PHANTOM®

2020
CASE STUDY

Shoot High-Speed Like a Hollywood Pro

A cinematographer and YouTube content creator offers helpful tips on how to deliver media-quality images in scientific and industrial applications.

From auto racing to rocket engines, no subject is too fast for Matt Mikka. The Hollywood-turned-YouTube cinematographer uses high-speed Phantom cameras to provide a rare glimpse into a world people normally can't see.

For over four years, Mikka has uploaded hundreds of slow-motion videos to his YouTube channel, *Warped Perception*, which has attracted over 650,000 subscribers and racked up over 115 million views. Most of Mikka's subjects are everyday occurrences—dogs lapping up water and cars running over potholes. Other videos have more direct applications in science and engineering. For example, Mikka has a series of videos that feature a see-through Briggs and Stratton engine, providing a close-up look at the combustion process.

But Mikka's popularity is not just what he records—but how he records it. With their exceptional detail and production-level quality, many of Mikka's videos scream Hollywood, not YouTube. Fortunately, any high-speed camera operator can achieve these same results with attention to a few important details.

Recently, Mikka sat down with Vision Research to share some of his high-speed insights, which he has learned and refined over the course of his professional career as a cinematographer. Implementing his strategies for lighting, shutter speed adjustments and lens selection can drastically improve the quality of your own high-speed images. This leads to sleeker, brighter and more detailed videos in various science, engineering and industrial applications.

VISION RESEARCH

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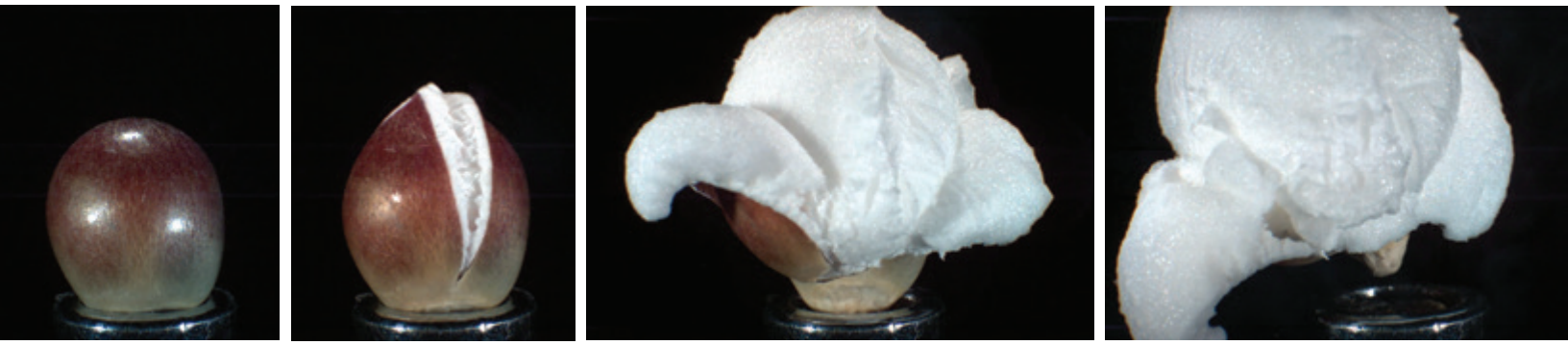
LET THERE BE LIGHT

When it comes to high-speed imaging, it's not enough to simply point your camera lens at your subject and hit record. You must pay special attention to several key factors, one of the most important is lighting. For his YouTube videos, Mikka typically uses one- and two-point lighting techniques. Although filming outdoors in the natural sunlight works well and is the most convenient, this scenario is not always possible. Laboratory experiments, automotive crash tests and production environments are three examples of high-speed imaging applications that usually occur indoors.

"One- and two-point lighting setups are my go-to whenever I can't film outside," Mikka says. "You can also use three- or four-point lighting techniques, but these tend to be more complicated and most of the time, unnecessary for what needs to be captured."



In this popular video, Mikka recorded a kernel of popcorn using a Phantom v2512 UltraHigh-Speed camera at 15,000 fps. This video was flat-lit, using only one LED pointed directly at the subject.

LED lights are a go-to light source for high-speed imaging due to their small size and high output, but not all LEDs are created equal. In general, LEDs are DC-powered, eliminating the light flicker that gets picked up in high-speed playback. However, it's important to note that lights with dimming capabilities usually introduce flicker at frame rates over 1,000 fps and at low exposure times. It is recommended to test the light at the required frame rates before committing to it, ensuring there is no flicker during playback.

In a one-point lighting setup, Mikka points an LED light in the same direction as his high-speed camera lens, providing direct illumination from the front and casting shadows directly behind the subject. He also frequently uses two-point lighting setups, which are a simple, yet powerful way to add dimensionality to the subject. In this setup, one LED provides direct illumination from the front, while a second LED casts light on the subject from an angle—roughly 30 degrees. "This technique comes in handy when you need to accentuate the edges of your subject," Mikka says. "It's also useful if you're filming moving or rotating components."

