

Guide to High-Quality Welding Imaging

The imaging of welding is often challenging since the camera can easily be blinded by the large amount of light emitted by the welding process. Cavitar presents key steps in achieving high quality images of welding.

1 Filtering and illumination

If a welding process is visualized without active lighting the only illumination source is the process light itself. Main source of radiation is the electric arc with temperature between 6 000 – 20 000 °C depending on the process. In addition to thermal radiation (Planck) there are emission peaks specific to process elements. For most camera sensors this process light is so strong that the image gets saturated and one does not see much of the process features i.e. “hot” and “cold” areas simultaneously.

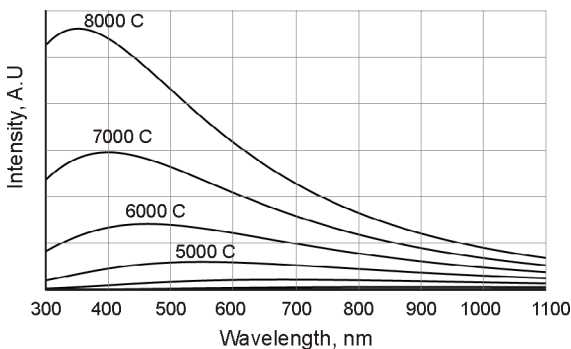


Fig. 1a. Thermal process radiation

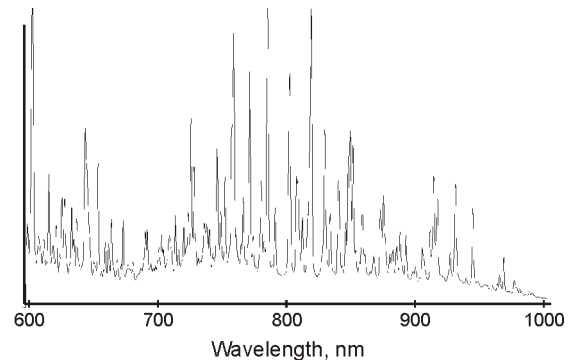


Fig. 1b. Emission peaks of process elements.

With e.g. neutral density filters one can reduce the amount of process light but at the same time areas with less process light become darker and darker. Such filtering thus merely makes it possible to “select” which features can be seen and which not.

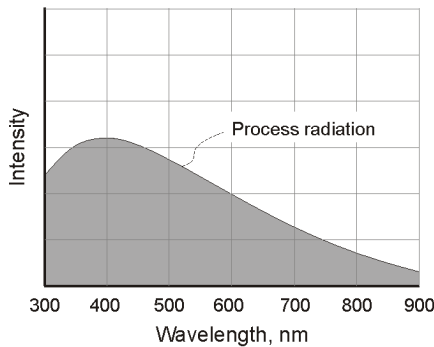
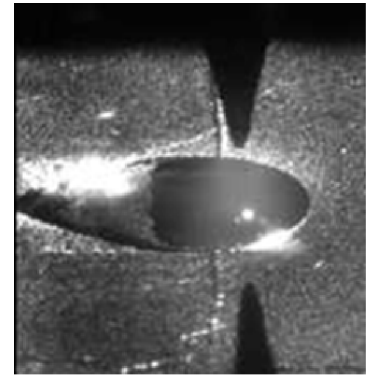
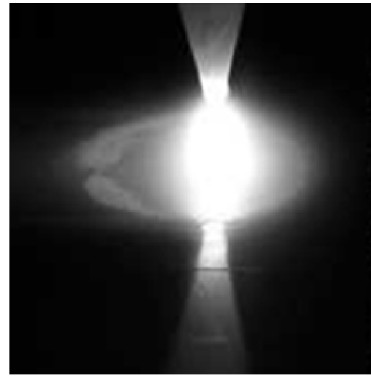
In order to be able to see both the “hot” and the “cold” regions of the object at the same time, the following conditions have to be fulfilled:

- a) apply a filter which prevents the saturation of the image by reducing the amount of process light in the image
- b) apply illumination which can illuminate the object appropriately and fits with the applied filter transmission band

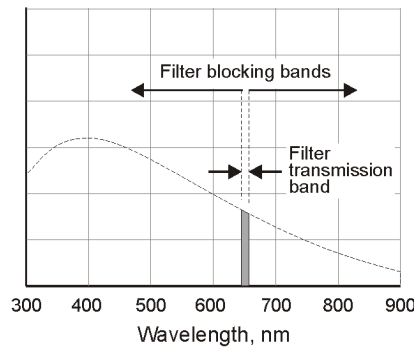
Since welding processes itself is typically acting as an extremely strong broadband light source, one would need to have an even more powerful broadband light source in order to be able to see all details properly. Such a starting point is obviously highly impractical.

On the other hand, if the object is illuminated with essentially monochromatic laser illumination, highly efficient narrow band pass filters can be applied. Such filters block practically all process light except for the process light emitted at the narrow transmission band of the filter. Therefore the active laser illumination has to be more powerful than the process light only within the narrow transmission band of the filter. In practice this can be accomplished with a laser power of a few hundred watts. As a result, both “hot” and “cold” regions can be clearly seen at the same time.

