different focal lengths fl_1 and fl_2 with the same aperture (that is same entrance pupil diameter d), this quantity of light will be more dispersed on a larger part of the sensor with large focal lengths and more concentrated on a smaller part of the sensor with small focal lengths, as illustrated on figure 13. Considering that the light source is the entrance pupil, we have

$$\frac{Q_1}{(fl_2)^2} = \frac{Q_2}{(fl_1)^2}$$

We remember from this section that the quantity of light received per second by the image sensor from a lens with a focal distance fl is inversely proportional to fl^2, that is of the form $c_{fl}\frac{1}{fl^2}$ where c_{fl} is a constant coefficient that depends only on the lens/objective (for example the optical clarity of the lenses in the objective).

34.8 Combined Effect of the Aperture Diameter and the Focal Length on the Quantity of Light Captured by the Sensor Per Second

We can now combine the effect of the aperture diameter d of the lens and the chosen focal lens fl on the quantity of light reaching the image sensor per second. It increases as $c_a d^2$ with the diameter d but is attenuated by a factor $c_{fl}\frac{1}{fl^2}$ because of spreading the gathered light over an area on the sensor inversely proportional to the square of the focal distance fl. The quantity of light receives per second by the sensor is of the form $c_a d^2 \times c_{fl}\frac{1}{fl^2}$ that is $c\frac{d^2}{fl^2}$ where $c = c_a \times c_{fl}$ is a constant specific to the lens.

34.9 Entrance Pupil Diameter

Lenses (of focal length fl) are always designed to have a diaphragm, such that, for each f-number f chosen on their aperture ring, the entrance pupil is opened to a diameter d

satisfying

$$f = \frac{fl}{d} \qquad \text{or} \qquad d = \frac{fl}{f} \tag{2}$$

This design ensures that any two lenses with different focal lengths fl_1 and fl_2 but same aperture f receive the same quantity of light per second (or very close ones).

To prove it, consider two lenses of respective focal lengths fl_1 and fl_1 set on the same aperture with f-number f. Then the quantity of light each lens receives per second is, by section 34.8,

$$\begin{array}{lll} & c_i \frac{(d_i)^2}{(fl_i)^2} & \text{for lens } i = 1, 2 \\ = & c_i \frac{(\frac{fl_i}{f})^2}{(fl_i)^2} & \text{by (2)} \\ = & c_i \frac{(\frac{(fl_i)^2}{f^2})}{(fl_i)^2} & \text{by } (\frac{a}{b})^n = \frac{a^n}{b^n} \\ = & c_i \frac{(fl_i)^2}{f^2 \times (fl_i)^2} & \text{by } \frac{\frac{a}{b}}{c} = \frac{a}{b} \times \frac{1}{c} = \frac{a}{b \times c} \\ = & \frac{c_i}{f^2} & \text{by simplification } \frac{a}{a} = 1 \text{ and } a \times 1 = a. \end{array}$$

This calculation proves that the two lenses receive the same quantity of light per second since in practice $c_1 \simeq c_2$ although they might be slightly different, as shown in figure 11 at the end of section 30, because of slightly different lens designs or use of different UV filters capturing more or less visible light.

34.10 Speed (Maximal Aperture) of a Lens

The "speed" of a lens is its minimal f-number F, corresponding to its maximal aperture. The "speed" is an inappropriate term, but follows from the fact that fast lenses (such as $F = 0.95$ or $F = 1.4$) allows for rapid shutter speeds, that is small exposure times, resulting in less blurring.

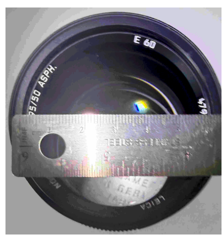
The “speed” of a Leica lens is written on that lens, for example, the SUMMILUX-M 1:1.4/50 ASPH is a lens of focal length 50 mm and maximal f-number $F = 1.4$. In general it will be written $1 : F/fl$ where F is the maximal aperture of the length ($F = 1.4$ in fact $\sqrt{2} = 1.41421356$ in our example) and fl is the focal length ($fl = 50$ mm in our example).

Applying equation (2) to this maximal aperture case, we get the maximal aperture F available which corresponds on that lens to a diameter d_m, such that

$$F = \frac{fl}{d_m} \qquad \text{or} \qquad d_m = \frac{fl}{F} \tag{3}$$

So for the SUMMILUX-M 1:1.4/50 ASPH the diameter d_m will be $\frac{50}{1.4}$ $= 35.7714$ while for the NOCTILUX-M 1:0.95/50 ASPH is will be $\frac{50}{0.95}$ $= 52.631$, as shown on the following pictures

1:1.4/50



1:0.95/50

The $1 : F/fl$ designation on Leica M lenses derives from $d_m = \frac{fl}{F}$ in equation (3). The “1:” prefix in Leica M lens designations signifies a division that is $\frac{1}{F}$ while / is multiplication by fl since $1 : F/fl = (\frac{1}{F})/fl = \frac{\frac{1}{F}}{fl} = \frac{fl}{F}$. For example

"1:2/75" on the APO-SUMMICRON-M 1:2/75 ASPH lens represents a maximum aperture diameter $d_m = \frac{\frac{1}{2}}{75} = \frac{75}{2} = 37.5$ mm[6]. Equivalently, a lens of focal lens 75 mm and maximal aperture 37.5 mm has a "speed", maximal aperture, or minimal f-number 2.

