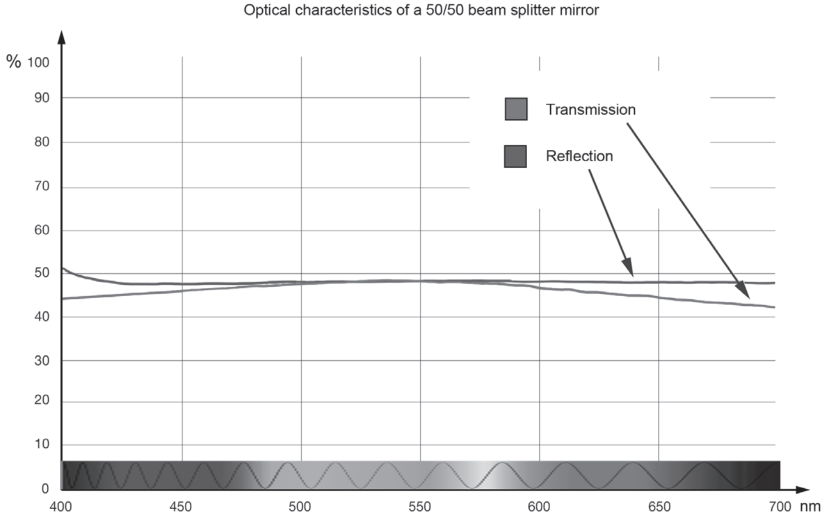


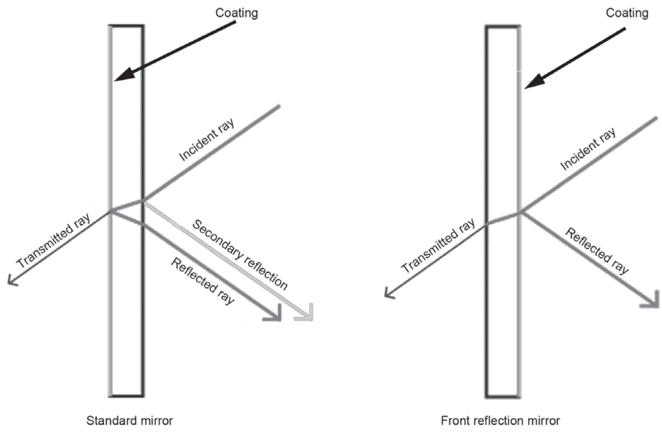
An ideal semi-transparent mirror reflects 50% and transmits 50% of the incident light. A good mirror in the real world tries to come close to this ideal.

Mirror Choice. The mirror is the most crucial component of a rig. Semi-transparent mirrors should ideally let 50% of the light pass through in a straight line and reflect the remaining 50% at 90° to the input axis; all this without introducing any geometric or color distortion and with perfect uniformity. It must of course be strong, not vibrate, and withstand shocks and scratches.

The reflective layer of the mirror is made by metal evaporation and deposition in a vacuum. To ensure that exactly 50% of the light will be transmitted, the manufacturer measures the mirror's reflectivity continuously during the process. Once the exact 50% figure is reached, the metallization stops.

3D rig requirements are contradictory and choosing the right mirror is always a compromise. For example, a thick mirror is resistant to vibration but distorts the image's geometry more; a front-coated mirror will avoid double reflections but will be much more sensitive to scratching.

Protective Glass. In the case of outdoor shooting in bad weather, exposing an expensive high-quality mirror to the elements is always unpleasant. There is a solution: Protect the front of the optical housing with a protective glass. For example, P+S TECHNIK and Schneider Optics (*www.schneideroptics.com*) offer a front-facing protective glass including a quarterwave filter (also known as a lambda/4 waveplate or incorrectly as a "depolarizer"). This added

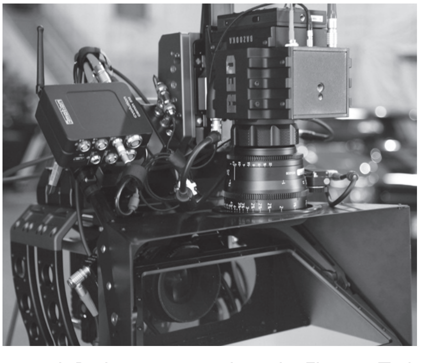


A front-coated mirror is more fragile but optically better than a standard back-coated mirror.

layer changes the angle of polarization, resulting in a severe reduction of polarization artifacts. The filter causes minimal loss of light, so the exposure stays practically the same as without the filter. And since the quarterwave filter is laminated between two layers of optical glass, it is protected from scratches and gives the protective glass better shock resistance than normal glass, similar to the performance of the safety glass used in car windows.

