TECHNICAL NOTE TN2021_7 – ILLUMINATION SOURCES

Introduction

This technical note depicts which illumination source should be used for hyperspectral imaging.

IR = INFRARED (ABOVE 700 NM)

LED = LIGHT-EMITTING DIODE

SWIR = SHORT WAVE INFRARED (1000 – 2500 NM)

NIR = NEAR INFRARED (900 – 1700 NM)

MWIR = MID WAVE INFARED (2700 – 5300 NM)

LWIR = LONG WAVE INFRARED (8000 – 12000 NM)

UV = ULTRA VIOLET (200 – 400 NM)

Article

Hyperspectral cameras measure light, which is emitted, transmitted or reflected by objects. In the cases of reflection and transmission, the incident light plays a major role in the relevance of the results. Since hyperspectral cameras measure continuous spectra, it is fundamental that the light source has a continuous spectrum too. Several light sources are suitable and available with such continuous property.

1. **Halogens**
   Halogens are probably the most common source of light for hyperspectral imaging, and the cheapest. Typically, halogens emission follows the Planks curves of black bodies between 3000 and 4500 K (see Fig.1).

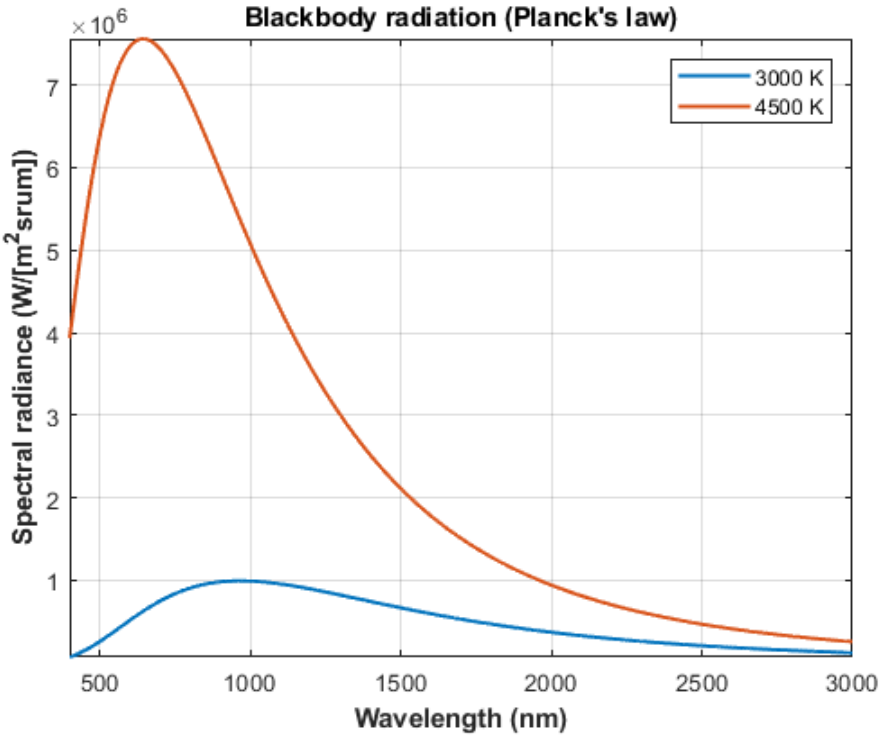


Figure 1: Typical emission curves of halogen bulbs.

Notice that warmer halogens contain more blue signal than colder ones, but on the other hand, have less IR. Also, warmer halogens are less balanced than colder ones. A spectral flattening filter could be used to even this.

Advantages:

- Not expensive
- continuous spectra over 400 – 2500 nm
- good IR emission

Disadvantages

- short lifetime
- produces heat
- requires optical mechanics to be focused (like elliptical reflectors)
- has poor blue emission and high intensity at ca. 1000 nm, which is not optimal for color measurements.

Since color measurement is required in many applications, some halogens have been modified with filters. These halogen lamps also have a reflector that do not reflect infrared radiation forward but lets it pass backwards therefore reducing infrared heat load to surface. **These lamps cannot be used in NIR or SWIR measurements.**

2. **Line light based on cold halogens.**
In order to obtain a collimated line light from a halogen source, it is also possible to use optical guide (fiber) with cylindrical lens.

Advantages:

- collimated line light
- no heat
- continuous spectrum over 400 – 800 nm

Disadvantages

- no IR signal
- short lifetime
- poor blue emission

3. **LED**
LEDs are quickly developing since the middle of 2010s and several are now available for hyperspectral imaging. However, all are not suitable, and only so-called white ones are suitable. Several manufacturers propose such LEDs.

Advantages:

- can be tunned
- no heat
- long lifetime
- collimated line light

Disadvantages:

- more expensive than halogens
- not very bright
- uneven signal with sudden drops
- poorly available above 900 nm

For color measurements, those are rather good since the signal in the blue end is good.

4. Supercontinuum laser

This is a rather new technology for hyperspectral illumination. Several options with different spectral range are available.

