Multispectral Imaging in the SWIR with Optical Filters

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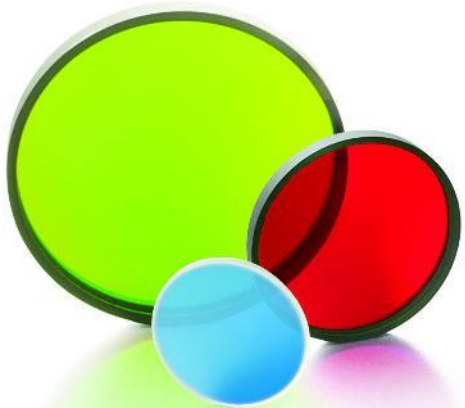
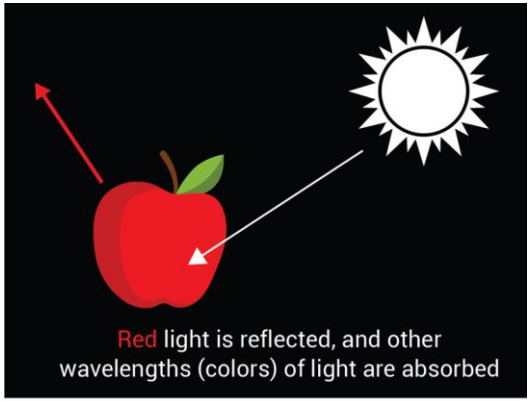
Outline

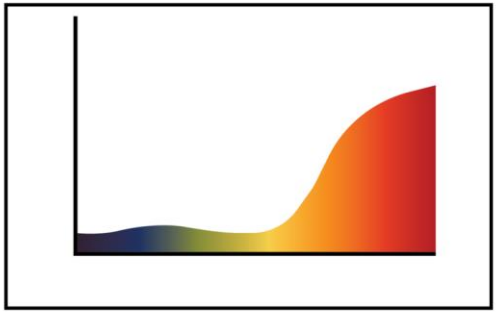
- Introduction
- SWIR
- Optical Filters
- Multispectral Imaging
- Choosing the Right Optical filters
- Examples

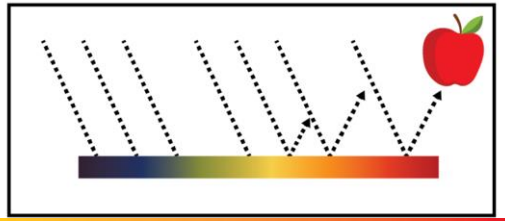


Introduction

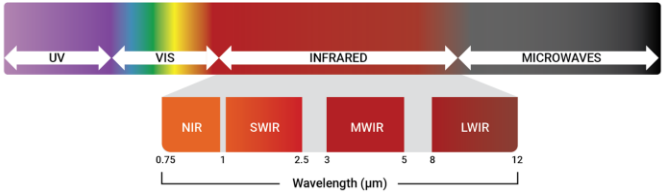
- Everything that has color has a **spectral signature**.
- When light interacts with an object, that object either reflects, absorbs, transmits, or re-emits incident light **energy**.
- The amount of reflection, absorption, etc., varies with **wavelength** and this variation depends on the wavelengths that constitute the incident light, and the nature of the object.
- Some objects, like this apple, reflect the red wavelengths from the sun's visible rays, but absorb the rest.
- What we see as color is due to the apple's **reflectance spectrum** that is heavily weighted to the red.
- In fact, this apple reflects light energy beyond the red, into the infrared, but our eyes cannot see this IR light.



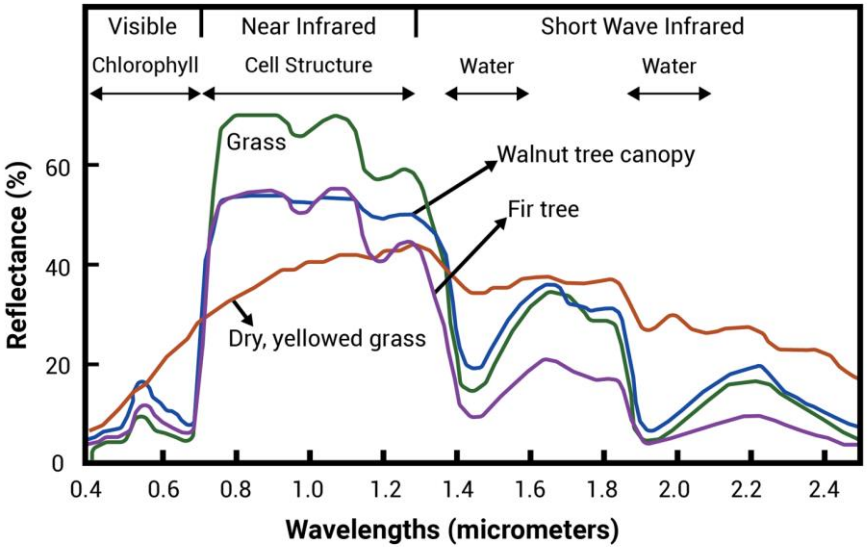




Introduction



- Some objects of interest have a relatively boring reflectance spectrum in the visible wavelengths, but more interesting spectral signatures in the SWIR (short-wave infrared).



