See the possibilities

Multispectral Imaging:
Possibilities using prism technology

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Global Product Manager for Prism
JAI A/S
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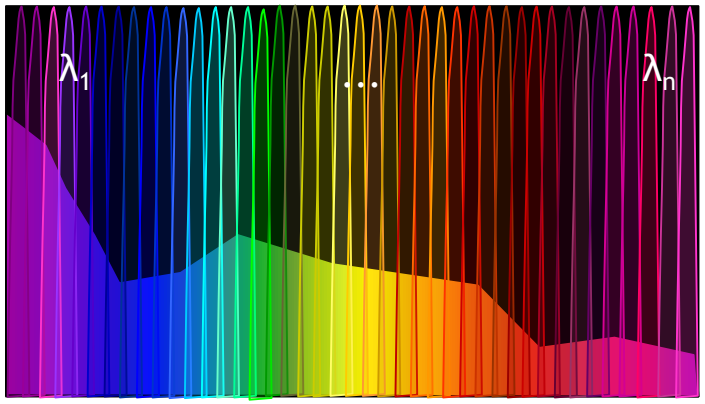
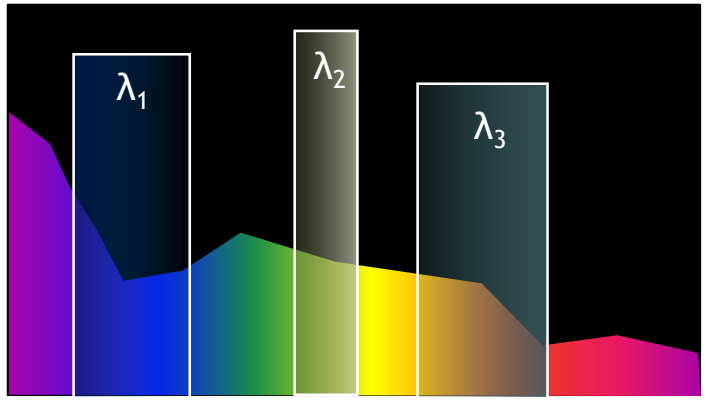
Multispectral or Hyperspectral?



Hyperspectral imaging

- Used for complete spectral analysis/spectral signatures
- Typically hundreds of narrow wavebands
- Wavebands are equally sized with no gaps between
- Many wavebands may not provide useful information for a particular application



Multispectral imaging

- Used for targeted application requirements
- Typically 2-15 wavebands
- Wavebands are discretely positioned and sized
- Each waveband has a specific purpose for a given application

The most common multispectral techniques

See the possibilities

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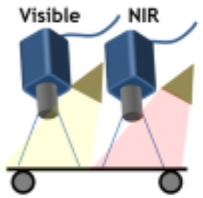
Two separate cameras



Two separate cameras

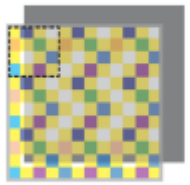
Key advantages:
No specialized technology required; easy to source with lots of options.

Main disadvantages:
Accurate pixel alignment/image fusion not possible due to optical parallax; two separate imaging setups to build and maintain.

Suitable applications:
- ✓ Where separate analysis of each waveband is acceptable
- ✓ Where separate pass/fail steps are acceptable

4

Sensors with multispectral filter arrays



Key advantages:
Single sensor/optical path; large number of bands possible; all bands captured in a single "snapshot"

Main disadvantages:
Demosaicing limits spatial precision; crosstalk and batch-to-batch consistency impacts spectral accuracy.

Suitable applications:
- ✓ Where lower resolution is OK (defects are large compared to FOV)
- ✓ Where some spectral uncertainty can be tolerated

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Filter-wheel cameras

Key advantages:
Single sensor/optical path; full spatial resolution per spectral band; ability to customize/change filter set.

Main disadvantages:
Sequential image capture means slower effective frame rate and possibility of position shift between wavebands; mechanical moving part in system.

Suitable applications:
- ✓ Where targets are static
- ✓ Where different filter sets are needed for different targets
- ✓ Where lower Mean Time Between Failure (MTBF) is acceptable

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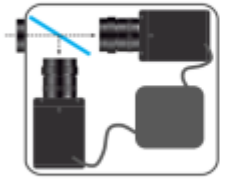
Multi-camera setups with beam splitter



Key advantages:
Single optical path; full spatial resolution per spectral band.

Main disadvantages:
Large and expensive; loss of light intensity from split.

Suitable applications:
- ✓ Where the target or the system is moving
- ✓ Where the system can be large/heavy
- ✓ Where illumination is plentiful

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Multi-sensor, multi-path imaging

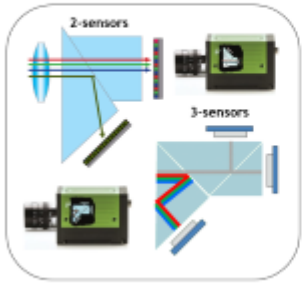
Key advantages:
Simultaneous capture of wavebands; full resolution of each sensor; strong spectral separation and full intensity; compact all-in-one systems.

Main disadvantages:
Multiple optical paths require complex alignment algorithms in post processing; doesn't tolerate angled viewing; slow frame rates.

Suitable applications:
- ✓ Where the target is flat and perpendicular to camera
- ✓ Where light weight is critical (e.g., drones)
- ✓ Where speed of motion is slow to moderate

8

Multi-sensor dichroic prism cameras



Key advantages:
Common optical path; simultaneous capture of wavebands; full resolution of each sensor; strong spectral separation and full intensity; high frame rate; compact system.

Main disadvantages:
Resolution and number of channels limited by current prism designs.