Above or Below? Two configurations are possible with a mirror rig: the front-facing camera is always in the direct viewing line, but the reflected camera can be installed above or below. Depending on the circumstances, one or the other configuration will be chosen: The top-mounted position is more often used for cinema shots and the bottom-mounted position for TV, but this is not an absolute rule.

© P+S Technik



© Element Technica

Setup with camera above: on the left, P+S Technik rig with Red cameras; on the right, Element Technica Atom rig with Red Epic cameras; the mirror is removed so we can see the front-facing camera.

Setup with camera under: on the left, shoulder-mounted rig; on the right, Steadicam mounted rig.

Advantages of camera on top:

- possibility of using very bulky cameras;
- better access to the various settings;
- more backward center of gravity for easier panning;
- better freedom of movement for low-angle shots;
- possibility of positioning very close to the ground.

Advantages of camera below:

- less view blocking for the audience located behind the camera;
- lower center of gravity;
- easier handling when mounted on the shoulder or on a Steadicam;
- better protection of the reflecting mirror from dust and scratches;
- fewer parasitic reflections in the mirror.

Camera Synchronization

Cameras synchronization is of utmost importance for depth quality. For example, a car traveling at 100 km/hr travels 3 cm in a millisecond, and 3 cm seen at a distance of 10 meters with an average focal length accounts for about 0.3% of the field of vision. If the left camera films the car a millisecond before the right one, the motion parallax created by the sync error can be five or six pixels, which will be interpreted as a depth difference of several meters! Without synchronization, we can always realign the two recorded streams with the closest image. Therefore, the maximum timing error will be half an image, or 21 milliseconds if shooting at 24 frames per second. Those images will be acceptable for very slow movements only and any fast action will cause disruptive effects: incorrect depth, distortion, duplicate objects, etc.

Synchronization with Genlock

Professional cameras have a genlock input accepting a synchronization signal from a reference source. The most precise genlock signal is called tri-level sync, because it synchronizes all connected devices on the level of the image, line, and even the pixel in the line.

© Aja

An HD sync generator suitable for 3D: The AJA Gen 10 is fitted with 6 BNC outputs.

A tri-level sync generator is neither expensive nor bulky (see photo below). It usually has multiple outputs, so we can use it to synchronize two or more cameras, a SIP, a recorder, etc. A word of caution about connectivity: Not all cameras use the BNC connector and a much smaller DIN 1.2/2.3 adapter will sometimes be required.

© B. Michel

The BNC to Din 1.0/2.3 adapter required by many cameras (RED, etc.).

The sync generator will be configured for the chosen frame rate; the usual values are 23.98, 24.00, 25.00, or 29.97 frames per second, more rarely 48, 59.98 or 60. The frame rate in each camera's configuration menu will have to be adjusted to the same value as the "genlock" signal. If the frequencies do not match, the camera will ignore the "genlock" and will not be synchronized! In general, a padlock icon appears in the viewfinder to confirm that sync is active.

Synchronization without Genlock

Shooting without "genlock" is still possible, thanks to one important detail: The cameras are shooting all the time, as soon as they are energized. When you press the Rec button, they begin to store images from the first scan following the record command, but the instant when the electronics was started is also when the camera's internal clock started. So to synchronize two cameras all you need to do is to start them at exactly the same time.

If your cameras are Sonys or Canons, you can use a LANC Shepherd controller (*www.berezin.com/3d/lanc/index.html*). The LANC is not a "genlock," it is simply a way to start the two cameras at the exact same moment and then check the gap between them afterwards. Depending on the match quality of the cameras, you can usually hope to keep acceptable synchronization for about 15 to 20 minutes. To resynchronize the cameras after a take, they must be shut down and the procedure has to be restarted.