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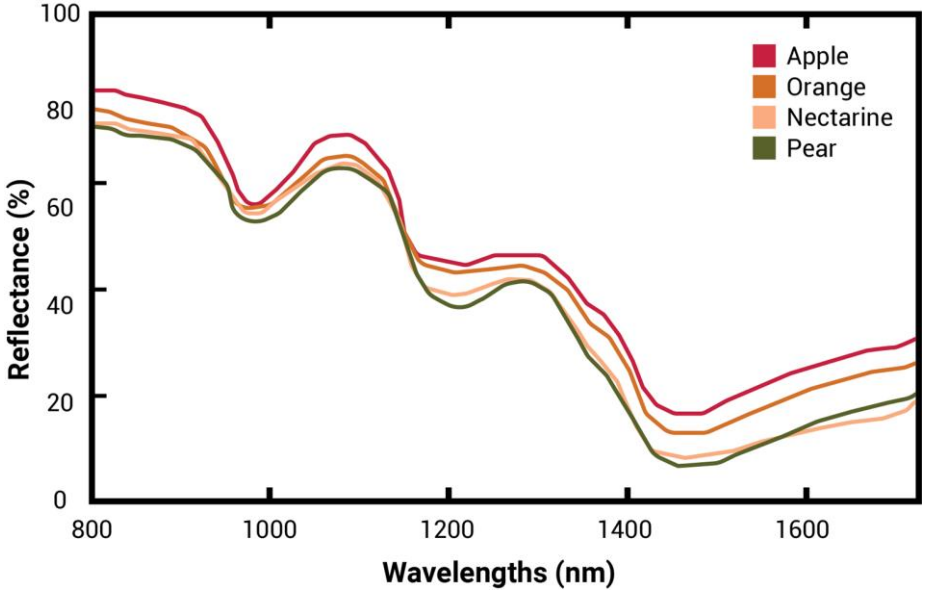
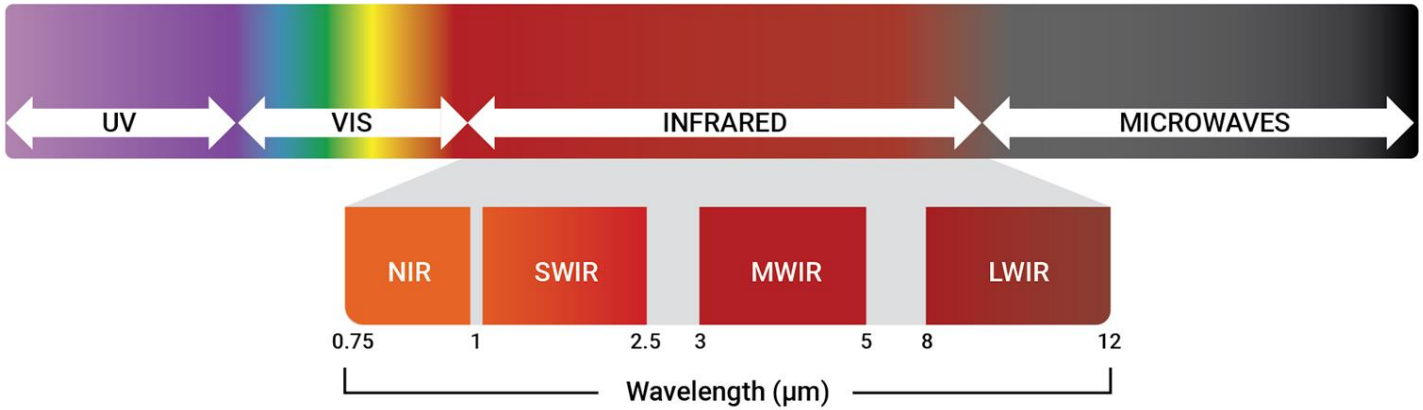


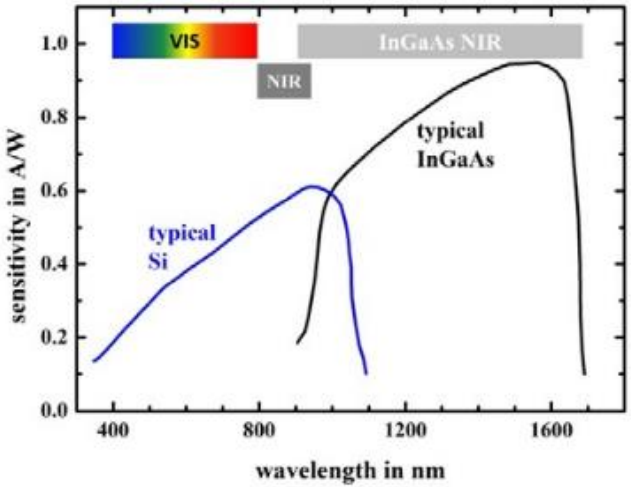
SWIR (short-wave infrared)

- Wavelength range past NIR from ~ 1um to 3um



SWIR (short-wave infrared)