Advantages:

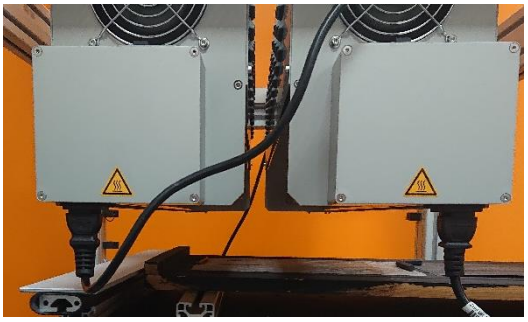
- tunable
- bright collimated line
- continuous spectrum

Disadvantages

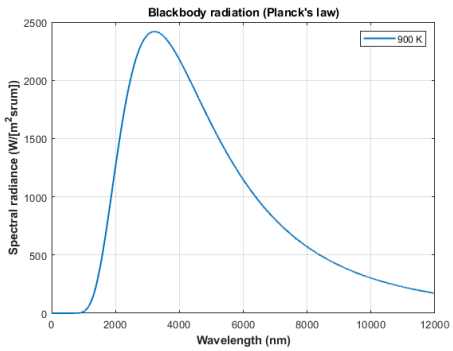
- expensive
- high peak at 1064 nm
- spectrum at the middle of the line is different from the edges
- signal dropped significantly after 2350 nm
- Class 4 lasers, which require safety instructions for integration and usage.

5. Radiators

Those are typically used for thermal imaging. They are emitters, like halogen bulbs are, but at lower temperature, so that their emission peak is between 3 and 12 um. Specim produces one, whose temperature is at 900K.



SPECIM thermal illumination



Emission curves of SPECIM radiators

Figure 2: SPECIM thermal illumination and the related black body emission curve.

SPECIM MWIR and LWIR cameras cover a spectral range 2.7 – 5.3 and 8 – 12 um. Those are ranges are located after the emission maximum of the illumination so that it is as flat as possible on the corresponding cameras wavelengths. A warmer illumination would have a steeper slope over the thermal spectral range, whereas a colder one would have too low intensity. There are other potential suppliers of thermal illumination sources like Elstein and Toshiba.

Advantages:

- continuous spectrum over the thermal spectral range
- long lifetime
- covers the full MWIR – LWIR spectral range

Disadvantages

- need reflectors to be collimated (as SPECIM one)
- needs to be handle with care (hot element)
- heat

6. Sun light

Solar illumination is used in many applications: precision agriculture, environment assessment, mining industry and all remote sensing related applications. By itself, sun provides a continuous spectrum illumination that a black body would emit at about 5800 K. However, the atmosphere surrounding the Earth contains gazes with absorption features, shaping the illumination reaching the surface of our planet.

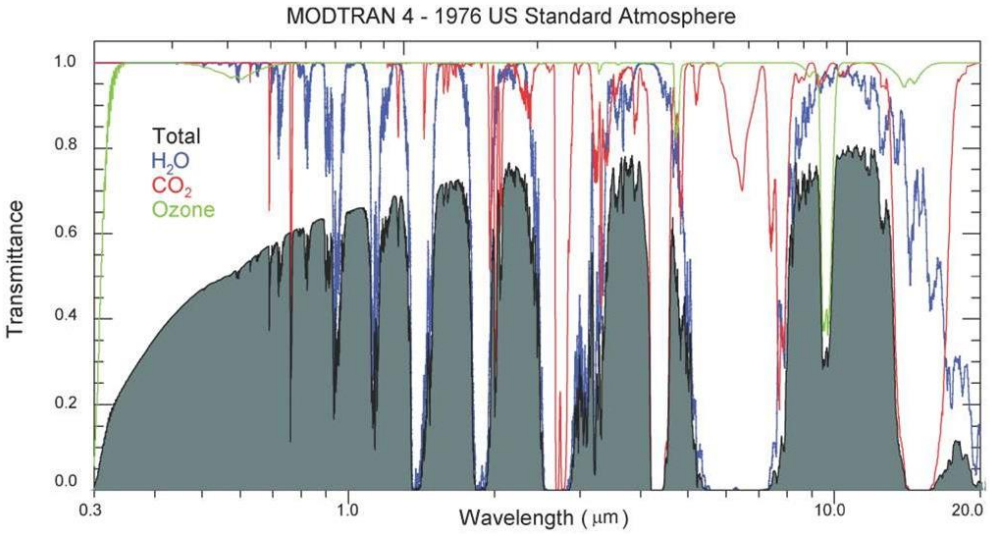


Figure 3: sun emission and atmospheric absorption.

As can be seen on Fig.3, solar illumination is very relevant between 400 and 1000 nm, but above this, atmospheric models need to be involved to correct spectra, when possible.

Advantages:

- homogeneous
- rather continuous spectrum over 400 – 1000 nm
- cheap

Disadvantages:

- available only during the day
- clouds affect the IR emission
- atmospheric absorption peaks

7. **Fluorescence**
   Unlike the other illumination sources, for fluorescence measurements light is needed to trigger a certain type of emission from the samples. This is not used for reflectance neither transmission, therefore continuous spectrum over the full spectral range is not required. Typical light sources used for fluorescence cover a rather narrow spectral range in the UV or are laser based.

Disclaimer

Version history

Version	Date	Author	Comments
1.0	Feb 18th 2022	MMA	