



Illuminating Weld Dynamics With Pulse Lasers

A manufacturer of precision sensing devices analyzes the performance of its welding processes by coupling high-speed imaging with an advanced laser-based lighting technique.

High-speed cameras are invaluable tools for analyzing manufacturing processes — including welding — providing highly detailed images of the way a weld forms and cools. The best imaging results, however, require a special lighting and filtering setup.

Because welding is too bright for standard imaging and lighting techniques, it needs a special laser-based lighting and filtering setup to mitigate the intense emission from the weld site. Compared to conventional lighting like LEDs, laser-based lighting enables high-speed cameras to capture highly detailed images of the weld dynamics for further analysis.

For example, Sigma-Netics — a manufacturer of pressure switches, pressure transducers, metal bellows and bellows assemblies — called on Vision Research (AMETEK) to record tungsten inert gas (TIG) welding processes in order to investigate the welding interface of a bellows and its flange. Sigma-Netics manufactures precision metal bellows assemblies for precision sensing applications, and commonly uses a variety of soldering, brazing and welding techniques.

Using Phantom high-speed cameras, a pulse laser lighting setup and a band-pass filter, Sigma-Netics successfully observed and characterized the melt-pool dynamics of its TIG welding process, enabling engineers to confirm the dimensional integrity of the bellows assembly.

CONVENTIONAL WELD IMAGING

Because welding events are so bright, they may require dynamic ranges of over 140 decibels (dB) for proper image capture. Unfortunately, some of the best scientific high-speed CMOS sensors only feature a dynamic range from 50 to 70 dB, resulting in images that are oversaturated or devoid of shadow detail. To resolve this challenge, conventional setups for welding applications often include a neutral density (ND) filter.

This filter prevents pixel saturation by evenly attenuating the photons emitted from the weld site, lowering the incoming signal below the upper limit of the sensor's dynamic range. However, adding the ND filter often generates images that feature a single, bright hot spot on the weld event, while the surrounding background is dark and noisy.

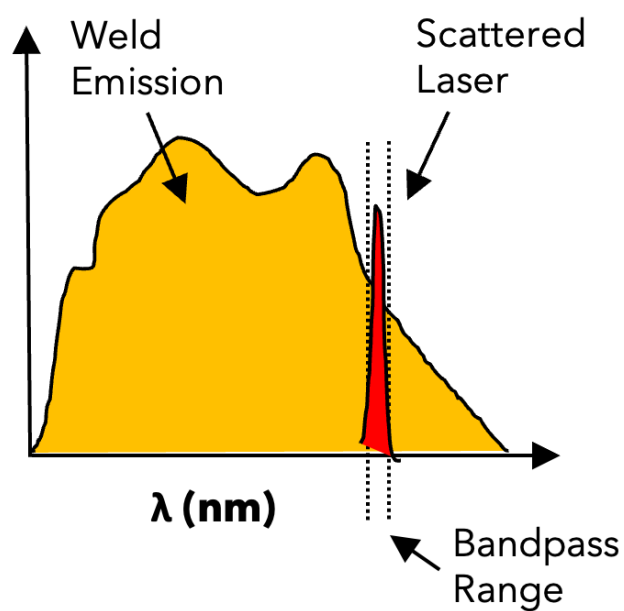
While adding a series of strong LEDs for illumination can brighten the shadowed areas, emission from the melt-pool saturates the image too much to yield any insights into the melt-pool dynamics.

PULSE LASER ILLUMINATION

Instead of using LED lighting and an ND filter, high-speed experts will opt for using a pulse laser and bandpass filter – an alternative method that illuminates shadows without oversaturating the weld site. It may seem counterintuitive to illuminate an extremely bright event with a powerful laser to avoid oversaturating images, but the cornerstone of this method is the combination of the laser and filter. By specifying a laser and bandpass filter that have a matching wavelength range, the laser delivers precise illumination while the filter only permits laser light scattering from the weld site that is necessary to capture a quality video.

Without the implementation of a pulsed laser, the sensor would produce saturated images. On the other hand, solely using the laser would brighten the subject, but the weld emission is still too powerful for the sensor. Adding a bandpass filter eliminates the vast majority of photons emitted from the weld event while permitting the scattered laser-photons through to the CMOS sensor. Note that the light emitted by the weld event that falls within the bandpass filter range is negligible compared to the laser light and is therefore undetectable.

Synchronizing the high-speed camera to the laser pulses generates a monochrome video that enables clear insights into the welding event.



The bandpass filter permits a narrow range of wavelengths, allowing scattered photons from the laser and some from the weld emission to reach the CMOS sensor. The remaining light is excluded.