Suitable applications:
- ✓ Where both spectral and spatial precision are required, including precise fusion of multiple wavebands
- ✓ Where there is large amount of motion - target or camera
- ✓ Where there is angled viewing, uneven surfaces, or varying object sizes

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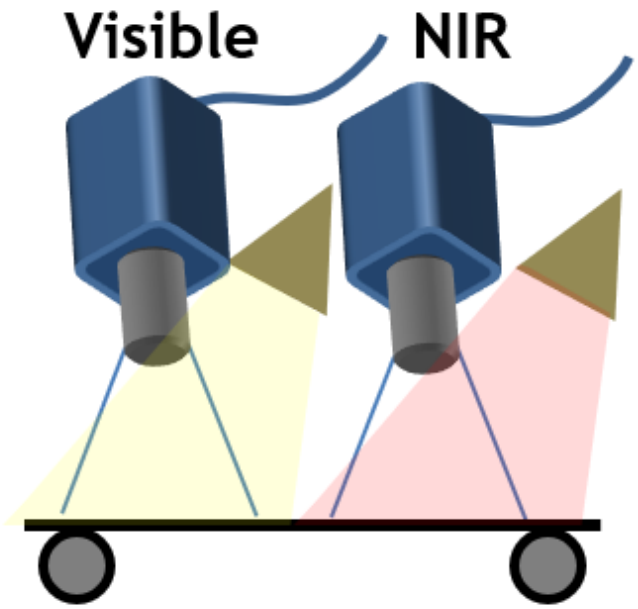
Two separate cameras



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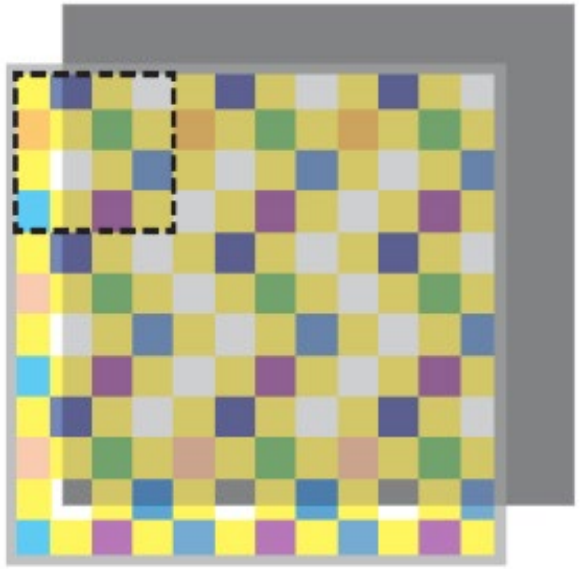

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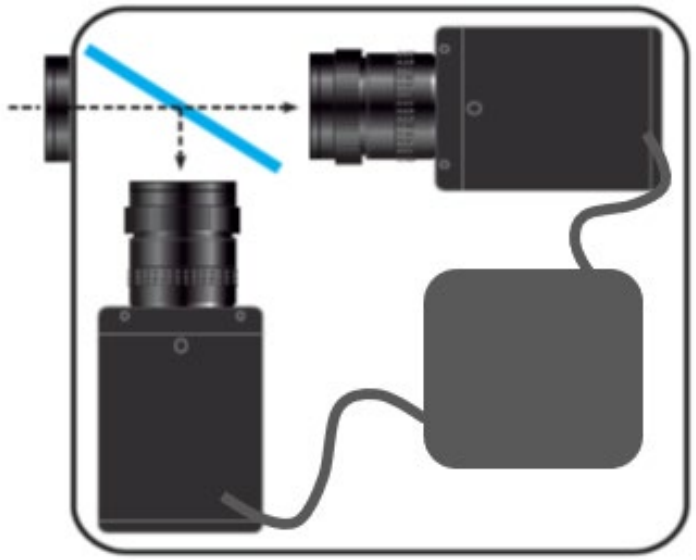

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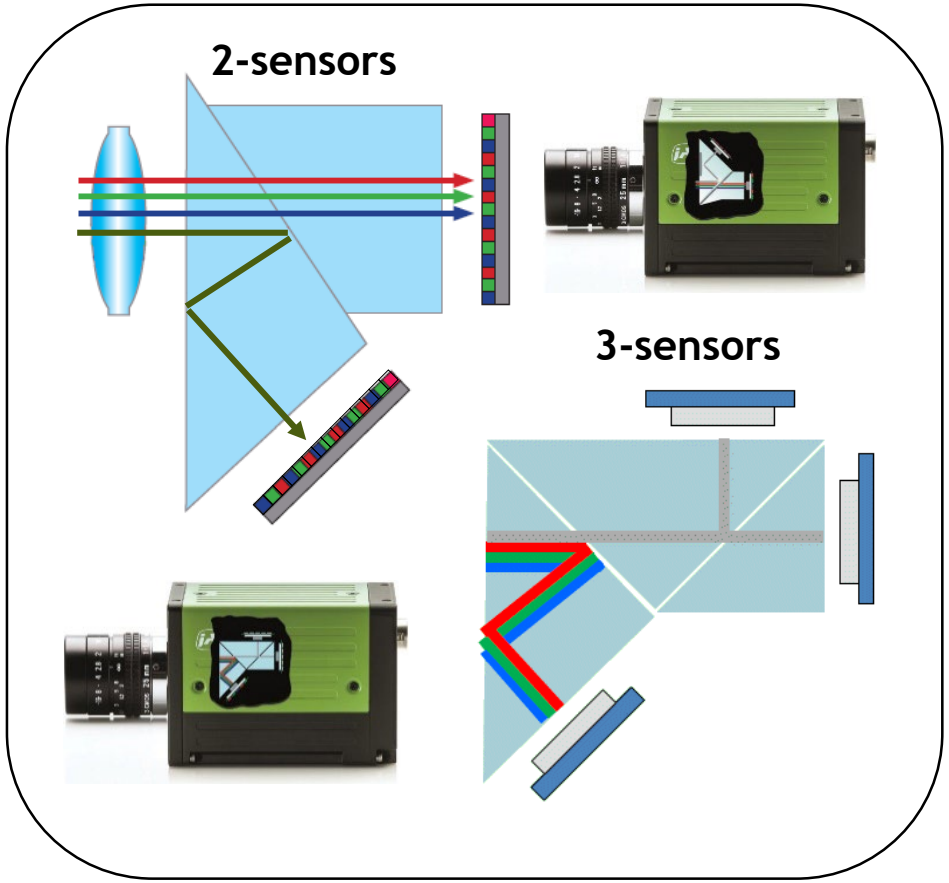
Multi-sensor dichroic prism cameras



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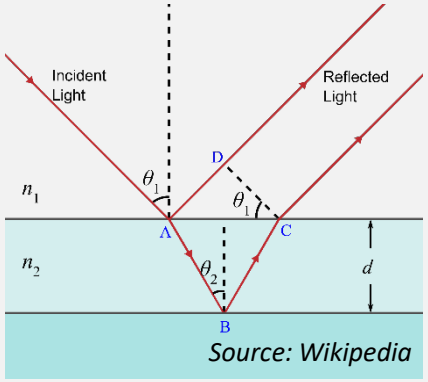
Dichroic Coatings

