Light You Need

Technical Note

Broadband Hot Mirror

Most traditional light sources produce heat as a byproduct. Unwanted heat can cause problems in certain applications. In bright light microscopy (phase or DIC) on live samples, such as cell cultures, the heat can alter normal cell behavior. This is of particular concern for long time-lapse experiments. Some detectors are extremely sensitive to extra heat in the system, especially in the area of astronomy where cooled cameras are often used. In operating rooms, TV studios and stage productions, significant heat is concentrated on the area of illumination causing discomfort for the participants.

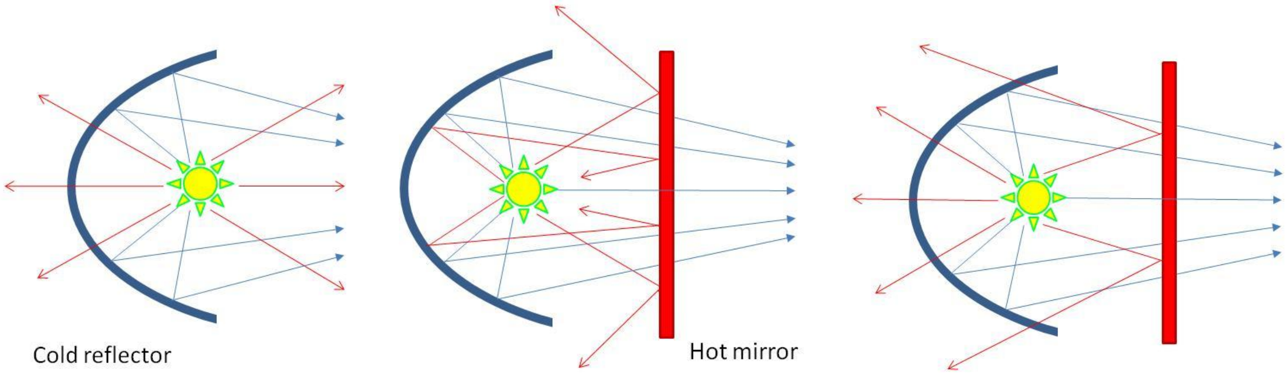

Figure 1. Left- A cold-reflector lets IR wavelengths (red arrows) pass through the back, while visible (blue arrows) and IR come out the front. **Middle-** a hot mirror reflects IR wavelengths back towards the lamp, while visible wavelengths pass through. **Right-** a cold-reflector and a hot-mirror combination lets visible wavelengths pass through, while IR wavelengths pass out of the back.

There are two techniques commonly used to reduce the heat at the illumination point. The first, (Figure 1, left) employs a cold reflector behind the lamp that lets infrared heat (IR) out of the back. This method does not eliminate the IR coming out of the front of the lamp, nor does it block re-radiation of the reflector as it heats up over time (explained in more detail below). The second method (Figure 1, middle) uses a hot mirror to reflect the IR back towards the lamp. This method provides more complete IR blocking, but can shorten the lamp life because of heat build-up. Although not widely used, a combination of both methods (Figure 1, right) provides the best performance with regards to lamp longevity and IR blocking. The visible light leaves the front of the lamp while the IR comes out of the back.

Typical hot mirrors reflect the near-IR wavelengths, cutting off anywhere between about 650 nm and 900 nm (Figure 2, blue traces). They begin transmitting again between about 1200 and 1400 nm. The blackbody radiation of a standard incandescent light bulb peaks at about 900 nm with a color temperature of roughly 3300 K. The curve has a long tail that extends into the IR region of the spectrum (Figure 2 black traces). Omega's Broadband Hot Mirror transmits well in the visible region of the spectrum, but transmits almost nothing above 900 nm (Figure 2, green traces). Omega can tune the cut-off wavelength according to the customer's specifications.

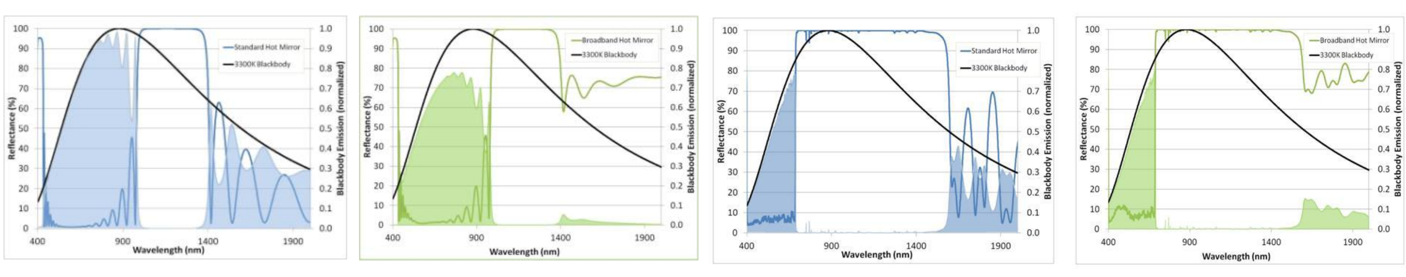

Figure 2. Blue curves- 3300 K blackbody curve (black) with two different hot mirrors (dark blue). **Green curves-** 3300 K blackbody curve (black) with two different Omega Broadband Hot Mirrors (dark green). Shaded areas indicate light that passes through the filter. Note that very little light is transmitted through Omega's filter at higher IR wavelengths.