SYNCHRONIZING THE CAMERA AND LASER

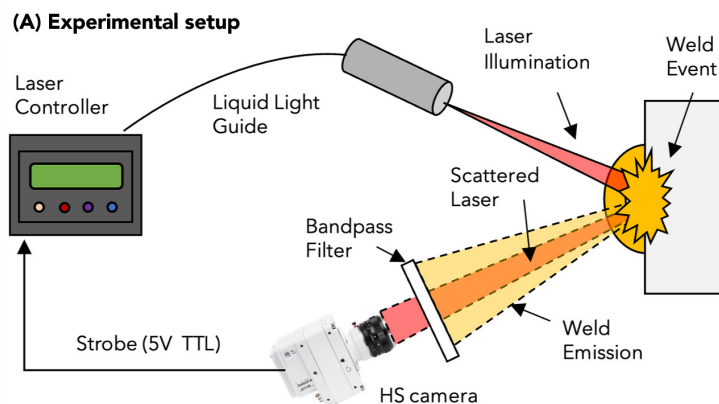
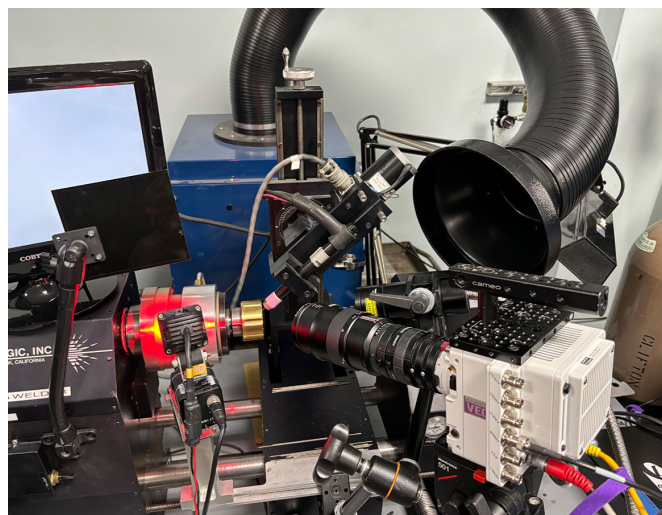
For the Sigma-Netics experiment, high-speed experts used a 1-kW, 808-nm Firebird pulse laser from Oxford Laser. The laser was equipped with a liquid light guide and a diffusing optic that enabled spot size adjustment. To illuminate the quarter-inch welding event area, the spot was adjusted to be roughly one inch in diameter.

The high-speed Phantom VEO 1310 camera included a 100-millimeter Makro lens, extension tubes and 810-nm band pass filter (+/- 5 nm). Synchronizing the camera to the laser via a 5-volt transistor-transistor logic (TTL) signal ensured that an image was only captured during each laser pulse.

The falling and rising edges of the camera's 5-volt TTL output signal corresponded to the beginning and end of when a frame is exposed and subsequently captured. By setting the laser controller to "falling," the laser fired a pulse every time the camera began image exposure. The pulse width, which is how long each pulse lasts, matched the camera's 1-microsecond exposure time. Recording at 2,000 frames per second (fps) and 1280 x 960 resolution, the team gathered high-quality video for further analysis.



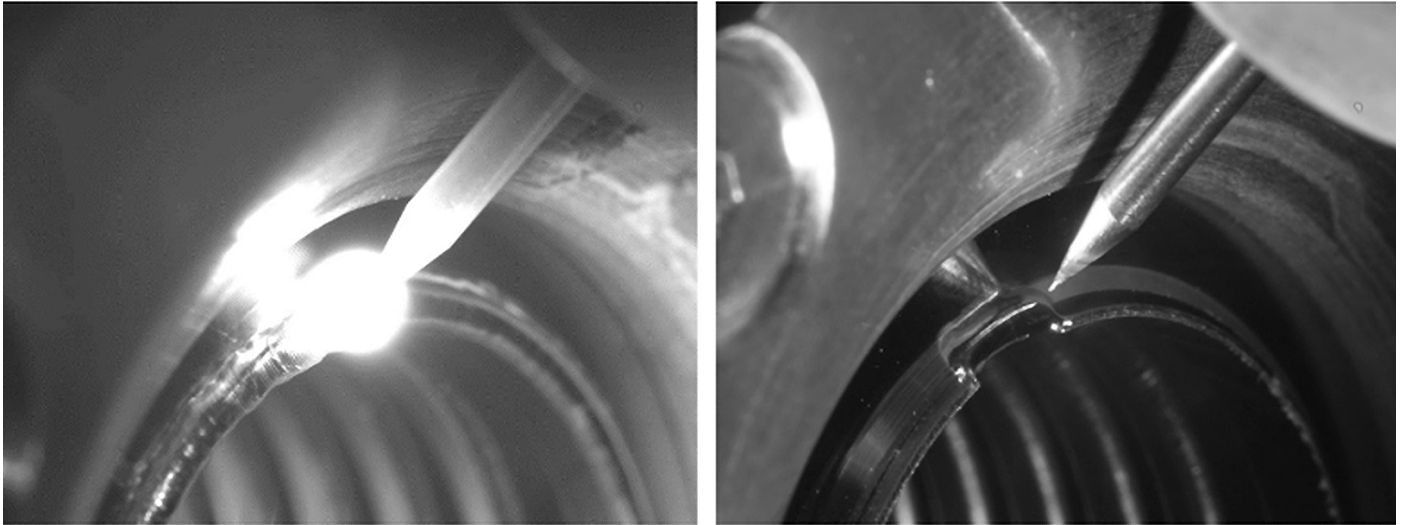
VEO 1310.



The pulse laser and bandpass filter allow the VEO 1310 to capture high-quality video of the TIG welding process.

BRIGHT OBSERVATIONS

Thanks to the advanced pulse laser-lighting technique, band-pass filtering and Phantom camera, Sigma-Netics successfully captured the melt-pool while eliminating oversaturation from the welding emission. The captured footage provided verification that the melt from the TIG welding process wicks into the interface between the flange and the bellows. This information validated that Sigma-Netics' TIG welding process indeed creates an assembly that maintains dimensional integrity.



The bandpass filter eliminates the bright pixel saturation and provides a clear view of the melt pool.

Pulse laser lighting setups are also applicable to other studies into ultra-emissive events like ballistics or combustion. Keep in mind that lasers used in this technique can be very powerful, like the Class IV used for this study. Lasers of this magnitude are very dangerous to operate and require proper protection equipment and facilities during operation. Find out more technical details on this application in our [technical note](#). To learn more about pulse-laser lighting, check out the [blog post](#) or watch the [video](#).

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