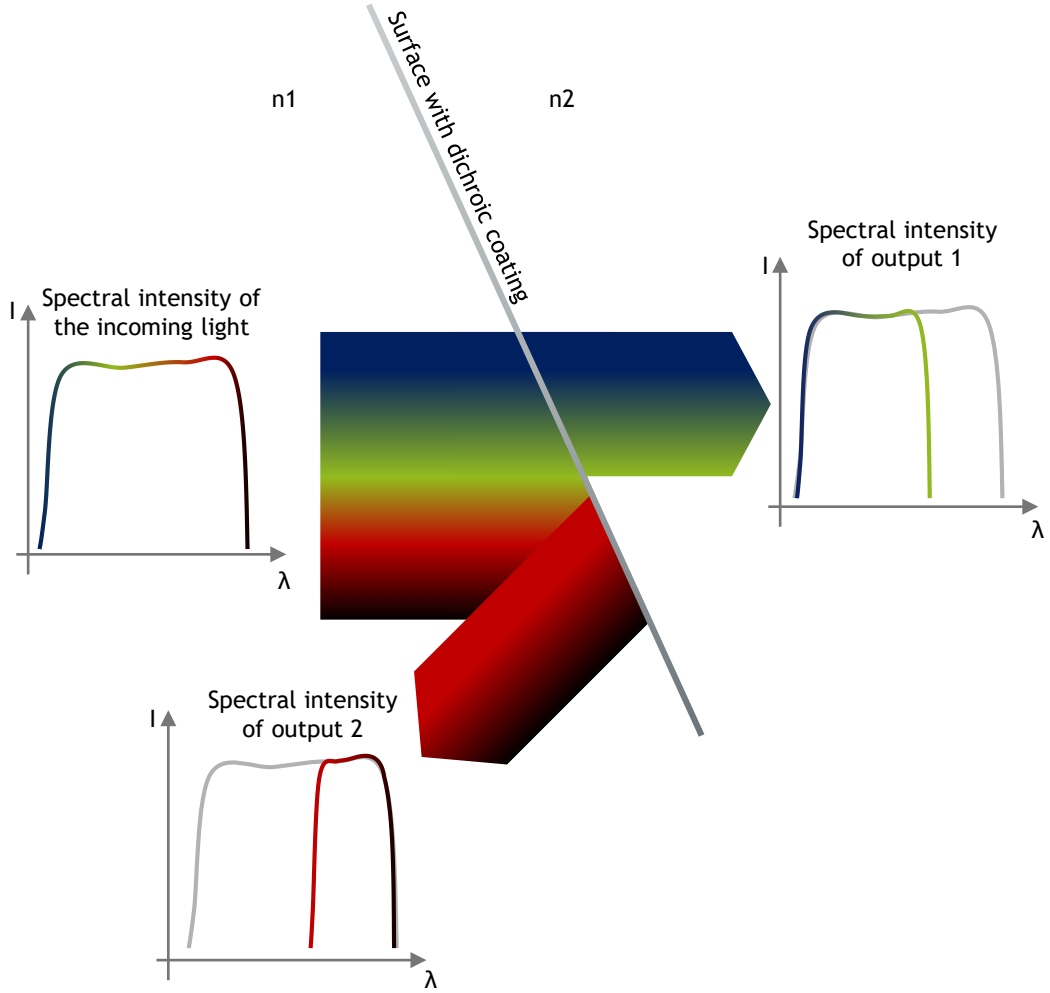
Dichroic coatings

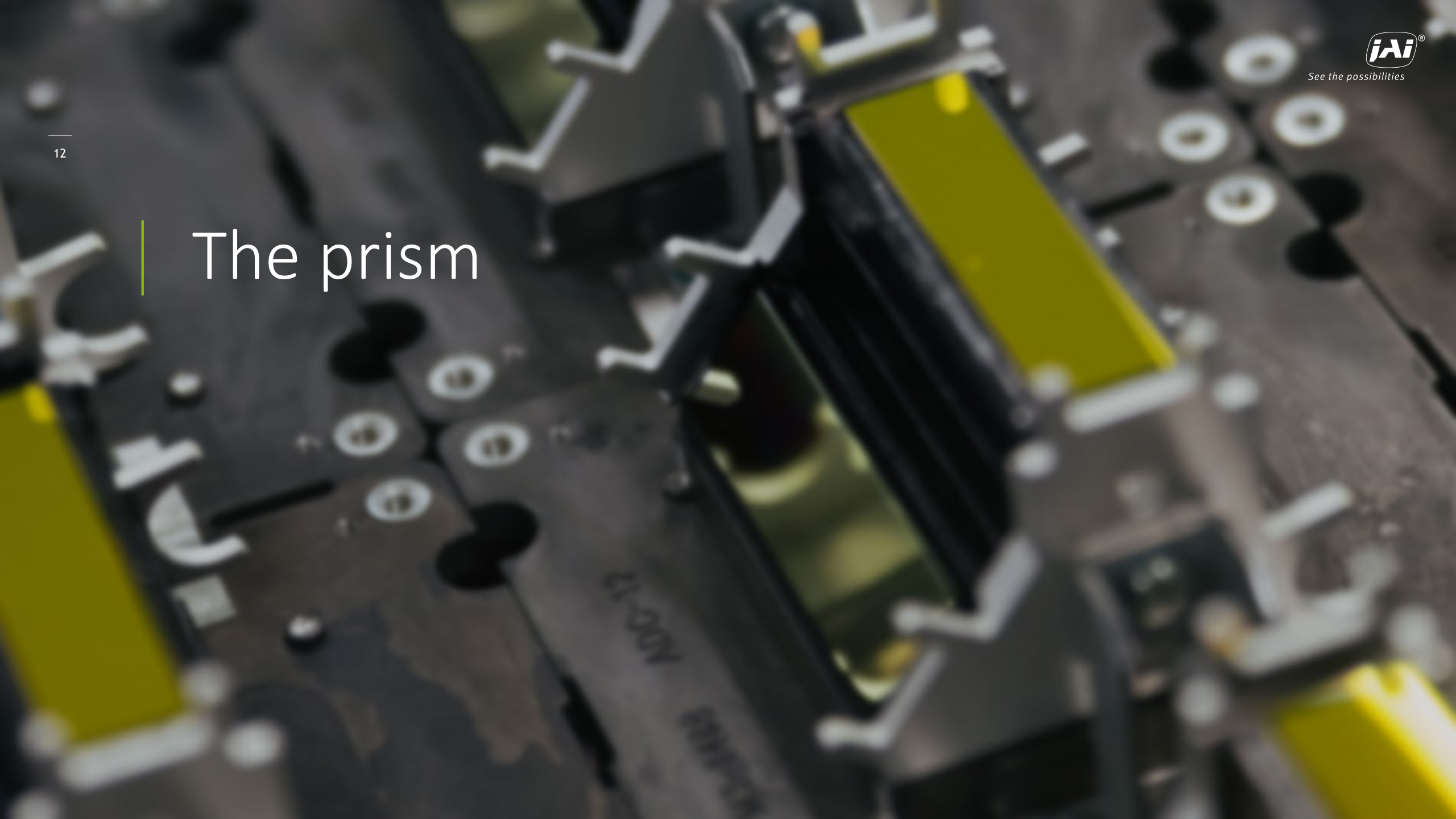
- Thin-film interference based (Vapor deposition)
- Optical coatings on the surface
- With different thicknesses
- Resulting in some range of the light being reflected, while some is transmitted