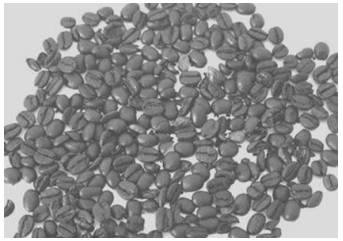
- Wavelength range past NIR from ~ 1um to 3um
- The range roughly follows the spectral response of the semiconductor detector indium-gallium-arsenide (InGaAs)



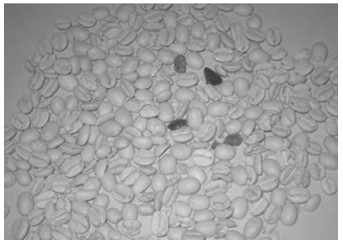
SWIR (short-wave infrared)

- Because most objects reflect some amount of SWIR light (as opposed to absorb it), the SWIR range can be very useful for a variety of imaging applications.

Visible



SWIR



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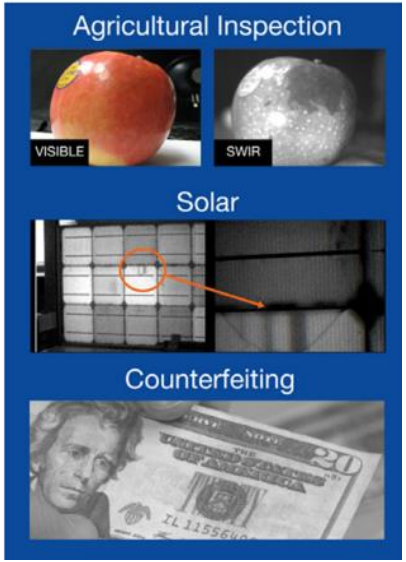
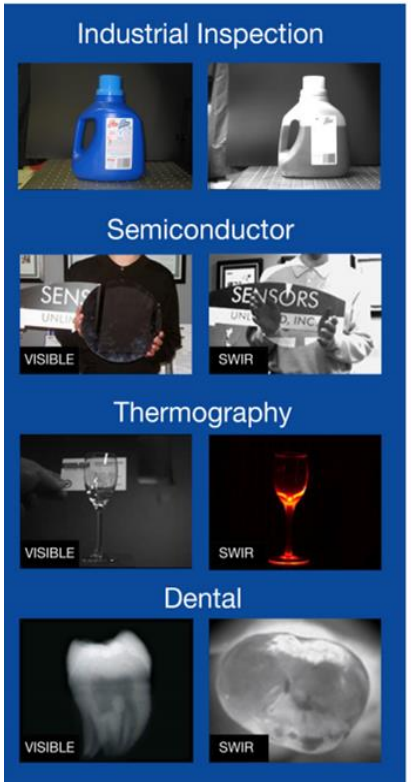
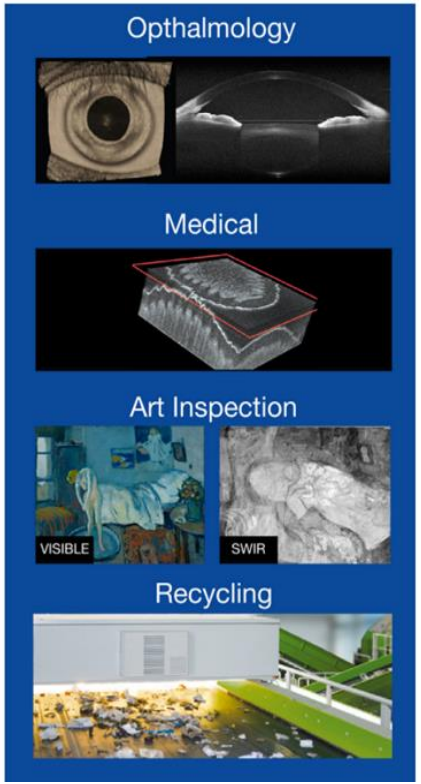
Courtesy of Smart Vision Lights

SWIR (short-wave infrared)

- Agricultural monitoring
- Waste management
- Semiconductor inspection
- Thermal Imaging
- Food inspection/sorting
- Life Sciences



