

ILLUMINATION

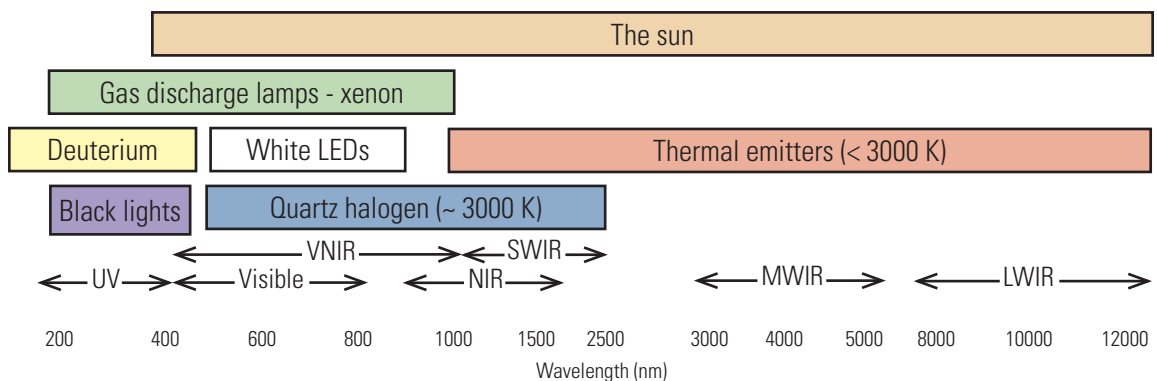
lamps and line lights

Hyperspectral Illumination

Illumination is a vital part of a complete functioning hyperspectral system. The amount and uniformity of light at the appropriate wavelengths and at the appropriate angles are critical to the success of the measurement. The main types of sources are included here. For development of custom illumination or advice regarding selection of available sources, please contact Middleton Research.

The factors to consider when selecting a light source are:

- Wavelength range of emission. Some sources produce continuous light as a function of wavelength, others have strong spectral lines.
- Source and measurement geometry. The placement of the source or sources must assure that the sample does not show hot spots. If the sample is diffuse, the light source can be placed at an angle off-axis from the camera. In some applications the sample illumination must be on-axis to probe a specularly reflecting surface.
- The illumination must be as uniform as possible along the line on which the push-broom camera is directed. Referencing measurements using highly reflective standards are able to correct for illumination non-uniformity. This referencing works well only if the sample geometry and the diffuse/specular characteristics of the reference standards are similar to the sample, which can be challenging for some materials.
- Distance variation between the sample and the camera also present a problem for proper referencing. The depth of focus and telecentricity of the camera lens may correct the sharpness of the image and keep the proper shape, but cannot correct the variation in illumination intensity. Special light source designs minimize the effect of the change in sample distance within a certain range.
- A stronger light intensity allows the use of a shorter integration time and thus reduces the dark noise contribution to the measured signal. In most cases, however, the higher light intensity means increased heat load on the sample. If possible, the light should be concentrated only on the area the camera is viewing thus avoiding unnecessary heating of the whole sample. Special sources, such as fiber optic line-lights or the proprietary SisuChema™ source modules are optimal for push-broom cameras.
- Some sources concentrate their energy output in short pulses. If the pulse can be timed with the camera data collection, the high peak energy level can increase the achievable signal.
- Lifetime of the sources, price and serviceability are additional practical considerations.



Basic light source types and their emission wavelengths



Light Sources

Type	Usage
Quartz halogen light sources	VIS-SWIR light sources for absorbance, transmission, reflectance and color measurement.
Deuterium light sources	UV absorbance and reflectance measurements, applications requiring a stable source. Low output sources.
Pulsed xenon lamp	Applications requiring a long-life light source for absorbance, reflectance and fluorescence measurements. Applications requiring synchronization (triggering) to process line. Good blue end. High power.
LEDs	Excitation source for fluorescence applications. Color measurement.
HgAr, HgNe, Xe, Kr	Wavelength calibration sources.
Calibrated halogen source	To calibrate the absolute spectral response of a system.
UV black lights	UV light sources for absorbance, transmission, reflectance.

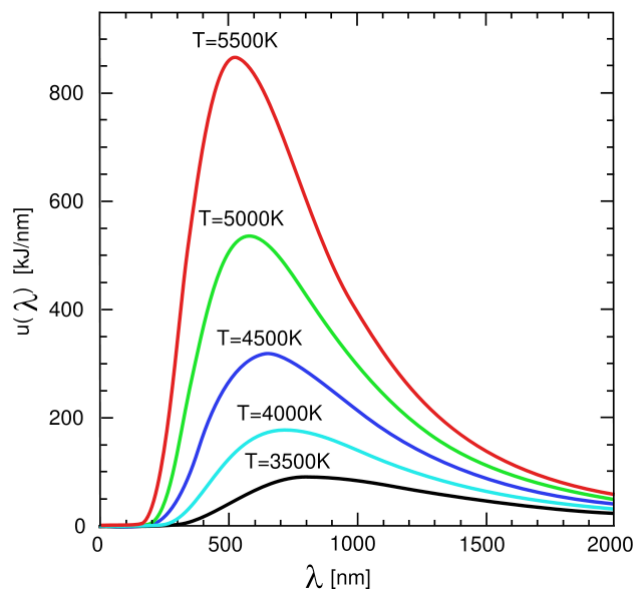
The most commonly used sources in the visible-to-SWIR range are the incandescent or halogen lamps. At a higher filament temperature, the overall light intensity increases according to Planck's law of thermal radiation, and the emission maximum shifts towards the blue (shorter wavelengths) according to Wien's Displacement Law:

$$I(\lambda) = \frac{2hcw^2}{\lambda^5} \cdot \frac{1}{\exp(hc/kT\lambda) - 1}$$

where c is the speed of light, h is Planck's constant, k is the Boltzmann constant, T is temperature in Kelvins and λ is the wavelength of light.

$$\lambda_{max} = \frac{b}{T}$$

In the above equation, b is Wien's displacement constant $2.897 \times 10^{-3} \text{ m} \cdot \text{K}$.