- At large angles the coatings' relative thickness to light is different

- High-pass/low-pass/bandpass





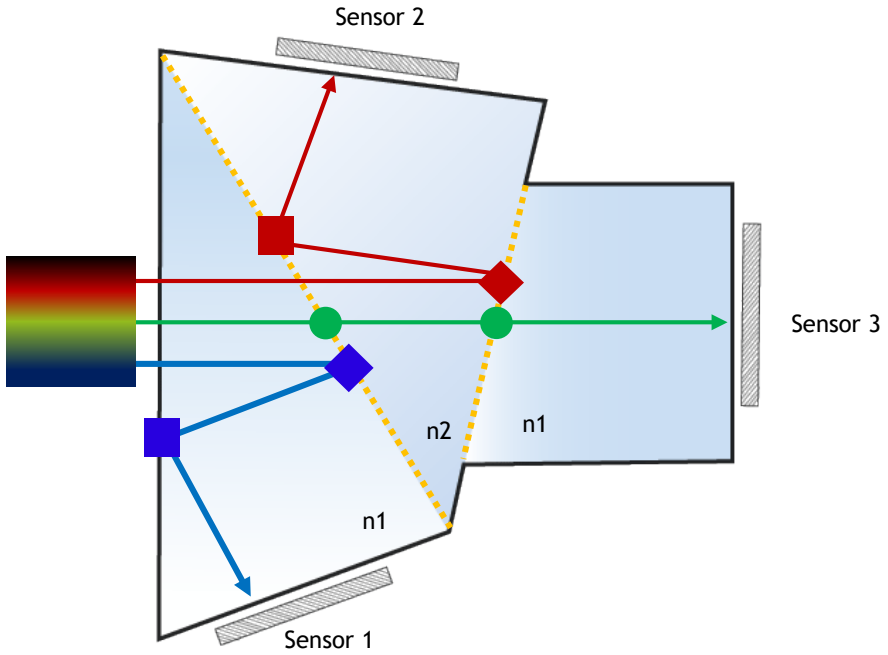
The prism

The prism

An optically glued assembly with:

- Multiple glass components with different refractive indices
- Multiple dichroic coatings
- Total internal reflections

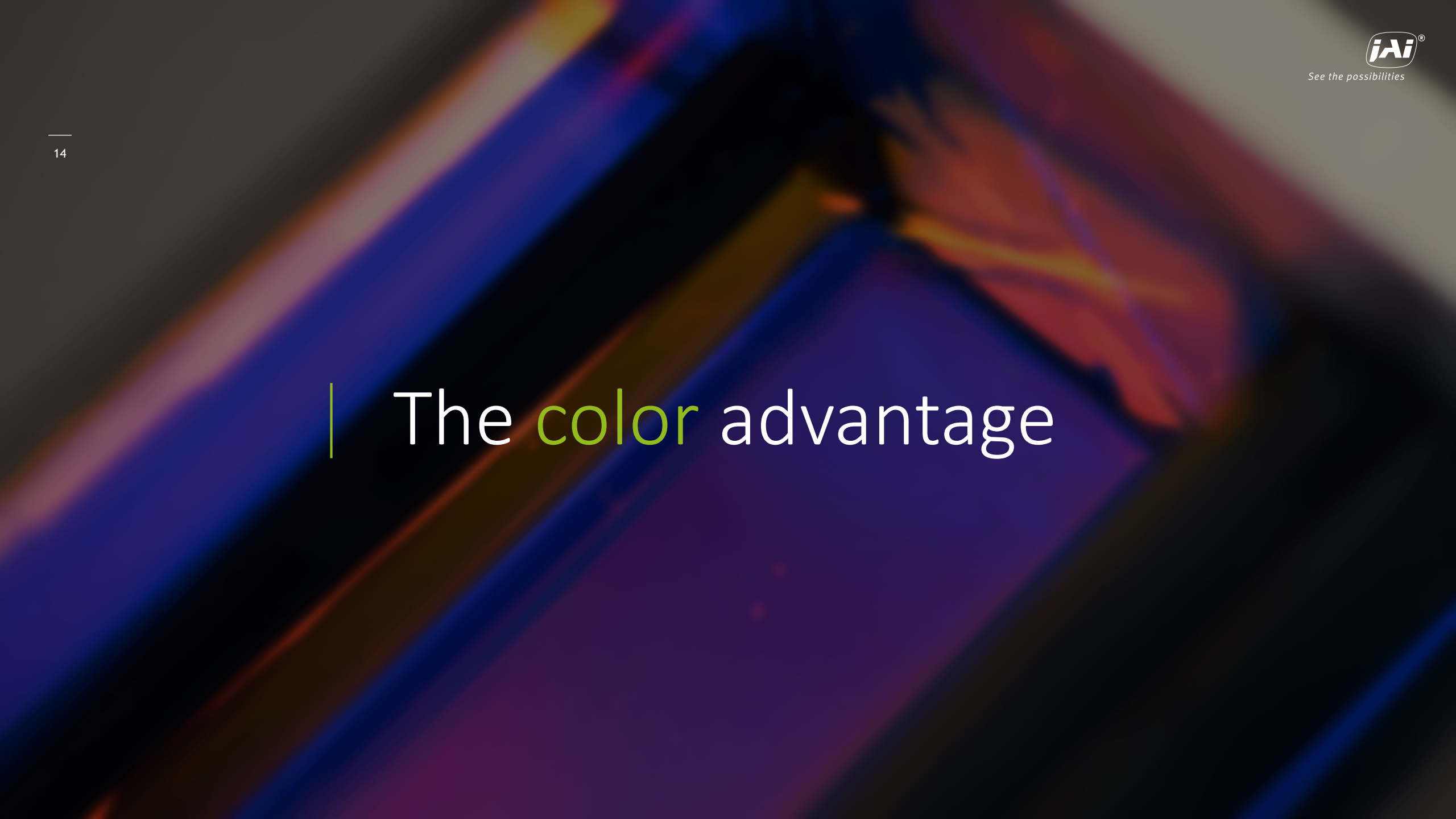
Resulting in a range of the light being reflected, while the rest is transmitted