34.11 Effect of the ISO on the Quantity of Light Captured by the Sensor Per Second

The ISO film speed (more precisely film sensitivity nowadays electronic image sensor sensitivity) has been defined so that when doubling the ISO, the film sensitivity doubles, so that the quantity of light fixed on the film or image sensor per second doubles. Taking the base ISO 100, the ISO 200 doubles the quantity of light captured per second, ISO 400 quadruples it, and so on for ISO 800, 1600, 3200 and 6400 as found on the ISO dial of figure 4. So the contribution of the ISO sensitivity I to the quantity of light captures by the sensor per second is $\frac{I}{100}$. Moreover doubling the ISO doubles the quantity of light captures per second, that is, corresponds to one stop.

34.12 Effect of the Exposure Time (Shutter Speed) on the Quantity of Light Captured by the Sensor Per Second

The shutter speeds on the dial of figure 5, are $\frac{1}{4000}$, $\frac{1}{2000}$, $\frac{1}{1000}$, ..., $\frac{1}{125}$, $\frac{1}{60}$, ..., $\frac{1}{15}$, $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, 1, 2, 4, 8, being each time

[6] The solidus symbol / was introduced by the English logician Augustus de Morgan in 1845 while the colon : was introduced by the German mathematician Gottfried Leibnitz in 1659.

multiplied by 2 (or so for $\frac{1}{125} \to \frac{1}{60}$ and $\frac{1}{15} \to \frac{1}{8}$ as well as $\frac{1}{n}$ written n to ease engraving of shutter speed on the dial, but the camera software that reads the dial positions can use the exact shutter speed values).

The quantity of light captured by the image sensor is proportional to the exposure time (shutter speed) s. This is the quantity received during one second multiplied by s so is of the form $c_s s$ where c_s is the quantity of light captured during one second. It follows that changing the shutter speed by one stop down double the quantity of light captures per second, that is, corresponds to one stop.

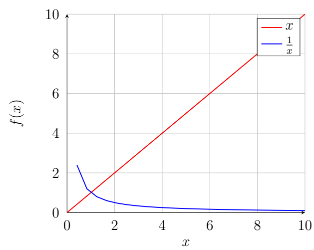
34.13 Combined Effect of the Aperture, Focal Length, and ISO on the Quantity of Light Captured by the Sensor Per Fraction of Second

We have seen that the contribution of the lens focal length fl and aperture (f-number) f is $\frac{c}{f^2}$ (thanks to the clever choice (2) of the diameter d of the entrance pupil). That of the ISO I is $\frac{I}{100}$. That of the shutter speed s is $c_s s$. Combining these effects is multiplicative, since one stop down on the ISO and one stop down on the aperture and one stop down on the speed divide the quantity of light received by the sensor by $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{8}$. It follows that the cumulated effect of the aperture, focal length, and ISO on the quantity of light captured by the sensor during s seconds is $\frac{c \times I \times c_s s}{f^2 \times 100}$ of the form $q\frac{I \times s}{100 \times f^2}$ where q is the quantity of light captured by the image sensor at ISO 100, for an f-number 1, during 1 second. The coefficient q can be measured precisely by photometry. The formula $q\frac{I \times s}{100 \times f^2}$ is close to (1) but different because we have reasoned on the quantity of light received by the film or image sensor per second whereas (1) is about the exposure value.

34.14 What is the EV (Exposure Value)

The quantity of light $q\frac{I\times s}{100\times f^2}$ captured in s seconds increases when increasing the ISO I, the exposure time s, or the aperture (which decreases the f-number) so that the photo will be brighter, if not overexposed. So higher values of $q\frac{I\times s}{100\times f^2}$ indicate more light captured.

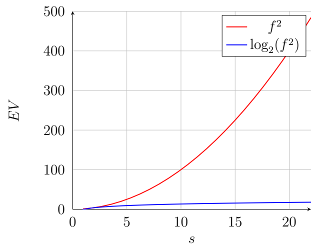
On the contrary, EVs are not about the quantity of light received but about the camera settings to cope with a given quantity of light received. So if the quantity of light received is very high, we must decrease the ISO, shutter speed, and aperture (that is increase the f-number) to capture less of the received light so that higher EVs indicate less light to capture. If the quantity of light received is very low, we must increase the ISO/aperture/speed (that is decrease the f-number) to capture more of the received light so that lower EV numbers indicate more light to capture. This corresponds to the inverse $\frac{1}{q\frac{I\times s}{100\times f^2}} = \frac{100\times f^2}{q\times I\times s}$, as shown when comparing x (in red) and $\frac{1}{x}$ (in blue),



Decreasing the ISO I or the shutter speed s or decreasing the aperture by increasing the f-number will increase the quantity $\frac{100\times f^2}{q\times I\times s}$, that is increase the quantity of light reaching the image sensor. If more light reaches the image sensor, it must capture less of the light for a correct exposure. Therefore, like the EV, higher values of $\frac{100\times f^2}{q\times I\times s}$ indicate less light to be captured while lower values of $\frac{100\times f^2}{q\times I\times s}$ indicate more light.

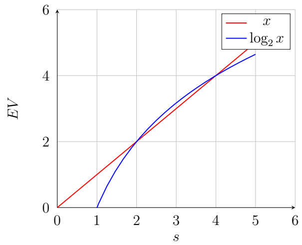
34.15 Why the logarithm?

Without the logarithm $\log_2$ [9, page 443] in formula (1), the value $\frac{100\times f^2}{q\times I\times s}$ grows rapidly. For example, with $q = 1$, ISO $I = 100$, and shutter speed $= 1$ s, the EV, which is f^2 in this case, is plotted in red as a function of f and rapidly reaches large numbers. By applying the $\log_2$ the numbers remains small (say less than 25, bright sun on snow being about 17). This is clearly shown by $\log_2 f^2$ plotted in blue. Moreover multiplications become additions (since $\log_2 a\times b = \log_2 a + \log_2 b$) which simplifies calculations based on $\sqrt{2}$ (since $\log_2(\sqrt{2}) = \frac{1}{2}$ and $\log_2(2) = 1$).