HALOGEN LINE LIGHT SOURCES

Halogen light sources are available in several different configurations and sizes. Although most of the light sources offered by Middleton Research are custom designs, some of the halogen illumination line lights are standard and are shown below. The line light source specified in this catalog is modular and can be manufactured to several different lengths based on the size of the sample area. Please call for other lengths or to discuss different arrangements and types of lamps.



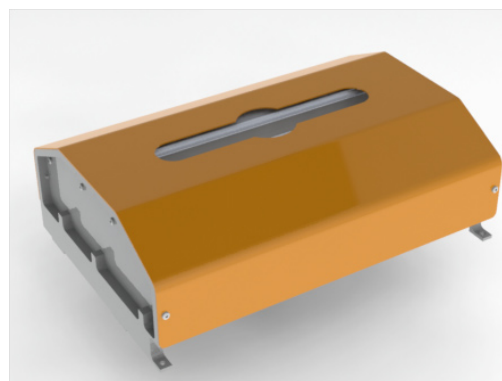
MRC-920-014 Powered 36" halogen line light source shown. Other standard and custom lengths available. Contact Middleton Research for more details.

Line Light Source Specifications

- Recommended for 400 - 2500 nm applications
- 3, 7 or 11 evenly spaced uniform illumination MR16 halogen bulbs
- Built-in power supply and fan cooling
- Either 115 or 230 VAC (please specify)
- 150, 300, or 450 W
- 36" x 8.7" x 5.25" (914x220x134mm) (MRC-920-014 36" light source)
- 26.5 lbs (12 kg) (MRC-920-014 36" light source)
- Customized lengths/number of lights available.

Dual-Sided Line Lights

A unique low power, dual-sided line light, Specim Ltd., evenly illuminates a target line from both sides while the camera and lens view the target through the center of the line light. The line light can be configured with either a narrow or broad illumination line depending on the application. A narrow illumination line is better suited for illuminating flat samples, while a broad illumination line should be used for samples with a rough surface. These illumination sources are custom, so please contact Middleton Research to discuss the details.



Example of a dual-sided, low-power halogen line light

Specifications	Narrow Line	Broad Line
Passline Variation	2% (+/- 2mm)	~5% (+/- 30mm)
Line Width	10mm	60mm
Line Length	Application Dependent	Application Dependent
Suitable Sample Type	Flat	Rough

Halogen Light Source Ordering Information

Part Number	Description	Product Name
MRC-920-010	10" Halogen line light source with power supply & built-in cooling, 150W	HLL/3/150C
MRC-920-012	23" Halogen line light source with power supply & built-in cooling, 300W	HLL/7/300C
MRC-920-014	36" Halogen line light source with power supply & built-in cooling, 450W	HLL/11/450C

FIBER OPTIC ILLUMINATION

Fiber Optic Line Lights

Fiber optic line lights are available in several different lengths as well as with different types of light sources. The line lights are coupled with a cylindrical lens to focus intense uniform lines of white light onto your sample for hyperspectral imaging measurements or for machine vision applications.



Dual line light bundle (shown without lenses)

The line lights are available in both single and dual line configurations. The dual line configuration may be useful in applications where the sample should be evenly illuminated from both sides simultaneously. This can be accomplished using the dual line configuration line light while still only needing a single light source.



10" Single line light (shown without a lens)



Example of halogen fiber optic light source

Different light sources are available for use with the fiber optic line lights depending on the spectral region of the application. The two most common light sources are a halogen and LED light source, two of which have been recommended below. Special low-OH grades of glass used to build the fiber bundles help extend the usability of these sources towards the near-infrared region. Please contact Middleton Research to discuss your application and to find the best light source for your needs.

Custom Fiber Optic Illumination

Custom fiber optic illumination is also available with multi-point configuration. Dedicated optics at the end of each fiber improve the light intensity at the illuminated points. Configurations with up to 40 channels are feasible. In most cases standard SMA connectors are preferable for mounting or coupling to standard collimating optics. On the common end the fiber bundles are equipped with a standard ferrule to match standard fiber optic light sources.

Fiber Optic Line Light Ordering Information		
Part Number	Description	Product Name
MRC-312-001-02	Line light for illumination source, 10" w/ lens	LLL/10
MRC-312-001-03	Dual line light for illumination source, 5" w/ lens	LDLL/5/2
MRC-207-002-01	Halogen fiber optic light source	FOLS/HAL
MRC-207-002-02	LED fiber optic light source	FOLS/LED

Note: Depending on the required wavelength range, different types of fibers must be used. Please consult Middleton Research for your particular application.