Effective and versatile laser illumination

Introduction

High-power laser illumination has several unique features that enable critical measurements in various industrial and scientific applications. It is an ideal light source for high-speed cameras of all speeds as well as for machine vision cameras. Laser lighting enables the visualization of applications that might be impossible to visualize with more conventional light sources like LED or halogene lamps.

Diode laser illumination has certain characteristics that are highly beneficial in the visualization of various applications. Firstly, the light is highly monochromatic which enables the elimination of thermal radiation or chromatic aberrations. Secondly, laser illumination can generate high power pulses of short duration which enables the precise visualization of small and fast objects at high resolution and without motion blur. This elimination of motion blur is possible regardless of the camera shutter since the exposure is determined by the laser pulse duration. Furthermore, laser light can be fiber-coupled which can be highly useful e.g. in limited space. These characteristics of diode lasers make them ideal light sources in numerous demanding processes such as welding, combustion, ballistics, explosions or flow and shockwave studies.

Diode lasers can be controlled very precisely. This enables the generation of short pulses which are essential in eliminating motion blur. Motion blur occurs when the object is moving too fast for the camera shutter. The combination of short pulses with high output -power makes diode lasers ideal light sources for ballistics, flows and shockwave studies.

In the following we will have a closer look at **different applications**.

See through heat

When imaging bright processes like welding, combustion or explosions the camera sensor can easily saturate completely due to large amount of process light. In order to make details visible there are different ways to eliminate process light.

The first element in reducing process light is proper ***filtering***. One can use e.g. neutral density or narrow band filters. Neutral density filters reduce brightness evenly over broad spectral band. Therefore they make the images darker but don't affect the relative brightness of objects in the images. So the brightest object in the image will remain brightest. As an example, in arc welding one could reduce the brightness of the arc by applying neutral density filters but at the same time the rest of the image would become very dark. Narrow band filters, on the other hand, allow only a very narrow range of wavelengths to pass to the camera. If the filter is selected properly, a large portion of process light can be eliminated. By actively illuminating the object with narrow band light matching with the transmission band of the filter, it is possible to both illuminate the object in a controlled manner and at the same time eliminate thermal light effectively.

Another important element in the imaging of bright processes is the camera ***exposure time***. The longer the camera integrates light, the brighter the image. Therefore short camera exposure time is highly preferable in the imaging of bright objects. Since laser illumination can generate sufficient power to illuminate the object properly already with a very short pulse, laser illumination enables the use of short camera exposure time. In addition, due to the high brightness of laser illumination, the light can be efficiently focused to the desirable area, thus further emphasizing the advantages of laser illumination as compared to conventional light sources.

With active pulsed laser illumination, short camera exposure time and optimized narrow band filtering one can realize the best possible image quality for light emitting and bright processes. This technique works very well for high-speed cameras as well as for machine vision cameras.

The image below shows the effects of no filtering (left), filtering without laser illumination (middle) and filtering with laser illumination (right):

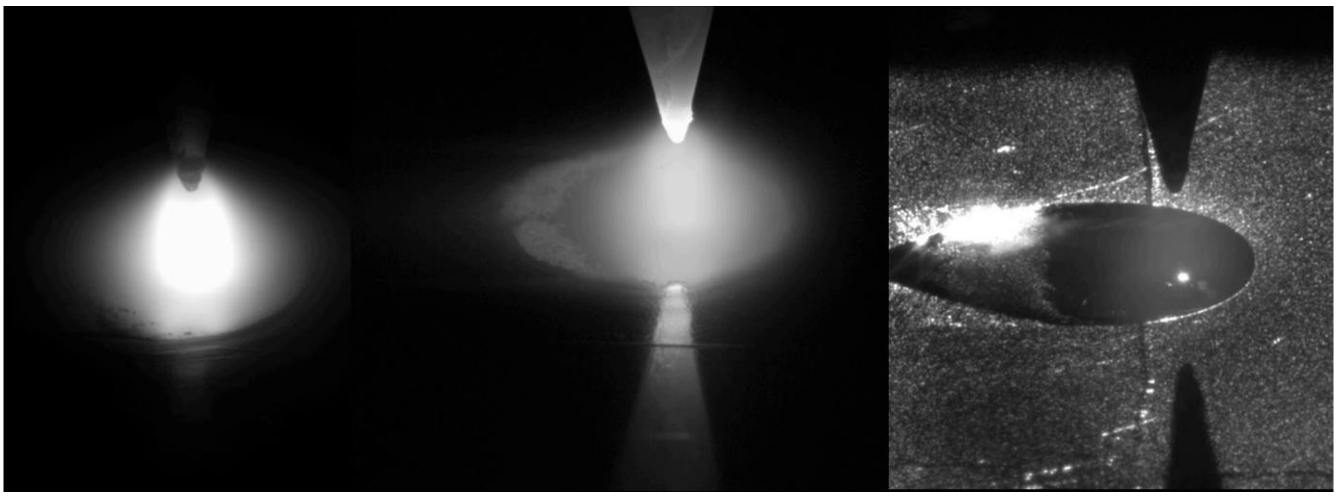

Figure 1: TIG welding process imaged at 1.000 fps (images courtesy of Nobby Tech, Japan)

Freeze the motion

Many industrial and scientific processes contain small and fast moving objects. As the velocity of the object increases, the amount of motion blur will increase for fixed camera exposure time and optical magnification. Motion blur reduces the amount of information in the images. In order to address this challenge, many cameras can generate very short exposure times in the micro second level. However, the shorter the exposure time, the higher the demands for illumination. As an example, if the camera exposure time is 1 µs, the illumination sufficient for illuminating the object properly has to be generated during that exposure time.