Because units can be chosen arbitrarily (such as the Kelvin (K), Celsius (°C), and Fahrenheit (°F) scales for temperature), we can arbitrarily scale by $\log_2$ in (1) that is $\log_2(q\frac{I\times s}{100\times f^2})$

$= \log_2(\frac{I\times s}{100\times f^2}) + \log_2 q$ and ignore the translation term $\log_2 q$. Moreover the logarithm is an increasing function. The larger is x, the larger is $\log_2 x$, as shown thereafter.



It follows that the requirement that higher EVs indicate less light to be captured while lower EVs indicate more light, as satisfied by $\frac{100\times f^2}{I\times s}$, is preserved by taking the logarithm $\log_2$.

This idea of logarithmic scale is frequent in physics to measure quantities with a broad range of values such as exponential growth. Another example is decibels to measure sound intensity levels relative to a reference value.

Finally, we have (hopefully) explained the meaning of the EV formula (1).

34.16 EVs and Stops

Observe that to stop up by one stop, we can either

- Increase the aperture by 1 stop, which multiplies f by $\sqrt{2}$ so that $(f \times \sqrt{2})^2 = 2 \times f^2$ so that the logarithm $\log_2$ increases the EV by 1 (since $\log_2(2x) = \log_2 x + \log_2 2 = \log_2 x + 1$), or

- Increase the ISO by 1 stop, that is double it, so that, again, the logarithm $\log_2$ increases the EV by 1, or finally

- Decrease the shutter speed by 1 stop, which multiplies s by 2, so that, once again, the logarithm $\log_2$ increases the EV by 1.

We conclude that stopping up by one stop increases the EV by 1, and similarly stopping down by one stop decreases the EV by 1.

More details on the exposure value can be found on Wikipedia, in particular its relation with the physical notion of luminance to characterize the brightness of subjects.

It just remains to cite the German camera shutter manufacturer Friedrich Deckel who is credited with developing the Exposure Value (EV) system in the 1950s.

35 Leica M-mount Lenses Designation

Back to pragmatism, the Leica M-mount lenses are designated by esoteric names, often of latin origin, depending on the maximal aperture of the lens:

- Noctilux: maximal apertures of f / 0.95 or f / 1.0 or f / 1.2 or f / 1.25;
- Summilux: maximal apertures of f / 1.4, f / 1.5 or occasionally f / 1.7;
- Summicron: maximal apertures of f / 2;
- Elmarit: maximum aperture of f / 2.8;
- Summaron: maximum aperture of f / 2.8 or f / 3.5 or f/5.6;
- Elmar: maximum aperture of f / 3.8 or f / 4 (Tri-Elmar is for a lens offering three different focal lengths);

This name can be preceded by

- APO: aprochromatic lens enforcing all colors to focus on the sensor at the same distances from a lens;

and the designation can be followed by

- ASPH: aspherical lens to reduce optical abberations.

The name is followed by 1:f/$n.n$ where f / $n.n$ is the maximum aperture (with minimal f-number)[7] and then the focal length (in millimeters mm).

Lenses are also marked E*dd*, where *dd* is a number indicating the diameter in millimeters of the filters that can be screwed in front of the lens. For example, the APO-SUMMICRON-M 1:2/90 ASPH lens is marked E55.

Other terms and abbreviations related to Leica lenses are explained on the Understanding Leica Lenses page on Leica web site.

36 Lens Mark

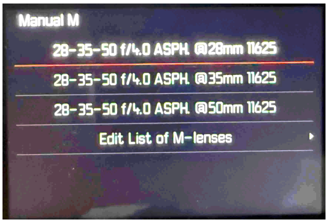
Recent Leica lenses have marks on their mount to distinguish them and allow the camera to show the appropriate frame in the viewfinder, see figure 14. The information can also be shown on the screen, used by the camera software to correct lens defects, and encoded in the digital photos. Choose the default MENU → ① → Lens Detection → Auto for marked

[7]The "1:" prefix in Leica M lens designations signifies a division. For example, "1:2/50" represents a ratio indicating the relationship between the lens's focal length and its maximum aperture diameter. So, "1:2/50" signifies a 50mm lens with a maximum aperture diameter that is half of its focal length (50mm / 2 = 25mm). This translates to a maximal aperture of f / 2. More details in section 34.6.

Figure 14: The white and black binary mark of the APO-SUMMICRON-M 1:2/75 ASPH lens on the left and the unmarked TRI-ELMAR-M 1:4/28-35-50 ASPH lens on the right.

lenses. Unmarked Leica lenses can be selected manually by MENU → ① → Lens Detection → Manual M then select the lens and On.

For the TRI-ELMAR-M 1:4/28-35-50 ASPH lens at 28mm this is



Choose MENU → ① → Lens Detection → Off for non-Leica lenses (or use some similar Leica lens instead, if any).

37 Perspective Control

Perspective control allows the position of the camera to be taken into account to correct the perspective. The perspective projection (where parallel lines converge at infinity on the photo) is replaced, for the part of the picture visible in a rectangle, by the more natural parallel projection (where parallel lines remain parallel on the photo).

screen


photo

Perspective control is selected by MENU → ③ → Perspective Control → On.

Since perspective control may not be desirable for all pictures, it can be assigned to the function button FN. Press the function button FN long enough, select Perspective Control with the down arrow of the directional pad and Center button.