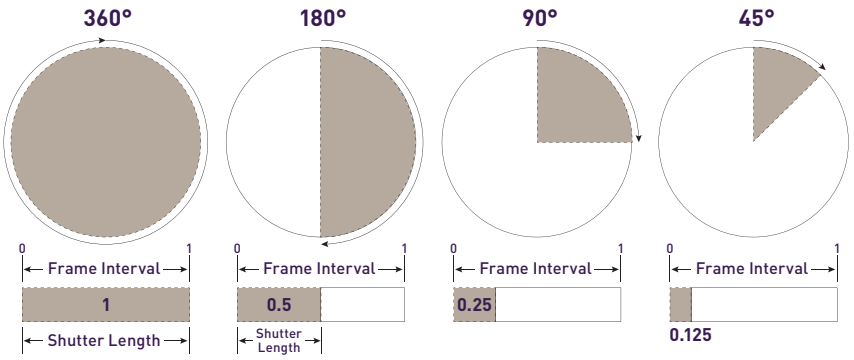
If an application involves shiny or metallic parts, Mikka suggests watching the lighting angle to ensure the subject isn't reflecting light back into the lens. "To prevent this from happening, you can simply move your light source in relation to the camera," he says.

THE FRAME RATE AND SHUTTER SPEED RELATIONSHIP

According to Mikka, the higher the frame rate, the more important lighting becomes. "Once you hit around 10,000 frames per second, you may need to use more or different lights," Mikka says. As a general rule of thumb, doubling the camera's frame rate requires twice the amount of light to successfully image a fast-moving subject.

Increasing the camera's frame rate also affects another variable—shutter speed. Also referred to as exposure time, shutter speed is a way users can control the amount of light hitting the sensor. In the world of cinematography, this variable is often represented as an angle, which describes the shutter speed in relation to the frame rate out of 360 degrees. "As the shutter angle goes down, the exposure time becomes shorter and reduces motion blur," Mikka explains. On the other hand, the larger the angle, the slower the shutter speed and the higher the amount of motion blur.

"The faster the subject, the higher your shutter speed should be," Mikka says. "But keep in mind, faster shutter speeds expose the sensor to less light, which means you'll need more or stronger lights. This process can be a lot of trial and error."



A 180-degree shutter angle is common for many cinematic applications. At 1,000 fps, the shutter speed equates to an exposure time of 500 µs, or 1/2000th of a second for each frame.

According to Mikka, this video exemplifies how one aspect of the shot—the water, which appears clear and crisp—was recorded using the right shutter speed. On the other hand, the balloon itself, which is moving faster than the water, appears blurry. "If I wanted the balloon to appear clearer, I'd have to increase the shutter speed," Mikka says.

ZOOMING IN

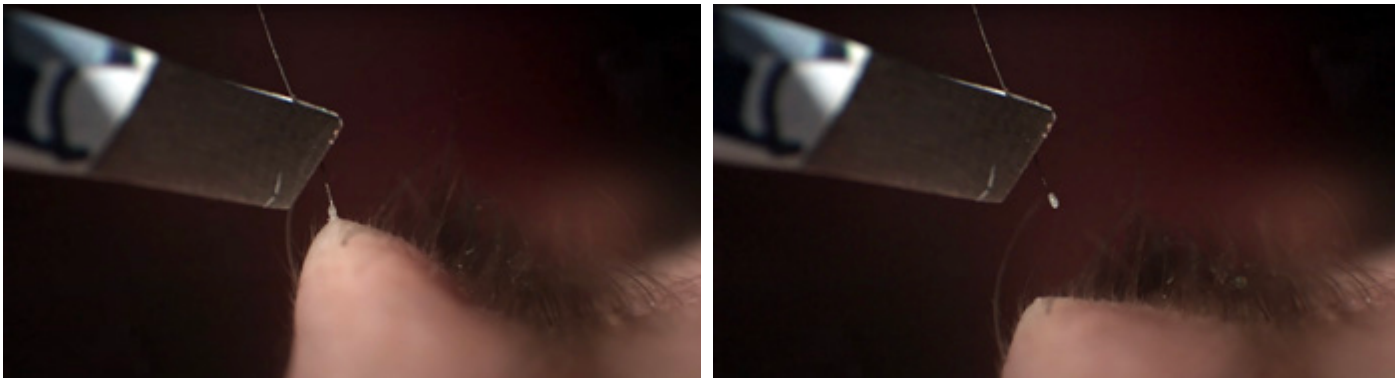
For Mikka, zoom lenses can be a versatile lens option, especially if you are not sure how far away your subject will be or if you have no control over this distance. He also suggests leaving room in the shot if you know something is going to break or fly apart. "I generally like to stay tight with my shots, but if I know something is going to explode, then I try to leave extra space to capture the action."