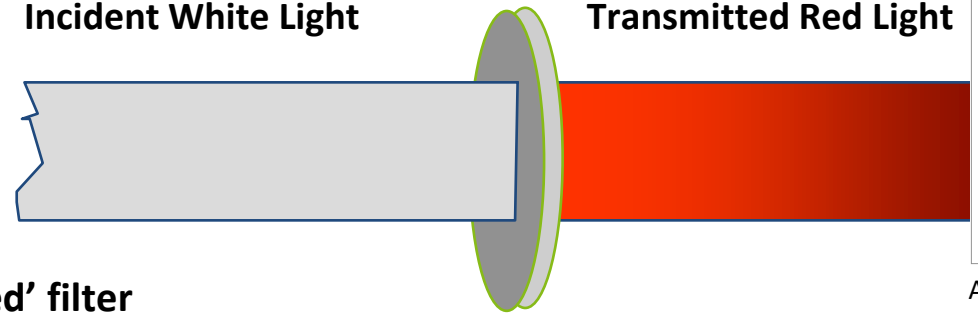




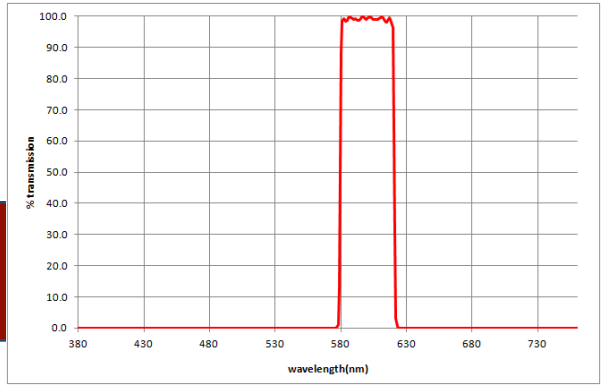
Courtesy: "Why SWIR & InGaAs? Why is it useful?" UTC Aerospace Systems

Optical Filters

- Transmit light of some wavelengths, and reject (or **block**) light of other wavelengths.
- They can be used in imaging devices to highlight the interesting spectral signatures of objects, **increasing the image contrast**.
- Give you the light you want, and reject the light you don't want.



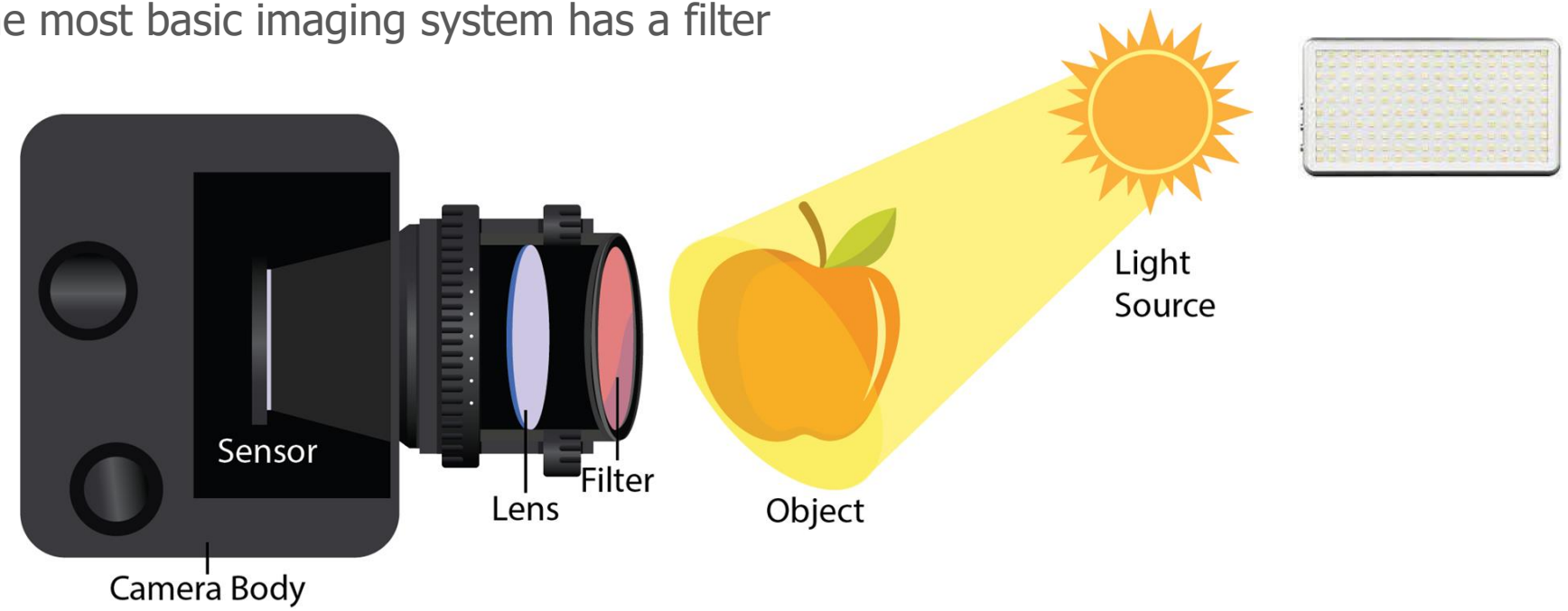
Example: 'red' filter



A spectral plot shows % transmission as a function of wavelength and represents the percentage of energy that gets through the filter -- what is not allowed to transmit is either absorbed or reflected. **T + A + R = 100%**