38 Profile

The camera settings (called a profile) can be saved in the camera memory and reused each time the camera is turned on.

38.1 Setting a Profile

A simple profile is the following.

- ON → MENU → ⑤ → Reset Camera → Yes (and No to all other questions). Restarting the camera, choose the Language, the Time Zone, time, Daylight Saving Time, Date Format, and date.
- Press down the small function button on top-right of the camera

and choose Live View in the menu. Then, this button can be used to activate/deactivate the screen when the camera is active (otherwise half-press the shutter button).

- Assign Exposure Compensation to the thumbwheel as explained in section 33.
- Assign Focus Aid to the function button FN as explained in section 22.3.
- Limit the maximum ISO as explained in section 26.
- Optionally, show the histogram, grid, and level gauge on the screen as explained in section 29.
- Choose the format and size of digital photos by MENU → ② → File Format → JPG. The DNG format is necessary only for say 2x3 meters photos or when later cropping part of the photo. Then select JPG Settings → Max JPG Resolution → S-JPG (18 MP) is enough for most family photos.
- To save these settings, MENU → ④ → User Profile → Manage profiles (well below) → Save as profile → Users 1 → Yes. If the camera is turned OFF and then ON, these settings for User1 will be automatically used.

38.2 Using a Profile

To use profile User1, select MENU → ④ → User Profile → User1 → Active. This profile will then remain active when the camera is turned Off and On. Before each photo, it remains to use either the automatic mode in section 27 or the manual mode of section 28.

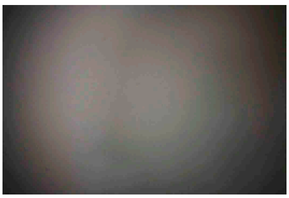
39 Lens Flare

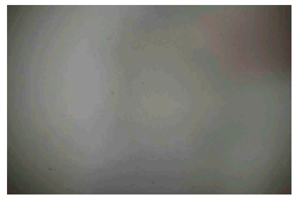
Lens flare and glare is often caused by very bright sources, giving the impression that the photo has been invaded by too much light. The problem is generally solved by slightly reorienting the camera.

Modern lenses are coated to avoid this phenomenon as much as possible by altering the way in which the lens reflects and transmits light. A lens hood can also reduce lens flare.

40 Vignetting

The subject seen in a disk by a lens must be projected to the 2:3 rectangle sensor, which may have undesirable optical effects. One of them is vignetting that is a reduction of an image's brightness on its periphery, often in the corners. Here is a first photo of a white wall taken with the Carl Zeiss DISTAGON 2.8/16 ZM lens, where vignetting is visible. By screwing a filter which is darker in the center in front of the lens (Carl Zeiss Center Filter (-1,5 EV) for the Distagon 2,8/15 ZN), the vignetting is attenuated, on the second photo, at the expense of exposure, which is reduced by the filter.



41 Bokeh

Bokeh is the effect described in section 23, where the depth of field is very small so that the subject is sharp with proper focussing whereas the foreground and background are blurry. Leica M 50mm, 75mm, and 90mm lenses are generally appreciated in portraiture for their smooth bokeh. The bokeh can be accentuated by a center spot filter to further blur the image periphery.

In this example, taken with a handheld M11-P equipped with the 2025 re-issue of the SUMMILUX-M 1:1.4/50 CLASSIC $f\,/\,1.4$ lens at 0.7 m and 1/200 with close focussing with the screen on the yellow spadix of a spathe of *Anthurium*, the foreground and background are blurry. This lens is known for its smooth creamy bokeh.

The bokeh can be accentuated using a warm center spot filter.

42 UV Filters

A UV filter (or UV (ultraviolet) pass filter) is often screwed in front of the lens to protect the glass and its coating. This may harm contrast and sharpness and be at the origin of lens flare (see section 39). An alternative is to use a hood adapted to the lens.

43 ND Filters

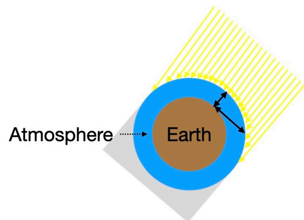
ND (neutral-density) filters can be used to reduce the quantity of light entering the lens (without changes in color rendition), for example to extend the exposure time. Variable neutral-density filters have several positions allowing to modify the quantity of light blocked.

An exposure correction using the ISO, shutter speed, and aperture is usually preferable, except for exceptional situations (such as long exposures of very bright subjects that would yield overexposed photos or to get bokeh in a portrait with a large aperture and bright lightning which cannot be compensated by a low ISO and fast speed).

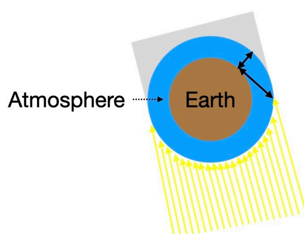
44 Rayleigh Scattering

The sunlight reaches the earth through its atmosphere. The molecules of our atmosphere modify the sun light by scattering and absorption. The thinner the layer of air traversed, the more the scattered light is concentrated in the short wavelengths (blue). On the other hand, the thicker the layer of air traversed, the more the light is concentrated in the longer wavelengths (red).

Everywhere on earth, the atmosphere is thiner when looking overhead and thicker when looking towards the horizon.



It follows that the blue sun light is less filtered by the atmosphere when looking straight up than it is when looking towards the horizon. This is called Rayleigh scattering. At sunset, the sun light is maximally filtered and so appears red.



The result is that during the day the sky is a much darker blue at the top of a photo than it is at the horizon, where it can even be white.

The eye and the brain may compensate but the camera doesn't. Moreover the dynamic range of the eye is much better than that of a camera, which means that a camera cannot capture details both in bright and darker regions of the subject. There are three possible remedies.