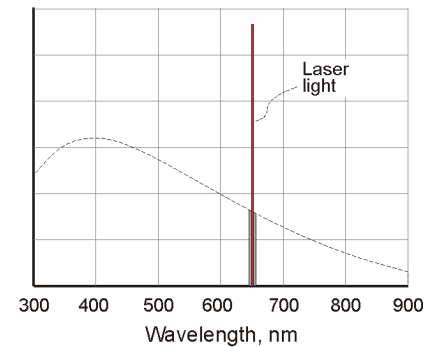
See the invisible world.



Process light



Bandpass filter


 Bandpass filter +
laser light

2 Camera properties

In industrial environment customers often want to observe the welding process continuously in real-time and therefore the frame rates are low. When studying welding processes for research and development purpose the use of high-speed cameras becomes more common.

Independent of the frame rate, a camera should preferably have a short exposure time, and ideally, a monochrome sensor if it is intended to be used together with laser illumination.

Short exposure times help to reduce the amount of process light that will pass through the narrow band pass filter. Equally important is that the process can be illuminated with a short laser pulse (preferably in the microsecond scale) instead of e.g. a continuous wave light source. Short laser pulses don't cause any thermal effects on the object and also simplify laser safety management.

In combination with laser illumination, monochrome cameras are preferable to color cameras due to improved sensitivity and image quality.

3 Properties of camera optics

Main criteria for selecting camera optics include the field of view and the working distance. Also the physical dimensions of the camera optics need to be taken into account. In addition, it is often useful to have an adjustable iris which enables the overall adjustment of the image brightness. A smaller iris enables also larger depth-of-view.

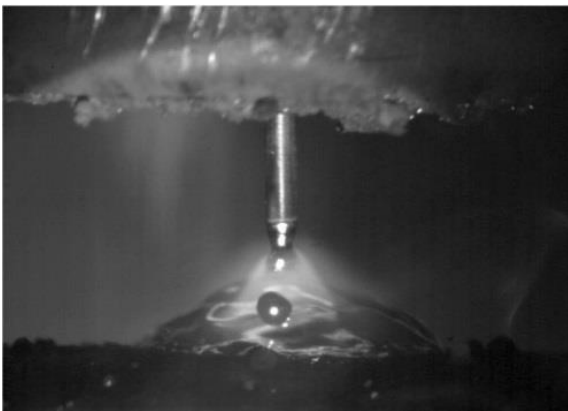
4 Positioning of camera and illumination

One can highlight different features of the welding process by modifying the relative angle between camera and illumination and also avoid unwanted specular reflections from the metal surface.

Common visualization geometries include:

- a) Camera and illumination looking from essentially the same direction towards the process. The surface of the object, welding wire etc. can be seen clearly. Specular reflections might be disturbing
- b) Side illumination (camera and illumination at around 90 degree angle). This setup often reduces specular reflections and can improve the visibility of the melt pool
- c) Direct back illumination (object between camera and illumination). This setup generates sharp silhouette images which can be suitable e.g. for drop formation studies
- d) Indirect back illumination (illumination not directed directly to the camera). This setup can improve the visibility of the melt pool as compared to direct back illumination
- e) Application of diffusing elements or multiple illumination sources (distributed illumination like light delivery via multiple illumination fibers) in order to reduce the amount of specular reflections from the object
- f) Combination of techniques described above

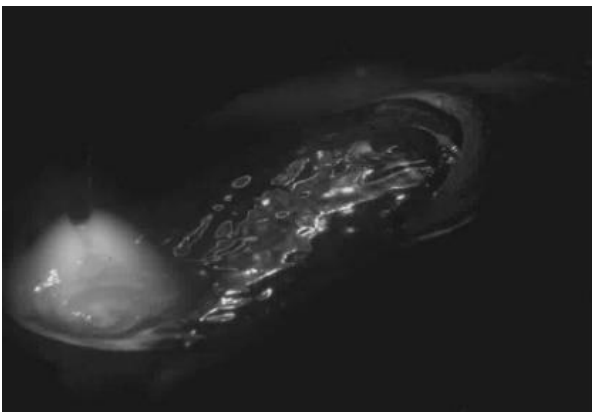
In many cases the best configuration can be found by testing different angles between camera and illumination.



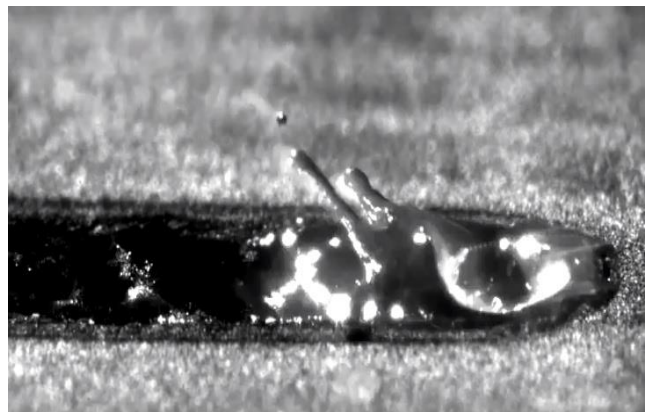
[Direct illumination of arc welding from front](#)



[Direct illumination of T-joint arc welding from front](#)



[Indirect illumination using a reflective plate to highlight melt pool dynamics](#)



[Direct illumination of laser welding from front](#)

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