□ : Total internal reflection

◇ : Filtered reflection

○ : Transmitted

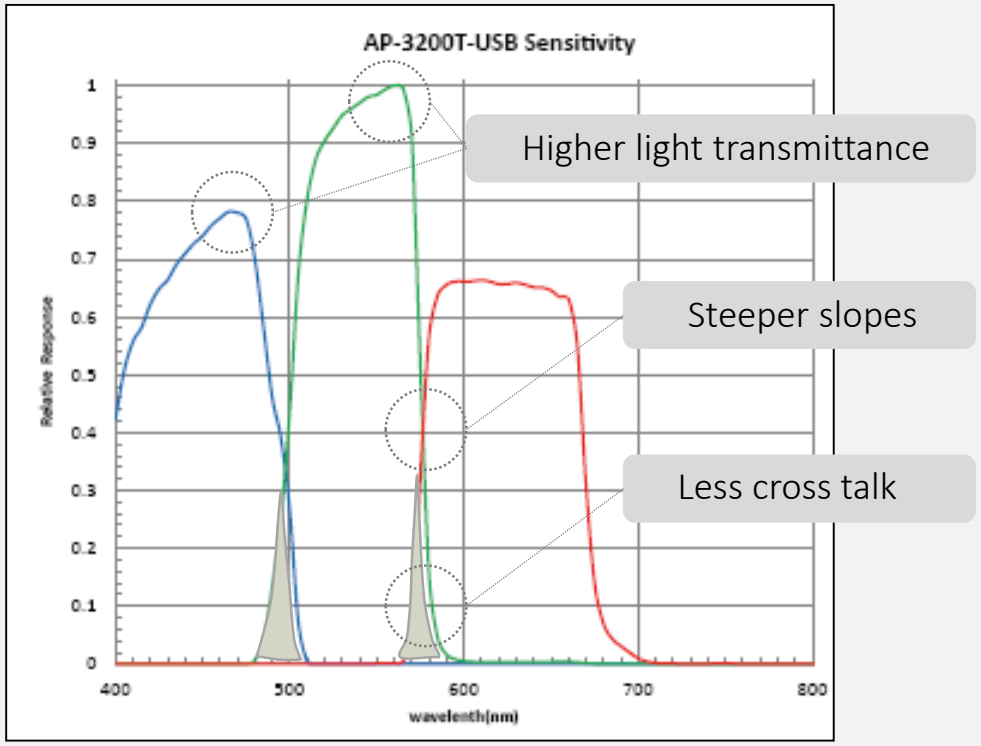


The color advantage

Less color cross talk in prism-based cameras

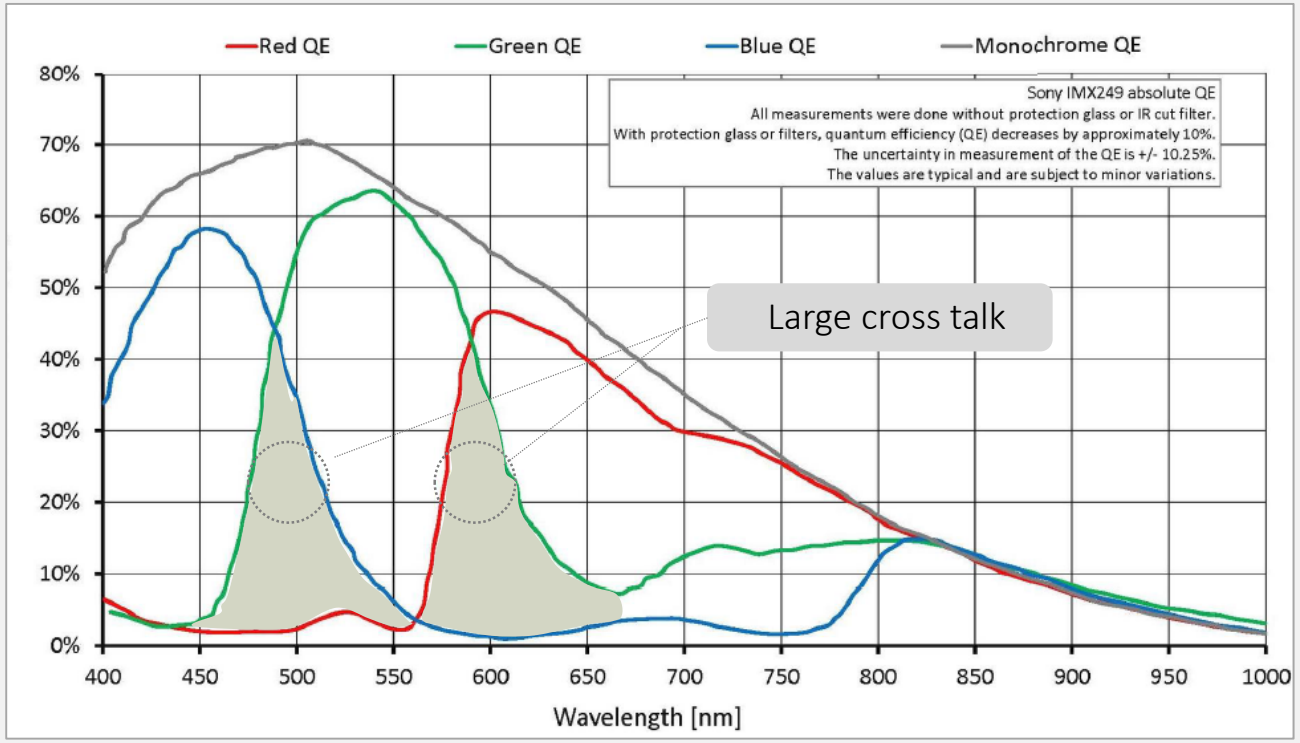
AP-3200T 3-CMOS camera

Precise wavelength cutoffs (steep slopes) using hard dichroic prism coatings provide for less color crosstalk and higher color precision.



Typical Bayer camera (IMX249)

Soft polymer dyes in Bayer filters produce much greater overlap (large color filter crosstalk) causing uncertainty in color values.



Prism-based imaging

vs.