- use a neutral-density filter, see section 45;
- use a polarizing filter, see section 46 and Rayleigh sky model;
- extend the camera dynamic range by shooting at 36MP or 18MP (MENU → ② → DNG Resolution → S-DNG (18 MP)) or, in JPEG mode, choosing a high extended dynamic range (MENU → ② → JPG Settings → Extended Dynamic Range → High).

45 ND Graduated Filters

A graduated neutral-density (ND) filter can be used to reduce the quantity of light entering part of the lens, typically half of it, with a gradual transition from one half to the other.

It can be used to darken a bright sky so that both the sky and subject can be properly exposed.

without ND Grad filter

with ND Grad filter

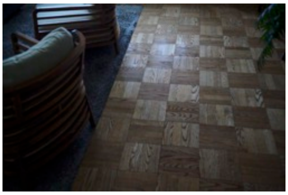
46 Circular Polarizer

A circular polarizer can be mounted in front of the lens to reduce light polarization (for the 16-18-21mm lens below).

A filter adapter may be necessary to adjust to the lens size.

By slowly turning the mobile part of the circular polarizer right or left, polarization will be attenuated (but not if the sun is in front or just behind) or even completely suppressed (if the sun is at 90 degrees).

Polarized light



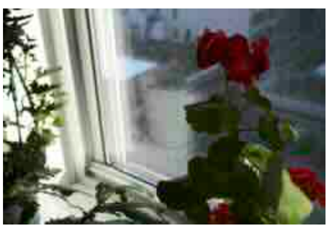
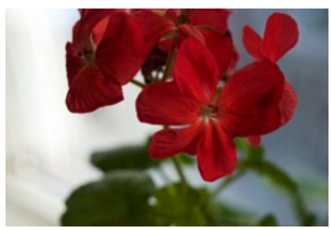
Reduction of polarization with a circular filter

47 Macro Photography

The M11 offers two possibilities for Macro photography:

- The magnifying glass Leica ELPRO E52 can be screwed in front of some lenses (in the following example a Voigtländer NORTON 40mm F 1.2)

Focussing must be with the screen (with the FN (function) button to magnify the screen)[8] The magnifying effect of the Leica ELPRO E52 is seen by comparing the following two pictures

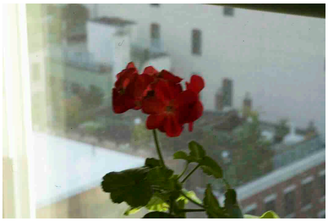



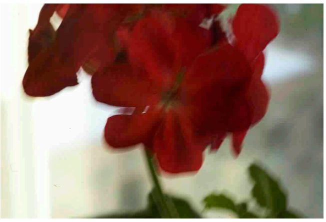
- The Leica Macro-Adapter-M, here mounted on a Leica MACRO-ELMAR-M 1:4/90 lens (which must be extended by turning and pulling the front of the lens before using) extends the

[8]If the camera settings have been changed, maintain the FN (function) button pressed down until a menu appears and select Focus Aid.

focal length of M-lenses, which has a magnifying effect, as explained in section 11.

Again focussing must be through the screen (since the viewfinder is unchanged while the focal length of the lens is increased by the adapter).





Notice that computer applications such as Darktable, GIMP, GraphicConverter, Lightroom, Luminar Neo, or Preview on MacOS and their counterparts on Linux and Windows can be used to select part of a image, but this reduces the image resolution, which is not the case with macro photography.

48 Cleaning the Electronic Sensor

If dust reaches the electronic sensor it will appear as dots on photos. The sensor can be cleaned but this is a very delicate operation better done by a specialist at a Leica store, as found at URL (universal resource locator) leica-camera.com or the Leica Camera official service page.

49 Using an Exposure Meter for Correct Exposure (*Optional*)

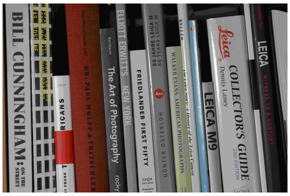
A light meter (or illuminometer) can measure the amount of light. In an exposure meter, the light meter is coupled to either a digital or analog calculator which displays the correct ISO, shutter speed, and f-number for optimum exposure. For example one or two value are chosen by the photographer and the other(s) is/are calculated.

49.1 Camera Measurement of the Reflected Light

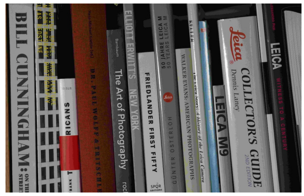
The exposure is measured by the camera (as explained in section 31) using its image sensor. This measures the light reflected by the subject. The camera has a computer to determine the correct ISO and shutter speed for a given lens at a given aperture (f-number).

These exposure measurement are used by the M11 in automatic mode (ISO, speed, or both) to choose the camera settings.

For example, we take a photo of books with an M11 on a tripod with an APO-TELYT-M 1:3.4/135 lens at $f/8$ and 1.7 m with different exposure measures. With automatic ISO and speed, the automatic choice with multi-field exposure metering is ISO 2500 and 1/320 s while spot metering (on the middle white book) yields ISO 2000 and 1/250 s.



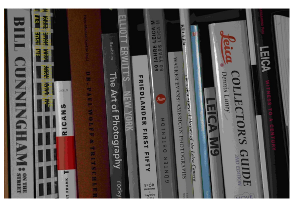
$f/8$, ISO 2500, 1/320 s
multifield



$f/8$, ISO 2000, 1/250 s
spot metering

In manual mode the M11 uses the exposure measurement to inform the photographer about the validity of his own settings. In the viewfinder, ▶ means underexposed, ● means well-exposed, and ◀ means overexposed. The information also appears on the screen, see section 32.