Above about 1400 nm, the standard hot mirror transmits a portion of the light, which can cause heating of glass in the system. Depending on the type of glass used in the system, it may begin absorbing IR at about 2700 nm (Figure 3, left). As the glass absorbs the IR light coming through the hot mirror, it heats up and begins to act like a blackbody itself, emitting at a much lower color temperature (longer wavelength- Figure 3, middle, right). Omega's Broadband Hot Mirror

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reflects the majority of the IR light generated by a 600 K blackbody (Figure 3, left, shaded area, multiplied by 10 for visibility) while the typical hot mirror transmits the majority of the IR light (Figure 3, middle, shaded area).

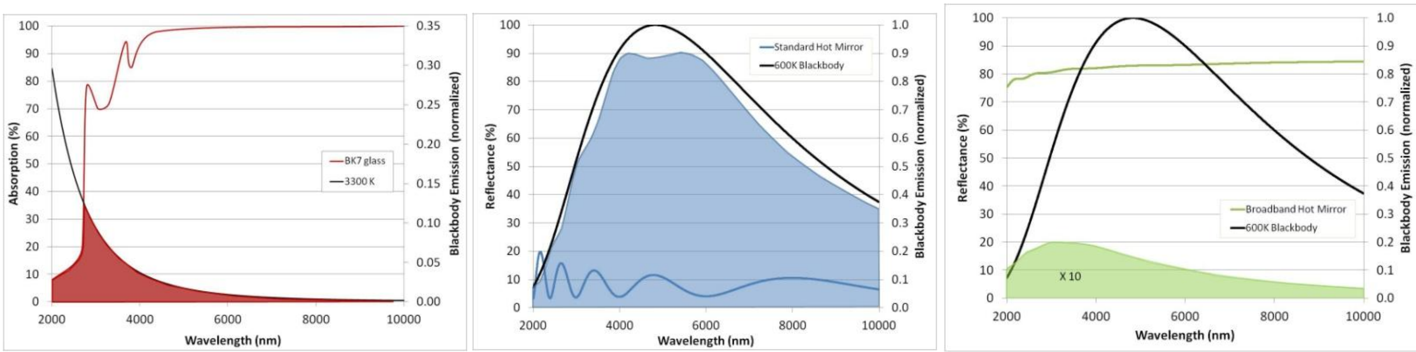

Figure 3. Left- % light absorbed by glass (red trace) with blackbody curve at 3200K (black), **Middle**- light re-emitted from glass at 600K (black) with % reflectance of typical hot mirror (dark blue), **Right-** light re-emitted from glass at 600K (black) with % reflectance of Omega's Broadband hot mirror (dark green). Shaded areas indicate the light that is absorbed (left) or that passes through (middle, right) the optical element.

Technology

Omega's Broadband Hot Mirror is produced by adding a transparent conducting oxide (TCO) to the back surface of a standard hot mirror. This coating absorbs slightly in the visible wavelengths (Figure 1, right) while acting as an IR reflector. This extends the reflecting range far into the IR. The top of Figure 4 illustrates the reflectance of a standard hot mirror (blue), the reflectance of the TCO (red) and the combined Broadband Hot Mirror (green). The design of the dielectric stack can be adjusted (indicated by the blue arrows) for a cut-off at a customer-specified wavelength or to minimize the reflectance dip between about 1400 and 2000 nm. The edge of the TCO film can also be adjusted somewhat (red arrow). The bottom of Figure 4 is a schematic of the Broadband hot mirror design. Because the complete filter uses both sides of the glass in reflection, it poses unique challenges in the measurements of the parts. See the product information sheet for more details.

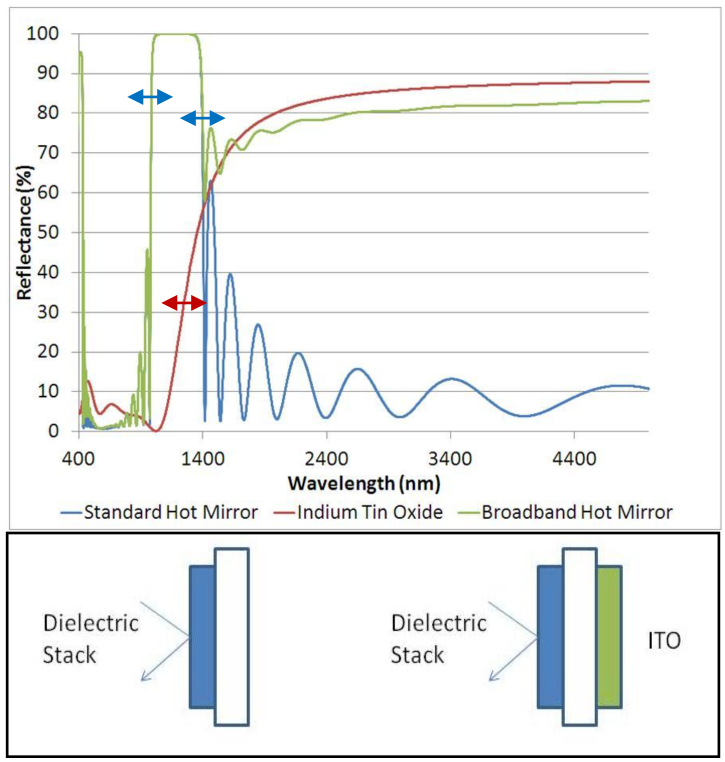

Figure 4. Top- the Broadband Hot Mirror (green) is composed of a Standard Hot mirror (blue) with an infrared reflector (red) on the back side as illustrated in the **bottom**