Bayer Mosaic imaging

See the possibilities

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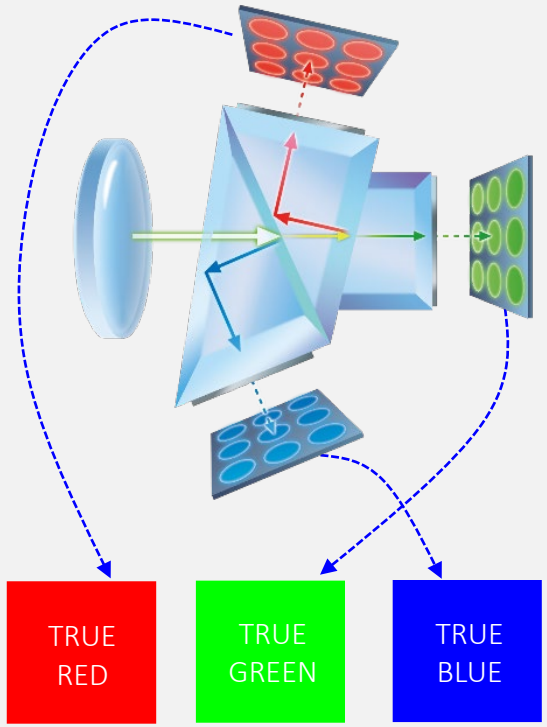
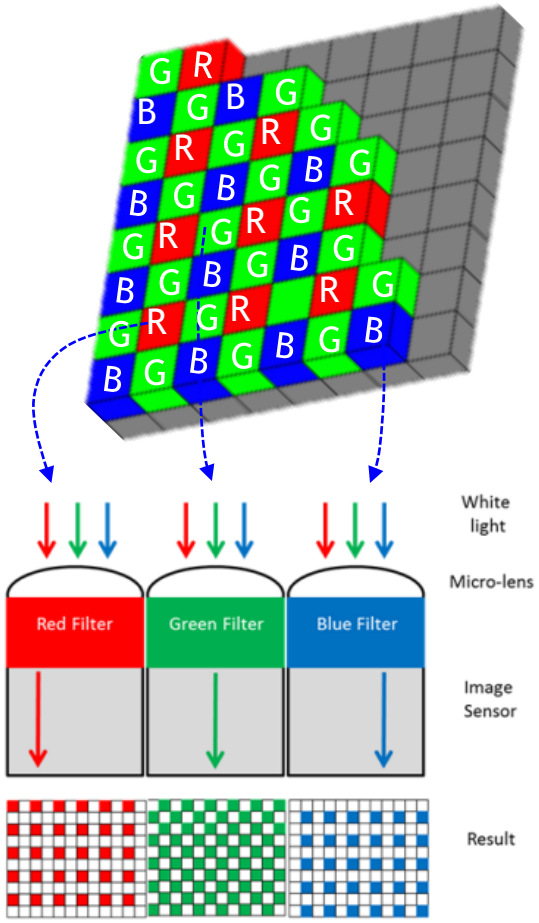
Delivering TRUE colors!

- In JAI's prism-based RGB cameras the incoming light is separated into red, green and blue wavelengths, which are directed to three precisely-aligned CMOS sensors. The JAI RGB color imaging technique provides better color accuracy and spatial precision than traditional color cameras usIng the Bayer mosaic technique.



Delivering "only" INTERPOLATED colors!

- In Bayer cameras, each pixel is filtered to record only one of three colors
- The filters absorb light that cannot pass through them
- Interpolated red, green and blue
- These algorithms make use of the surrounding pixels of the corresponding colors to estimate the values for a particular pixel



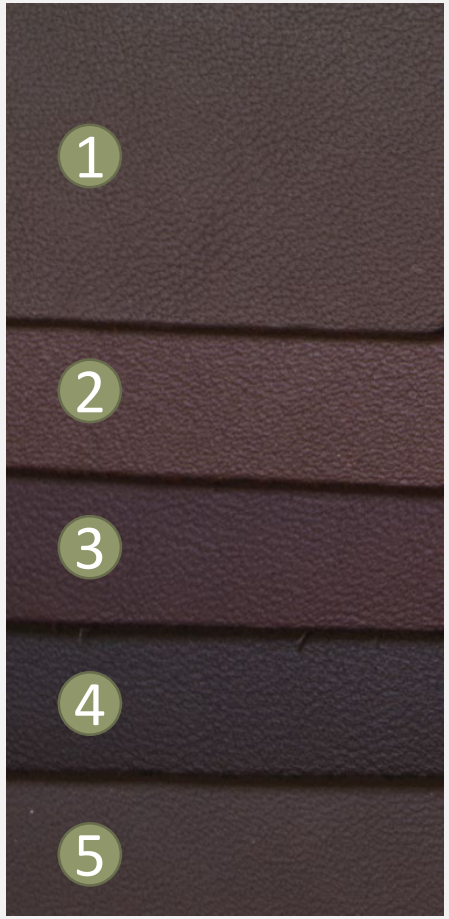
Organic material inspection

Inspection of dyed leather, to sort leather pieces in same color nuances.