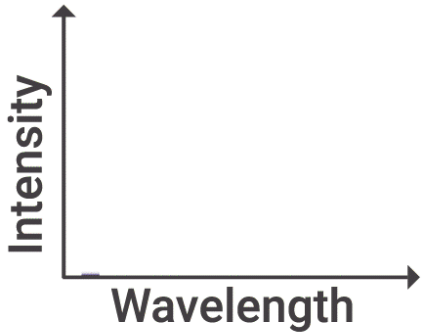
Optical Filters

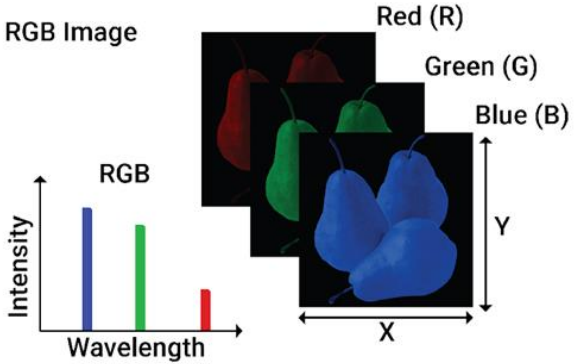
The most basic imaging system has a filter

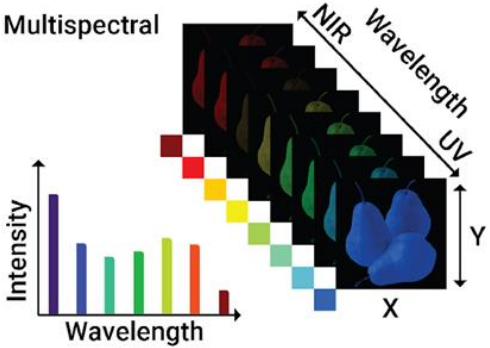


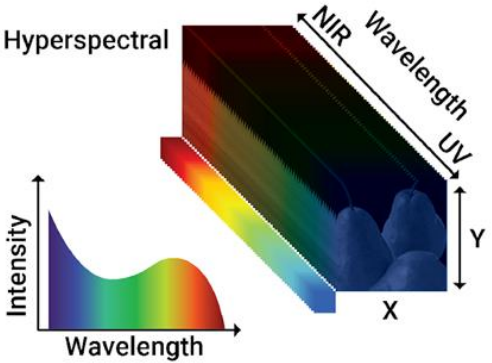
Multispectral Imaging

- Multi-image capture, each of a particular color or spectral band.
- RGB camera provides images in three bands.
- Multispectral camera gives several discrete bands, while a hyperspectral camera produces images over a continuous spectrum.
- Having these different channels allows much more information to be obtained.