In some cases even the micro second level exposure time may be inadequate. Examples of such processes include shockwaves, small-scale explosions or microscopic imaging of fast moving webs. This deficiency can be solved by using a pulsed light source that can generate pulses that are much shorter than the camera exposure time and still contain sufficient amount of light to illuminate the object properly. Diode laser illumination is ideal for this purpose as the pulses can be easily created by digital inputs enabling very short pulses in nano second level. In order to achieve high brightness with such short pulses, the output power of the laser has to be high.

The image below shows the difference between a CW (continuous wave) light source (left) and laser illumination with very short pulses (right). In both images the camera exposure time is short. Laser illumination reduces motion blur and provides more information as compared to the CW light source.

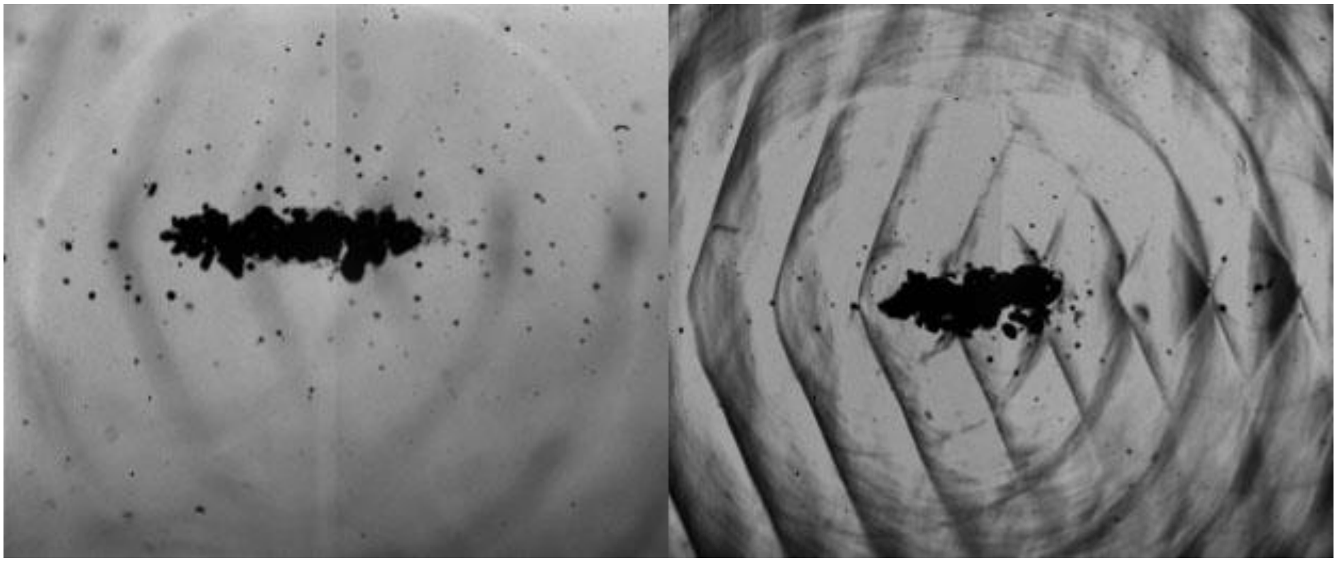

Figure 2: Shockwave in gel created with sonosensitizer imaged at 500.000 fps.
(Images courtesy of Prof. Umemura and Prof. Yoshizawa from Tohoku University, Japan)

Focused light without heat creation

Many traditional light sources create a significant amount of heat to the environment and to the object under study. Furthermore, such light sources cannot easily be focused to the target. Therefore a substantial part of the illumination is not utililzed as it doesn't fall on the region of interest. The light from diode lasers can be easily fiber-coupled and also focused with different optics. This enables the access to limited spaces which is not possible for many other light sources. Furthermore, due to the possibility to generate light only when the camera is exposing, the heat generated by diode laser illumination is minimized. Diode laser illumination is therefore an ideal solution for heat sensitive targets like paper webs and explosive environments such as liquid tanks in chemical process industry.

The image below shows the surface of a paper web. The high speed of the paper web and the high resolution require high-power illumination with short pulses. Since paper is flammable, it is important that the light source doesn't heat up the object.