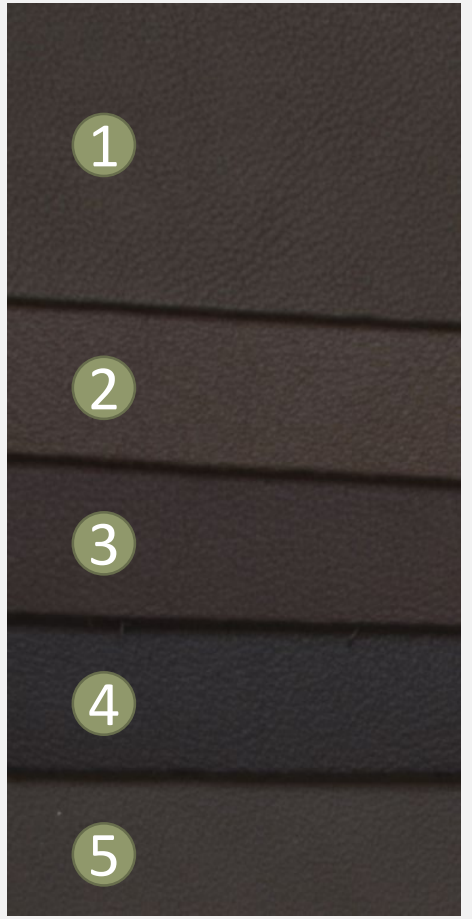
Δd color difference between the objects

	Max	Min	Avg
Bayer Camera	27.3	2.4	**15.5**
3CMOS Camera	40.6	5.3	**22.9**

Comparison between prism camera and Bayer camera



3-CMOS - AP-3200T

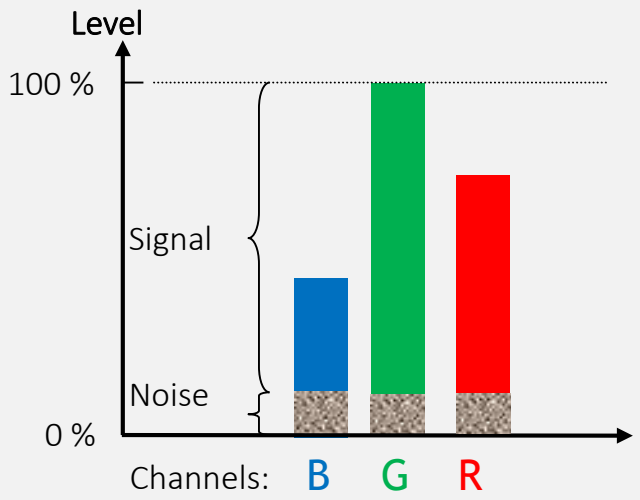


Bayer Camera - GO-5100C

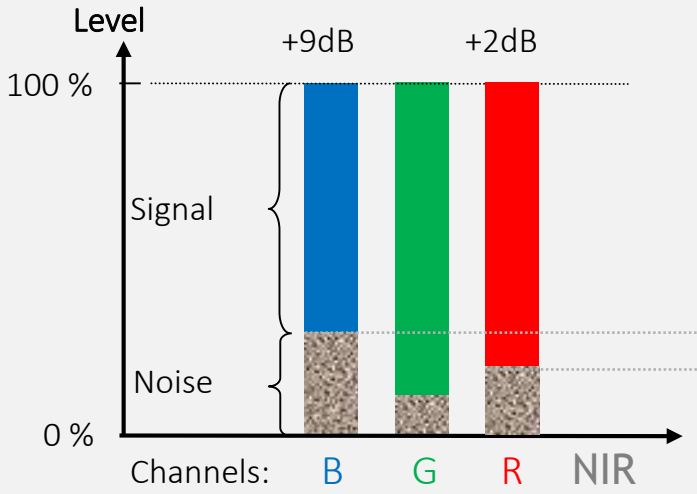
Individual exposure control

Minimize image noise using shutter-based white balancing.

Typical CMOS image.
Level balancing required!

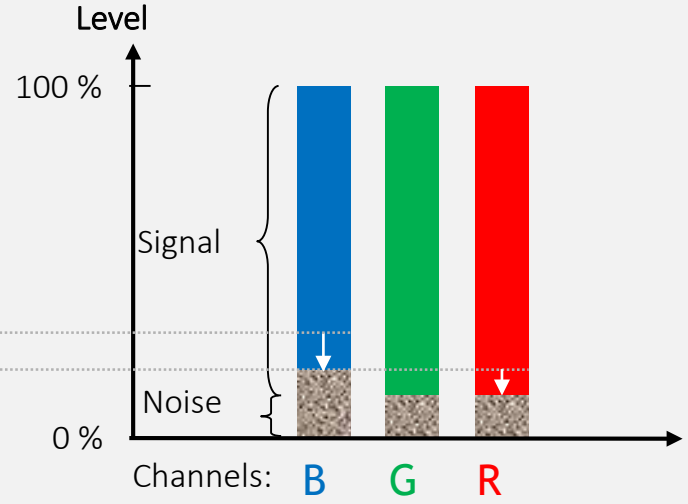


Bayer cameras can only balance levels via **gain**.



Noise increases proportionally

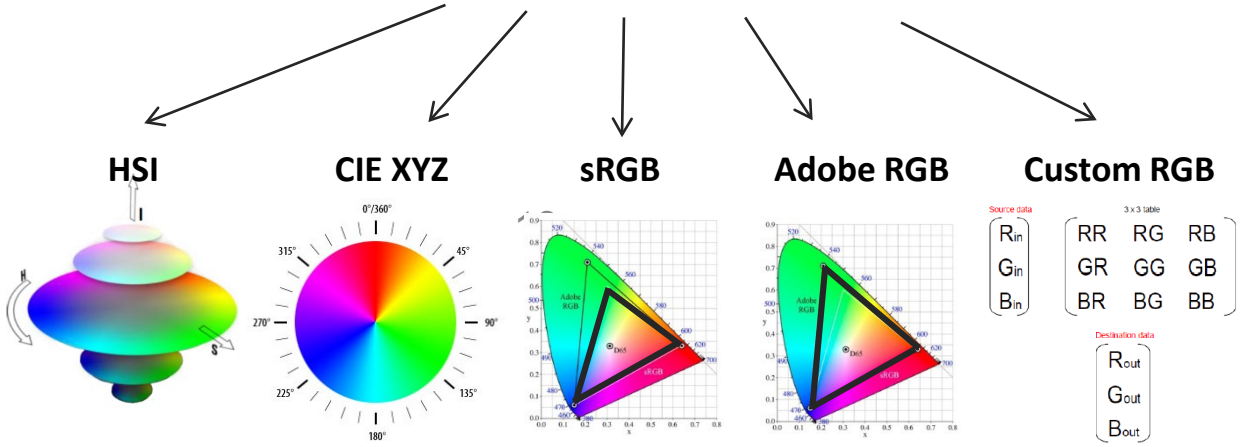
Levels balanced via
Individual **exposure** time.



Noise stays at minimum

Display and LED inspections

- Exact color values via separate R-G-B channels.
- Individual exposure control and analog gain per sensor to improve calibration routines
- Calibration of chrominance and luminance values to specified color spaces