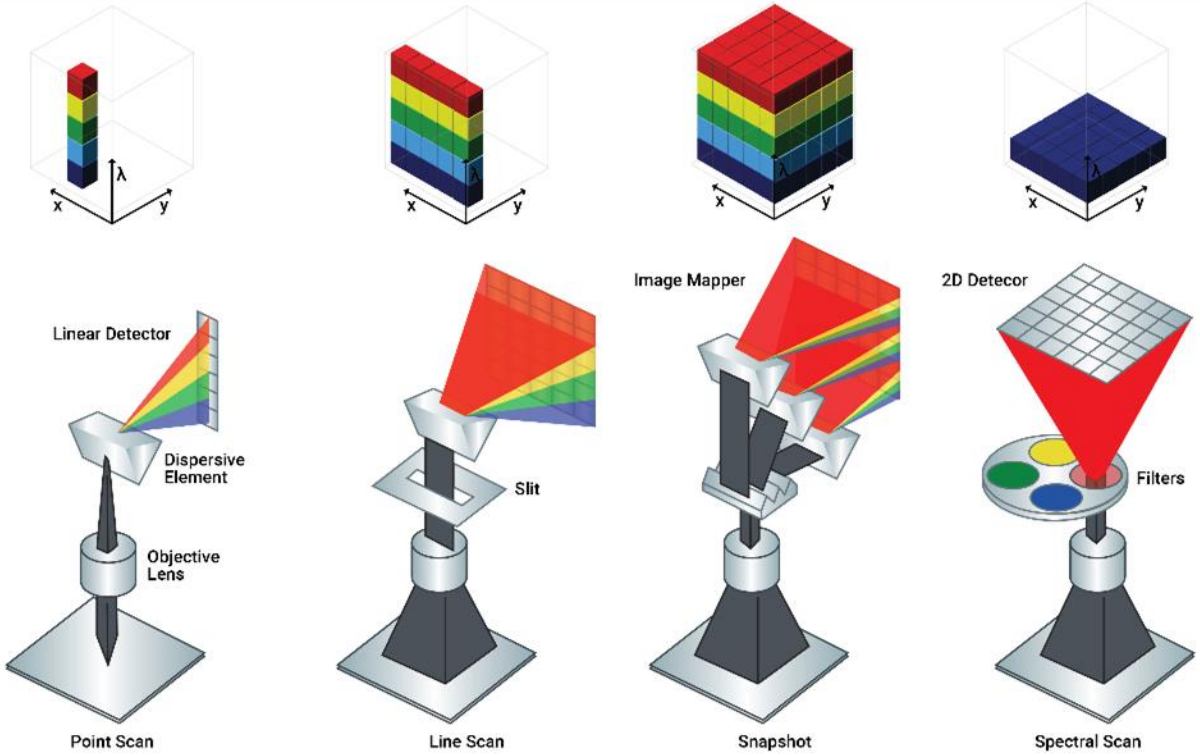




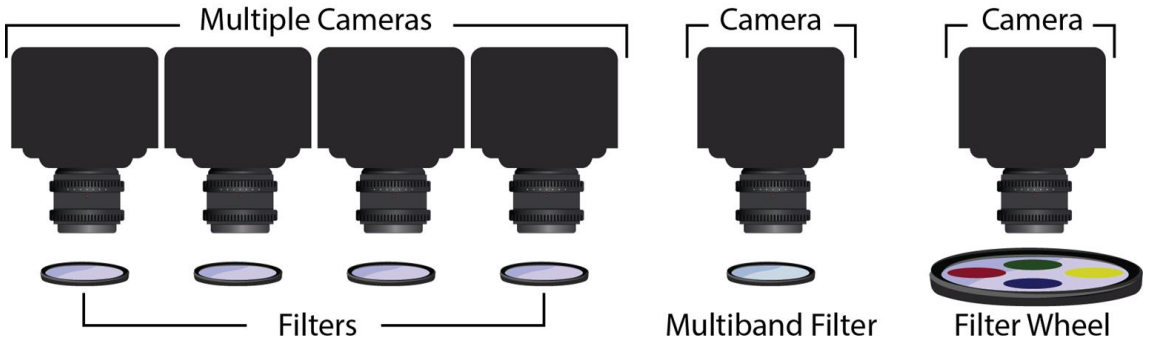
Variety of Approaches

- The specifics of the application, including the environment in which the imaging must be accomplished, determine which approach is most appropriate.

- Techniques that use the passive component optical filter are often the simplest and cheapest solution.



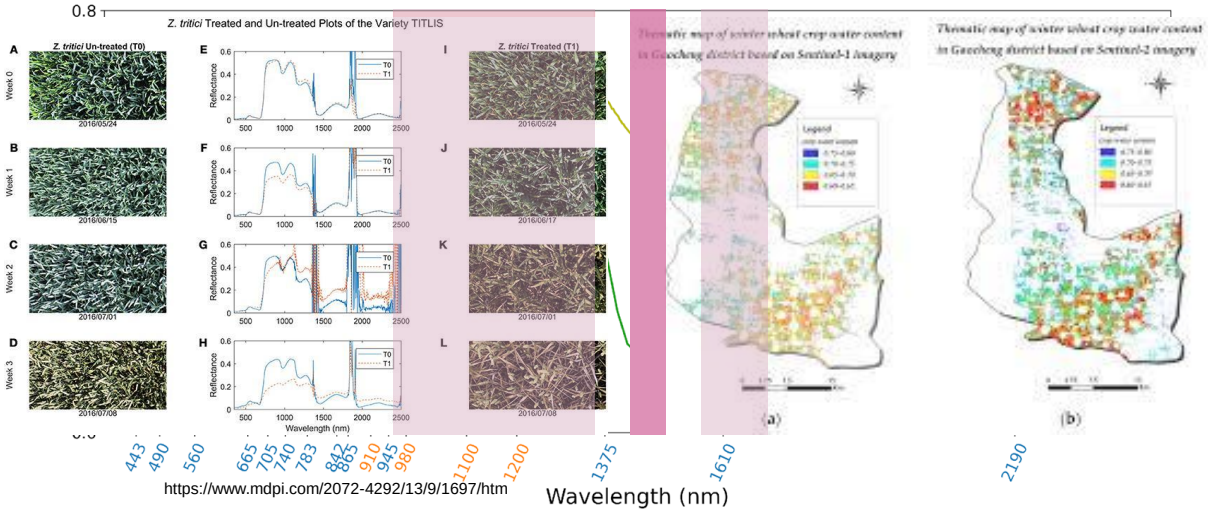
Using Optical Filters for Multispectral



- For remote sensing applications, multispectral imaging using optical filters is a simple way to **operationalize imaging for precision agriculture** (“smart farming”).
- For machine vision/industrial applications, advantages include lower-cost cameras, the need for only one light source, and **filters can be customized** exactly for the situation for pass/fail outcomes.
- Filters allow for better spectral separation to reduce crosstalk resulting in higher contrast (higher signal/noise) - this in turn allows the robot or inspection line to **move faster**, and the inspection overall to be **lower cost**.
- For systems with multiple LEDs, **multiband filters** can be used with strobing to save on expensive cameras (only one camera may be needed, and with no filter-wheel!).

Choosing the Right Optical Filters

Filters can be customized to place the band exactly where you need it.



https://www.mdpi.com/2072-4292/13/9/1697/htm

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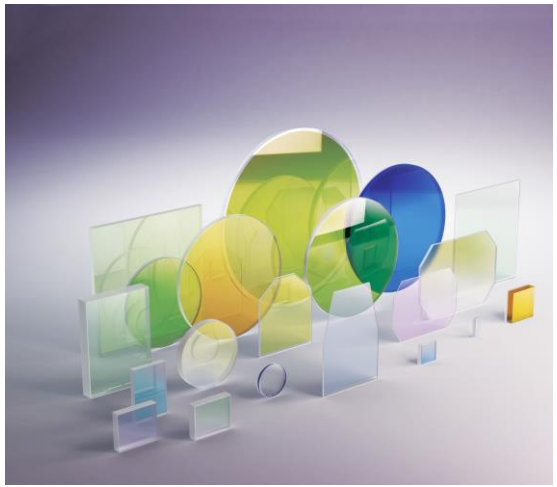