This video demonstrates the importance of leaving room in your shot if you know the subject is going to break apart or explode.

CHOOSING THE RIGHT LENS

When it comes to lenses, a common mistake Mikka sees is when users select a lens with too small of an aperture. An aperture is the opening through which light travels and is measured in f-stops. "Lower f-stops correspond to larger apertures," Mikka explains. "And higher f-stops correspond to smaller apertures. In this case, less light can enter the sensor, leading to darker images and placing greater importance on your lighting technique."

In Mikka's experience, many users automatically reach for lenses with higher f-stops. This is because a higher f-stop, despite the limited amount of light, provides a larger depth of field (DOF). This enables users to bring more aspects of their shot into focus. But according to Mikka, focusing on everything isn't always necessary, especially if you're only trying to capture a small detail or component. "So, by using a lens with a small aperture, you're just compromising on your lighting," he says.



In this video, Mikka recorded the eyebrow-tweezing process using a Phantom v2512 UltraHigh-Speed camera, coupled with a macro lens, which can handle extremely close focusing distances.

To address these issues, Mikka suggests first asking yourself how much DOF you need for the subject, as well as how large the subject is. In general, for most high-speed applications, he suggests using a lens with the largest possible aperture, otherwise known as a "fast" lens. A large aperture brings in more light and allows for faster shutter speeds.

THE PHANTOM Flex4K

For his *Warped Perception* videos, Mikka uses an arsenal of Phantom high-speed cameras, including a Phantom v2512 and Phantom v2640—both of which are part of Vision Research's UltraHigh-Speed camera line. But Mikka's favorite and most heavily used model is his Phantom Flex4K, a high-speed professional cinematic camera. "For me, this one is the all-around winner," Mikka says. "It utilizes the same workflow as the other Phantom cameras, but it produces crisp, detailed videos with cinematic quality."

In terms of its features, the Flex4K produces highly detailed 4K images at 1,000 frames per second. Designed for professional cinematography, this camera hits a homerun when it comes to lighting possibilities, shutter speed and lens versatility—all of which are important for cinematographers like Mikka:

- **Sensitivity.** The Flex4K's super 35-millimeter CMOS sensor has an exposure index range of 250 to 1250 ISO with exceptionally low noise and a dynamic range of 12 stops.
- **Shutter speed.** Able to be set in degrees or microseconds, the Flex4K allows an exposure time of 5 microseconds to 1/frame rate.
- **Lensing.** For added versatility, the Flex4K features several lens mount options, including PL, Canon EF and Nikon F—encouraging shot variety.

The Phantom Flex4K high-speed camera.

EXPERIENCE VERSUS MATHEMATICS

Although high-speed cameras require practice and experience, there are tools and formulas available for help. "A lot of high-speed imaging is trial and error," Mikka says, "But a lot of it is also math."

For example, the following formula can help you calculate motion blur in terms of your exposure time if you know the speed of your subject. For example:

- The velocity of your subject (V) = 8,750 meters per second
- Frame rate (f) = 288,800 frames per second

The maximum exposure time (E) is 1/f or 1/288,800, which equals 3.46 microseconds. Next, to calculate motion blur:

- Motion Blur = V×E
- (8,750 meters per second) × (0.00000346 seconds) = 0.03 meters, or 30 millimeters

This means that the object will have a 30-millimeter motion blur. You can then use these values to calculate blur in terms of pixels, which will vary based on pixel size and focal length. If this pixel number is greater than 5, then you may need to select a shorter exposure time. An exposure time calculator is available at www.phantomhighspeed.com to help with planning the shoot.

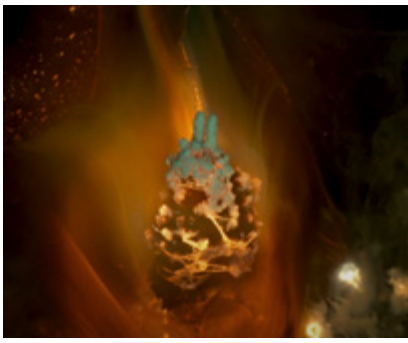
READY, SET, ACTION!

Mikka's tips on lighting, shutter speed and lens selection are simple, yet effective ways for high-speed camera users to take their images to the next level. Whether you are a researcher, engineer or budding Hollywood director, these strategies can help you create bright, high-quality videos that provide a unique look at phenomena that occur too fast for the naked eye to see.

Subscribe and watch more high-speed videos on Matt Mikka's Warped Perception YouTube channel at: **www.youtube.com/WarpedPerception.**







To learn more about Vision Research high-speed expertise and equipment, visit ***www.phantomhighspeed.com***

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