© Berezin Stereo

The LANC Shepherd electronic sync generator from Berezin Stereo

Still and video cameras from Canon usually have a LANC. On Sony cameras, the LANC connector is referred to as "ACC" or "Control-L." The LANC uses a communication protocol specific to Sony that allows a remote controller to synchronize not only the start of two cameras, but also to control focus, shutter, and zoom. The LANC Shepherd display shows the offset between two cameras in milliseconds. If the offset is too large, the box is used to stop and restart the camera. In general, a first switch generates a relatively large timing offset, but once the electronics reaches its working temperature – which takes only a few seconds – the following restarts offer a sync that is good enough for 3D shooting (less than a millisecond).

What is a good enough synchronization? In photography, it is commonly accepted that the timing must be accurate to one tenth of the exposure time (0.1 milliseconds for a shot at 1/1,000). In video, an offset of 0.02 ms will produce only one hundredth of the statistical offset obtained without using LANC at 25 frames per second. Fortunately, the LANC Shepherd regularly achieves 0.01 ms.

Non-Synchronized Cameras

What can be done if the cameras are incompatible with the LANC protocol?

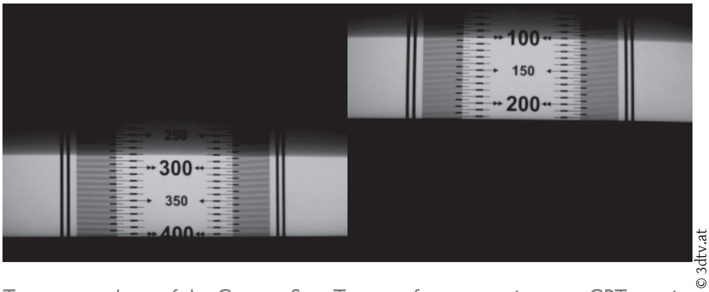
If the cameras are not synchronized at all, the best you can do is to start the two cameras simultaneously. The traditional method is to couple the power sources and synchronize them. We use the external power connectors to power the cameras from a single source, battery or mains, and then we power them on with a unique switch common to both cameras. In this way, we can hope that their internal clocks will be synchronized. Tests have shown a success rate of 75% on Panasonic HVX200 cameras and on some JVCs. An empirical way to verify the sync is to film a rubber ball bouncing quickly vertically. It is quite easy to compare the left and right images visually and then to calculate the offset in milliseconds by interpolating the distance traveled by the ball between two successive images and comparing the left-right offset. A more accurate, but more cumbersome, method is described below (see later in this chapter, "Synchronization Measurement").

The 3D Slate application for iPad or iPhone. This application displays in a fast sequence all information about the actual shot, i.e., interaxial distance, convergence, foreground and background distances, and various notes, to ensure that it is transmitted to postproduction.

Even with internal clocks synchronized, care must be taken to trigger the shooting at the same time on both cameras. Again, the simplest empirical solution is to use an infrared remote control. Most cameras come with a remote control that should trigger the two cameras at the same time. Synchronizing the two streams with the image manually will of course be required in postproduction. If the cameras are recording the sound, a clap at the beginning of the shot will serve as a benchmark. Several low-end editing software packages (e.g., Magix Video Deluxe) incorporate such audio sync functions in their 3D-enabled versions. In all cases, using a visual and audio clap is a way to check the sync, even when using a "genlock." Various clap applications for the iPad and other tablets are available on the web at very low prices. The time display in this type of application may be used to synchronize the clips with accuracy to the image and even to assess the offset between the left and right recorded streams. Those applications cost typically less than a simple mechanical clap.

Synchronization Measurement

If you have any doubts about the sync's reliability, there's nothing better than to check its accuracy. To do this, you will need a PC, testing software, and a good old CRT monitor (CRT). As scanning in a CRT monitor is progressive, it can serve as a yardstick for measuring time lags, even very short ones. Camera Sync Tester software is freely available on Peter Wimmer's website (*www.3dtv.at*); Peter Wimmer is the author of Stereoscopic Player. Once the characteristics of the monitor are known, the software displays a numbered vertical scale. Whatever the method you used to sync the cameras, after taking a synchronized view of the screen, simply note the difference between the last displayed line numbers and multiply them by the time needed to display a line on the monitor.



© 3dtv.at

Two screen shots of the Camera Sync Tester software running on a CRT monitor recorded by two slightly out-of-sync cameras: The last displayed line is #403 on the left and #223 on the right. With 31 microseconds needed to display one line, we determine a sync error of 5.7 ms.