For example at 400 ISO, the manual choice of the correct speed is 1/60 s, as indicated by ● in the viewfinder.



$f/8$, ISO 400, 1/60 s

49.2 Exposure Meter Measurement of the Incident Light with a Handheld Exposure Meter

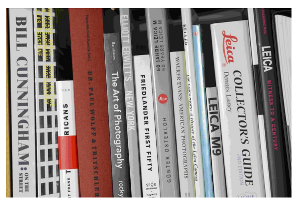
A handheld exposure meter is an alternative method to measure the amount of light.

These exposure meters can be placed just in front of the subject to measure the incident light directly received by the subject from a source (like the sun or an artificial light). Since the amount of light is measured directly from the source, the measurement is usually more precise than the amount of light from the source reflected by the subject (which may absorb some of it).

These exposure meters have a white bulb (called lumisphere) through which the received light quantity is measured. (They can also measure the reflected light, usually when used without the bulb).

49.2.1 Spherical incident light measurement

When the bulb is out/on, the incident light is diffused through the bulb, so that the measure is the mean of the light received around the bulb (that is by the subject on which the instrument is placed).



f/8, ISO 400, 1/24 s

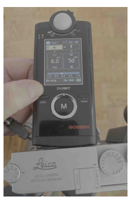
49.2.2 Flat incident light measurement

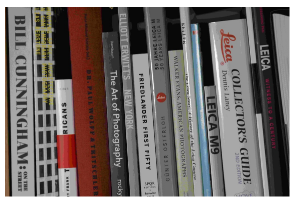
When the bulb is in/off, the measure is restricted to the light amount received exactly at the bulb point.

$f/8$, ISO 400, 1/15 s

49.3 Exposure Meter Measurement of the Reflected Light

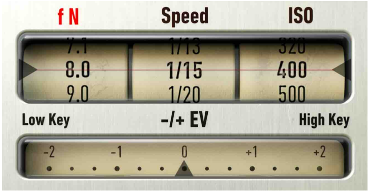
Exposure meters can also be used to measure the light reflected by the subject (so called reflected light measurement). In that case the meter is placed near the camera and pointed to the subject. The zone measured is a disk which size is determined by a fixed or variable angle degree (for example 1 to 40 degrees, 20 degrees in our example) from the meter cell.





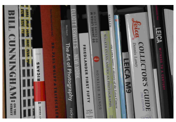
$f/8$, ISO 400, 1/50 s

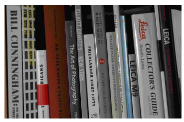
Phones have light meter applications operating through the phone lenses that are generally less precise than dedicated instruments.



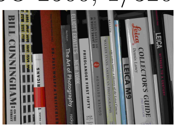
$f/8$, ISO 400, 1/15 s

Notice that the previous examples have slow speed but the image is not blurred since the camera is on a tripod. All examples look pretty the same although they are not.


ISO 2500, 1/320 s


ISO 2000, 1/250 s


ISO 400, 1/60 s

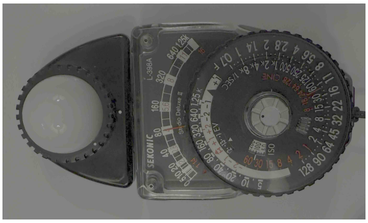

ISO 400, 1/50 s


ISO 400, 1/24 s


ISO 400, 1/15 s

Handheld exposure meters can be coupled to a flash to measure the light received when flashing.

An exposure meter may be indispensable for purely mechanical film cameras, with a rangefinder but no electronics at all, such as the Leica M-A (Typ 127). Selenium meters were purely mechanical and existed well before the electronic age, so work without battery. They use a selenium photocell to produce electricity from light and moving a needle on the meter. Most modern versions use amorphous silicon photodetector to measure the intensity of illumination on a surface.



(the measure of 80 foot-candles (about 7.43 lux) at ISO 100 is manually reported under Ĥ so that the proper exposure is 1/250 s at $f/5.6$, 1/30 s at $f/16$, etc.)

50 Additional Information on How the Rangefinder Works (*Optional*)

The Leica M camera is a rangefinder camera which has a coincidence rangefinder (also called coincidence telemeter) using the principle of triangulation. The principle has been known since antiquity. It was applied by the military to measure the distance to distant targets. Leica's credit was to miniaturize the coincidence rangefinder so that it would fit in a compact camera.

We have explained in section 22.2 how to focus using the viewfinder by moving the focus ring to have the viewfinder and rangefinder images coincide. The rangefinder is purely mechanical and optical so does work when the M11 is turned off or on the Leica M-A (Typ 127), without needing a battery. For those enjoying technique, we now explain how that works. If you hate physics, skip to the conclusion since you already know from section 22.2 how to focus with the rangefinder.