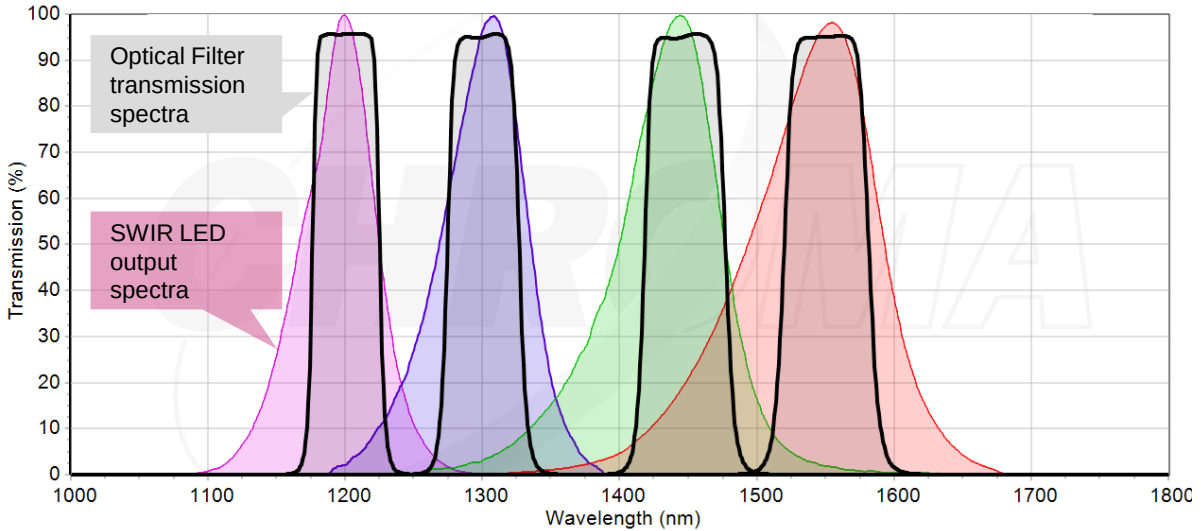

These filters remove the overlap present with the SWIR LEDs, increasing image contrast by removing more unwanted light from each image.

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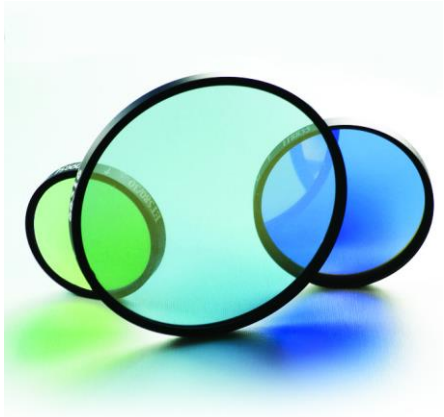
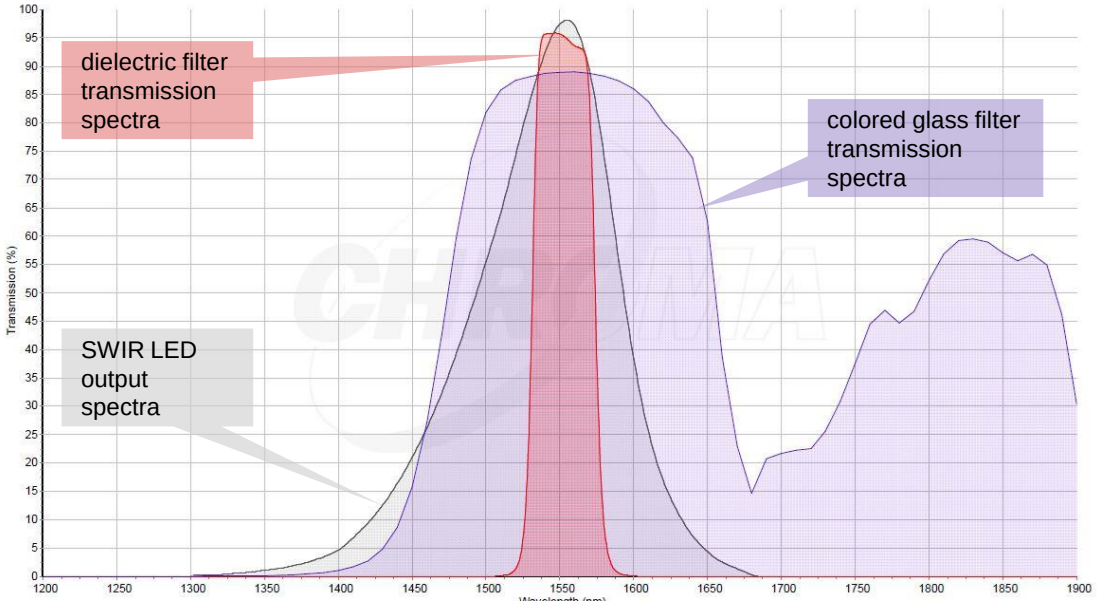
Choosing the Right Optical Filters

Optical filters made from sputtered all-dielectric interference coatings on glass have the highest level of spectral performance and the durability to handle extreme conditions.