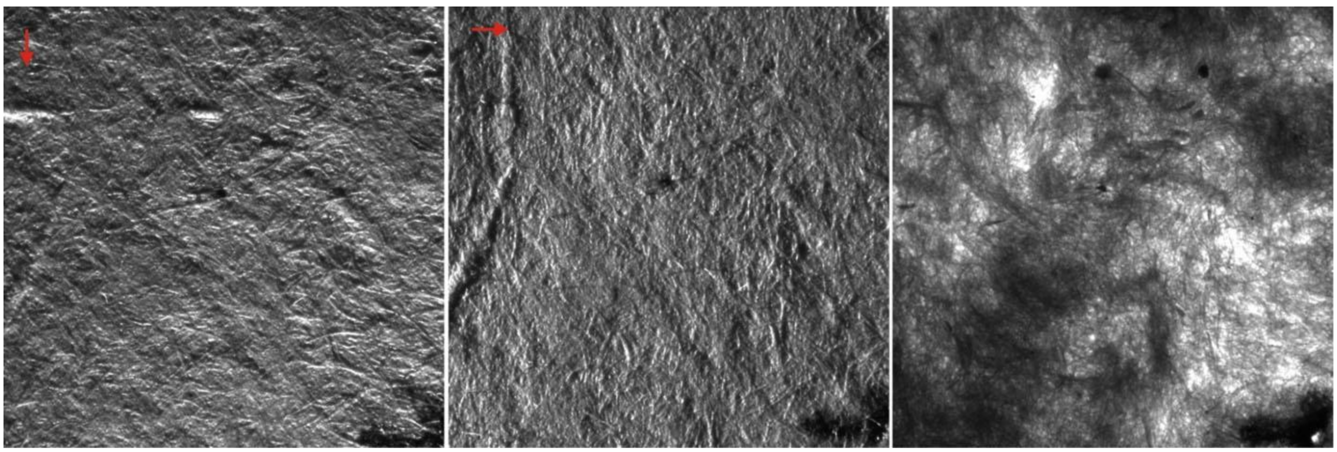

Figure 3: Surface topography of paper web imaged at 20 fps.

Intelligent light

With diode lasers it is possible to create different illumination shapes to address the needs of different applications. In most front illumination applications a round uniform spot is used. The spot covers the area of interest and the spot size can be easily adjusted. In some cases the area of interest can be e.g. reduced in height and increased in width. With suitable optics the laser light can be shaped e.g. to an elongated ellipse to address the area of interest. It is also possible to create light sheets that are used e.g. in PIV (Particle Image Velocimetry) imaging. While diode lasers do not provide as high intensity as traditional PIV lasers, they can be applied in some micro-PIV applications. Diode laser illumination is also suitable for Schlieren and Shadowgraph applications. With multi-output light guides it is also possible to reduce unwanted reflections from shiny objects. Another benefit of lasers is the possibility to create various illumination patterns with active or passive lines. As an example, in the image below a pattern of shadow lines is shown. It can be used for triangulation measurements while the illuminated part of the image can reveal surface properties.

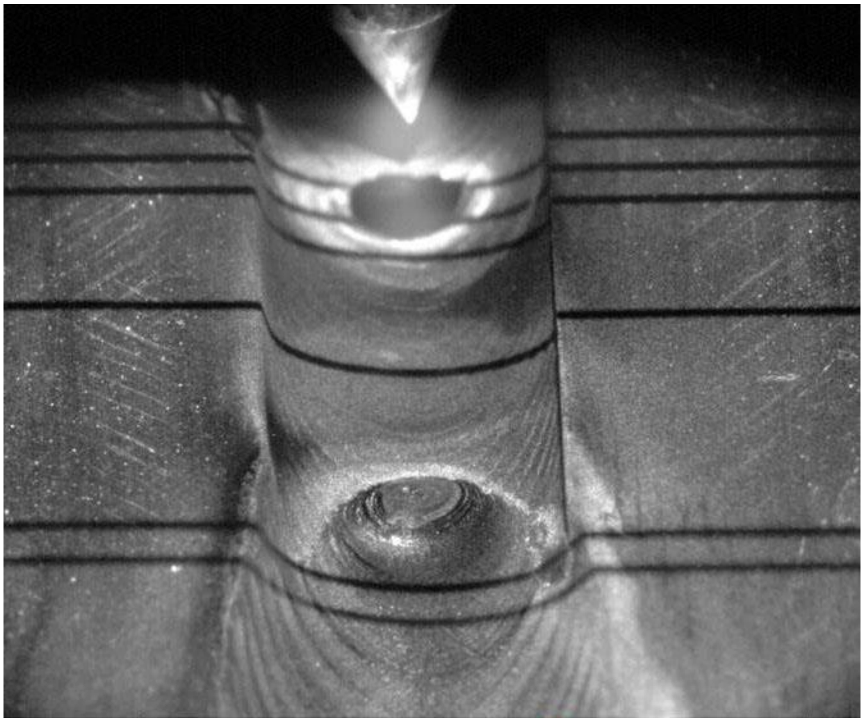

Figure 4: TIG welding process illuminated with structured light at a frame rate of 20 Hz. (Image courtesy of at Hollming Works Oy, Finland).

High-power diode laser illumination enables many new applications in machine vision where traditional light sources cannot fulfill the requirements.