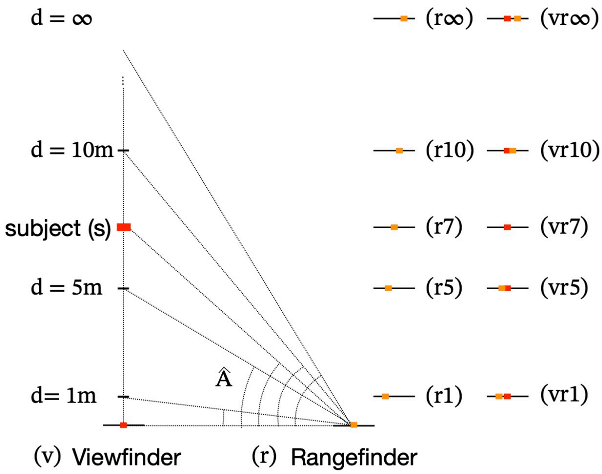


Figure 15: Principle of the rangefinder

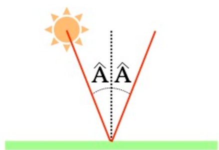
50.1 Principle of the Coincidence Rangefinder

The rangefinder idea is shown on figure 15. The subject (s) is viewed at a fixed horizontal position in the viewfinder (v) while it can be viewed at different angles $\hat{A}$ in the rangefinder (r). Each angle $\hat{A}$ corresponds to different horizontal positions in the rangefinder. These related angle and horizontal positions depend on the distance from the camera electronic sensor to the subject. For each angle $\hat{A}$, hence distance d, the subject will appear shifted left or right horizontally (that is (r1) at 1m, (r5) at 5m, (r10) at 10m, and (r∞) at infinity, as seen on figure 15. The two images exactly coincide only at the focus distance, (vr7) on figure 15. They differ at all other distances (vr1), (vr5), (vr10) and (vr∞).

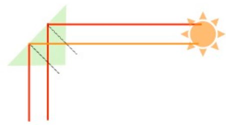
50.2 Reflective Prismes

We must now understand how it is possible to have the image of the subject (s) shift left or right depending on the distance d that is the angle Â.

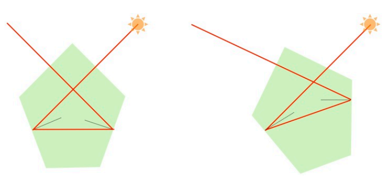
This is an optical device built out of prisms. Reflective prisms are transparent (glass) objects that use flat surfaces to redirect the light in another direction, like a mirror. The angle Â which the incident light beam makes with the perpendicular to the mirror is equal to the angle Â which the reflected light beam makes to this same perpendicular to the mirror.



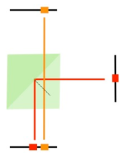
Right-angle prisms are common for redirecting a light beam by 90 degrees. Viewed from above, this is



Pentagonal prisms can redirect a light beam at different angles when rotating them.

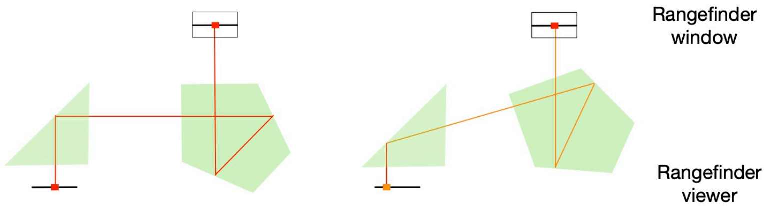


Finally a cube beam splitter is made of two prisms that form a cube. One beam of light is transmitted while the other at 90 degrees is reflected so that both beams are directed into a common path.



50.3 Realization of the Rangefinder

We can now use prisms so that at difference distances d, hence angles $\hat{A}$, the subject (s) will be seen at different horizontal positions in the rangefinder views (r1) to (r∞) in figure 15.



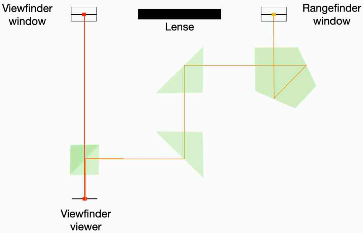
The pentagonal prism is mobile. By rotating it, we have different angles $\hat{A}$ on figure 15 each one having the image appears at a different position in the rangefinder viewer.

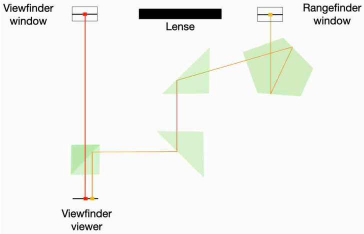
50.4 Superposition of the Viewfinder and Rangefinder Views

On early screw mount Leica cameras, the viewfinder and rangefinder small viewers were separate.

The photographer used the rangefinder viewer to focus and then the viewfinder viewer to compose. This is still the case when using an external viewfinder for short focal lengths such as 10mm, 15mm, 21mm, and 24mm, see section 15. The viewfinder and rangefinder were first merged into a single window on the M-mount Leica M3 introduced in 1954.

A cube beam splitter (plus a right-angle prism) is used to superpose the viewfinder and rangefinder images so as not to have two different viewers but a single one.





In Leica M cameras, the rangefinder window is smaller that the viewfinder window and so appears in a small rectangle centered in the middle of the viewfinder view.

50.5 Connection of the Rangefinder and the Lens

It remains to understand how the lens acts on the pentagonal prism and turn it to have the two images coincide when the lens is in focus.

The lenses have a focus ring graduated in meters (m) (and feets usually marked in red or orange). Turning this ring will move the lens elements in and out, each position of these elements corresponding to a graduation bringing the subject (s) in sharp focus at that designated distance, see section 22. These lens element positions and corresponding distances of sharp focus have been calculated once for all by the lens designer and engraved on the lens (together with the corresponding depth of field, see section 23).

Assume that through the viewfinder (v), the photographer points to the subject (s) so as to see it (smaller) in the viewfinder. The focus ring is mechanically linked to the rangefinder pentagonal prism, so that at different distances on the focus ring, the pentagonal prism will be turned by different angles $\widehat{A}$. As explained previously, the subject seen in the rangefinder window will be reflected at different angles $\widehat{A}$ by the pentagonal prism and so will appear shifted left or right horizontally (that is (r1) when the lens is focussed at 1m, (r5) at 5m, (r10) at 10m, and (r∞) when the lens is focussed at infinity, as seen on figure 15).