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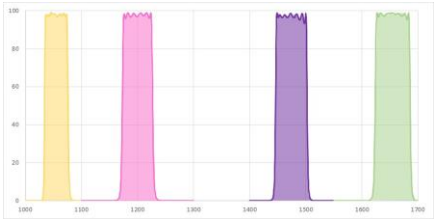
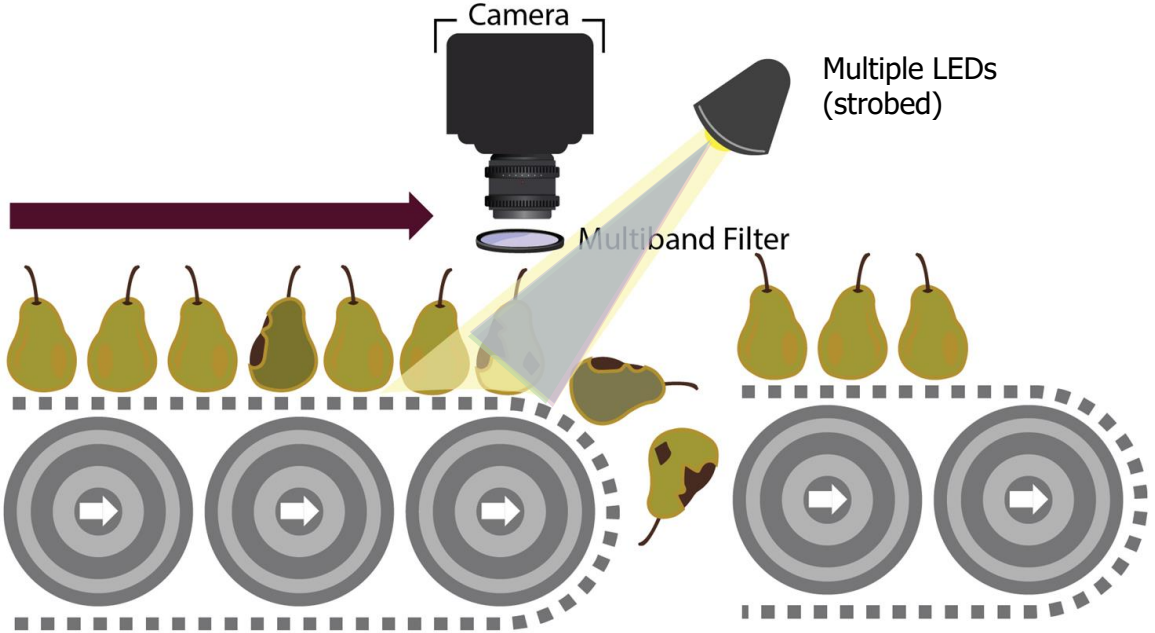
Machine Vision example



quad-band filter spectra

A multiband SWIR filter used with multiple LED light sources (turned on/off sequentially) in this application helps identify the defective fruit as well as potentially identify which wax is on the pear (or if there is any wax at all).

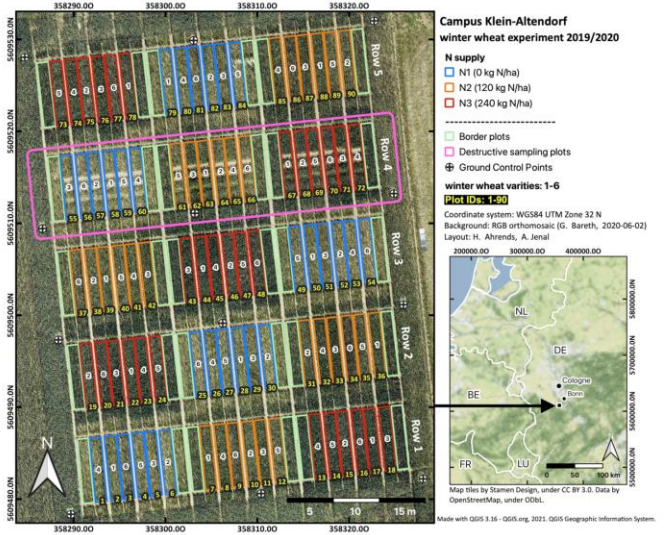
The multiple bands give more information by which the inspection system can determine good vs. bad, wax vs. no wax, or wax type as the line moves quickly by.



Remote Sensing example

Multispectral imaging with UAVs holding multiple low-cost cameras, each with a filter, significantly lowers the cost and weight as compared with a hyperspectral camera, effectively operationalizing precision agriculture.

- The simpler approach means more flights with less data to crunch, and reduces the impact of a drone accident.
- Filters can be customized to highlight key absorption features related to, for example, biomass and nitrogen which are located in the SWIR range.



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- Founded and headquartered in 1991 in Vermont USA
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- Offices world-wide
- Engineering subsidiary 89North
- One-Stop-Shop for Photonic Applications

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Thank you!

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