To mechanically link the lens focus ring to the camera, the lens has a notch and a control cam which is a mechanical piece behind the notch moving up and down. The position of the control cam depends on the focus distance (see figure 16 at 0.7m and infinity ∞ with a SUMMILUX-M 1:1.4/35 ASPH lens). At the top of the screw mount of the camera is a roll acting as a lever which is moved by the moving control cam of the lens behind the notch (see figure 16 above).

When moved by the lens, this lever will rotate the pentagonal prism changing the rangefinder angle of view $\widehat{A}$ horizontally, to produce the images (r1) to (r∞) on figure 15.

Of course to have the rangefinder work properly, there are a lot of calculations using the laws of optics and mechanics to position properly the two images visible in the

control cam position at 0.7m | control cam position at ∞ | camera lever

Figure 16: Mechanical link between the lens focus and camera

viewfinder with the focus ring movements on the lens. At the time of the first Leica M cameras this was done by hand. This is now done with computers using more sophisticated mechanical and optical modeling which explains, together with better materials, the progresses in lenses.

The mechanical coupling of the focussing ring to the pentagonal prism of the rangefinder in the camera is the same for all M-lenses of any focal lens. So it is part of the lens design to move the camera lever (on the right image of figure 16) the same way for all lenses at the same focussing distance. You can compare for example figure 16 for the SUMMILUX-M 1:1.4/35 ASPH lens with figure 17 for the much smaller SUMMARON-M 1:5.6/28 lens. The position of the control cam visible through the notch is the same at the same focus distance despite the fact that the two objectives have different sizes hence need different extensions of the lens for focussing.

control cam
position at 1m

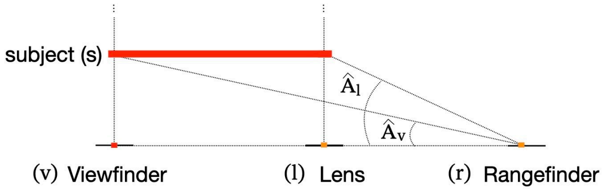
control cam
position at ∞

Figure 17: Notch and a control cam on a lens

This also means that you can use your camera to measure the distance to a (not too close) subject by focussing on it, with any lens.

50.6 Parallax Error

As already observed in section 22.2, focussing with the rangefinder at short distances (0.7 to 1 m) can be imprecise. This is due to the fact that the viewfinder is not above the lens but on its side (see figure 7). It follows that the angle measured by the rangefinder with respect to the viewfinder differs from that with respect to the lens. This introduces a parallax error, which is important enough only for short distances.



The angles $\hat{A}_v$ and $\hat{A}_l$ differ significantly at close distances so that the rangefinder measure which should be by $\hat{A}_l$ is by the smaller angle $\hat{A}_v$, hence, as shown on figure 15, too short.

In that case, one can use focus peaking on the screen (see section 22.3.2) or empirical measurement (such as about 60 cm if you can touch the subject with your arm while holding the camera).

51 Conclusion

We have explained the basic concepts in photography and elementary use of the Leica M11. We have added optional technical explanations to appreciate the ingenuity of photographers over almost two centuries!

The Leica M11 instruction manual [30] is indispensable to go beyond an elementary use of the Leica M11 and explore its numerous other possibilities.

Research on photography goes on, in particular in computer science, where is it called computational photography. The research results are published in scientific conferences such as the annual IEEE *International Conference on Computational Photography*,

Numerous books are available to explain the historical [28, 39, 41, 60], technical [**Carroll1**, 2, 6, 7, 13, 31, 33, 38, 46, 53, 56, 58], and artistic aspects [1, 49, 3, 4, 5, 8, 10, 11, 12, 15, 16, 17, 18, 19, 21, 22, 20, 24, 25, 27, 29, 14, 32, 34, 35, 36, 37, 40, 42, 43, 44, 45, 48, 50, 52, 54, 55, 57, 59] of photography, including for Leica cameras [26, 28, 39, 41, 46, 47].

Magazines, like LFI, Modern Photography and Popular Photography (PopPhoto), review contemporary photography.

Online discussion groups such as Irys can be used to share interest in photography.

Going to *photography museums* (such as the International Center of Photography (ICP), The Met, or the MOMA in New York, the Photography centre in London, the Albert Kahn museum in Boulogne-Billancourt near Paris, the Maison européenne de la photographie, the Fondation Henri Cartier-Bresson, the Centre Pompidou in Paris, or the Maison de la photographie Robert Doisneau in Gentilly near Paris), visiting *temporary expositions* (in particular in Leica stores) and *photography galleries* (like Danziger, Howard Greenberg, and Sorrel Sky in New York, Autograph and The Photographers' Gallery in London, Polka and Le Bal, or the avant-garde François Bourdoncle, in Paris), attending *photography festivals* (such as Photoville in Brooklyn, Paris Photo New York in New York, NY, USA, FORMAT in Derby, Photo Oxford in Oxford, Photo London in London, UK, and the Rencontres d'Arles, the Visa pour l'image in Perpignan, and the Paris Photo, France), as well as joining *photography collectives* (such as NYC Street Photography Collective or the London Alternative Photography Collective) can also be an inexhaustible source of endless inspiration.

Happy photo shooting! (More precisely, focussing, framing, and shooting. :)

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Introduction to Photography with the Leica M11

Patrick Cousot

A short, simple, and illustrated introduction to the fundamental concepts of photography (with a few optional technical explanations), and their practical application with a Leica M11.

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