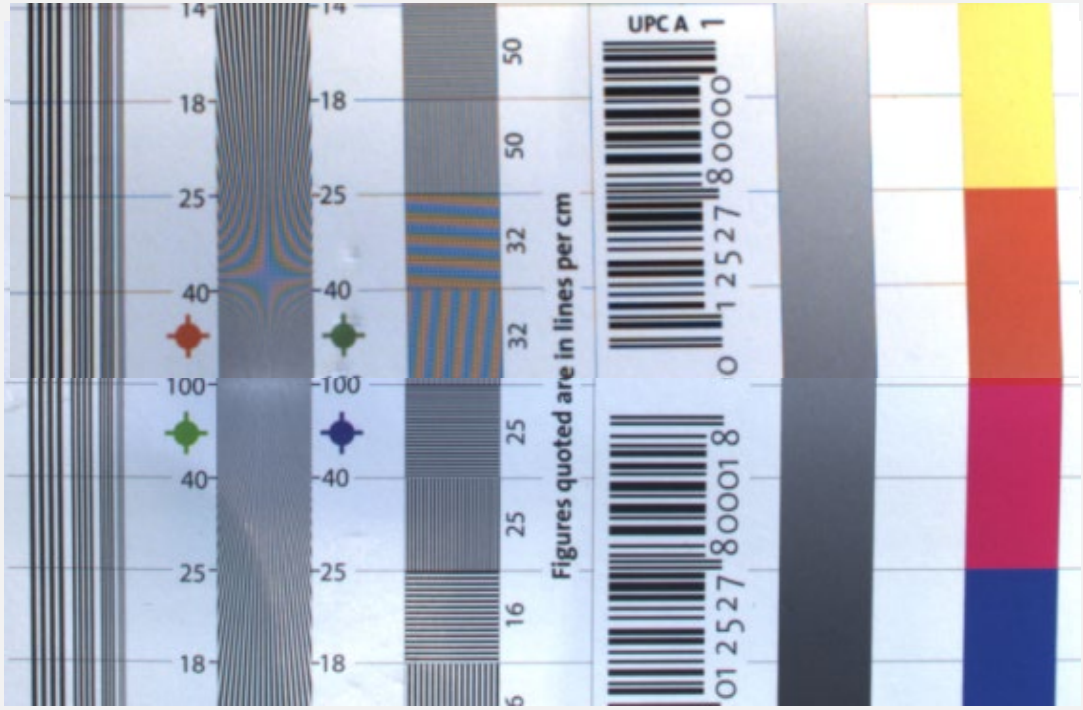


High-speed analysis | Device independent | Screen displays | Printing standard | User-specific

Image comparison – the Moiré-effect

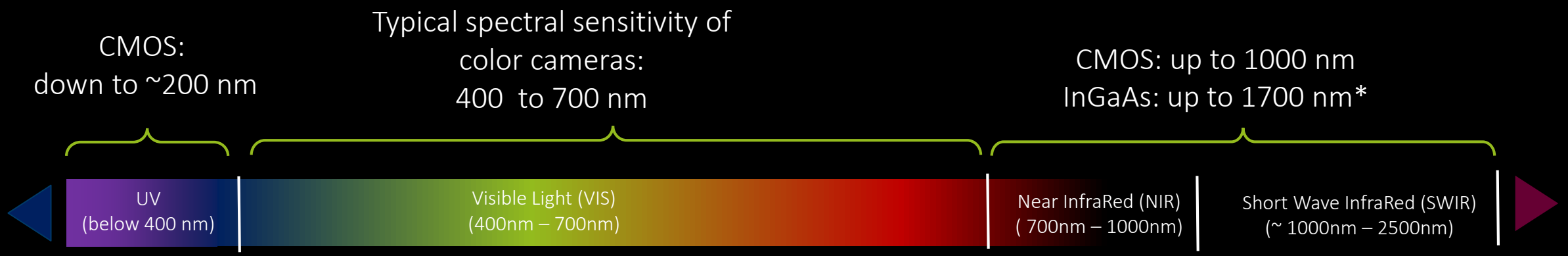
Bayer-filter RGB

Prism RGB



Going beyond colors

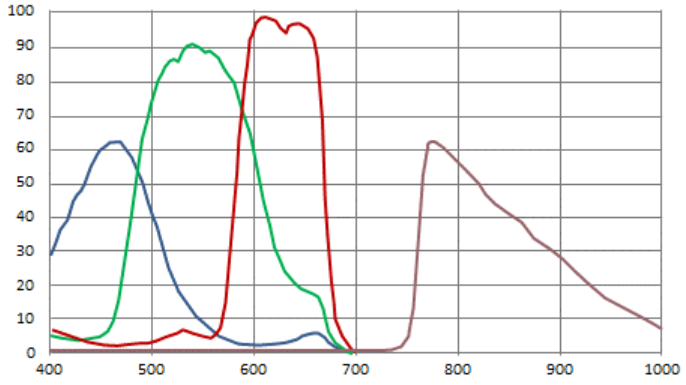
But what is beyond?



** +new technologies, such as Ge-on-Si or Quantum Dot reaching to 2000nm and above*

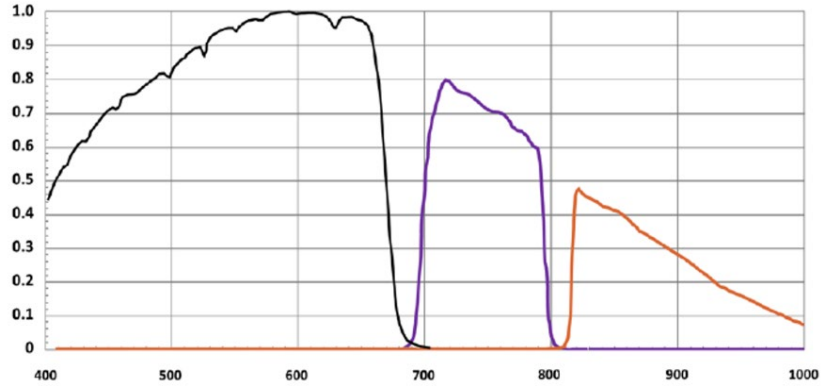
Typical multispectral combinations

- The prism must fit between the flange and the sensors
- C- mount (17.526 mm in air)
- or M42 (45.46 mm in ar)



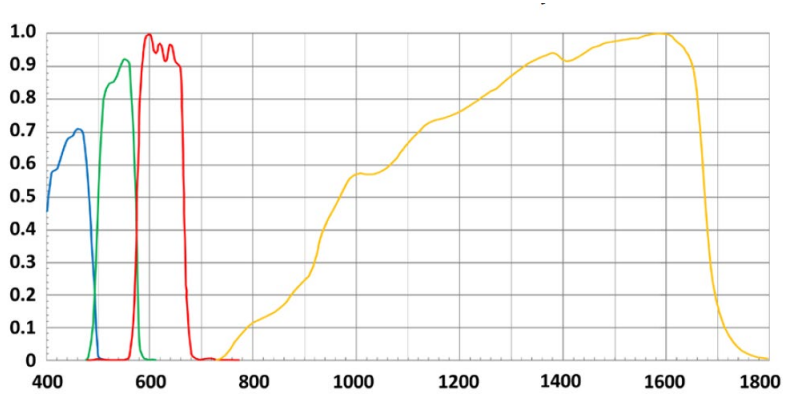
2 sensors

- Mono VIS + NIR
- Bayer VIS + NIR
- Mono + SWIR?



3 sensors

- Mono VIS + NIR + NIR
- Bayer VIS + NIR + NIR
- Mono + NIR + SWIR?



4 sensors

- R + G + B + NIR
- R + G + B + SWIR
- VIS + NIR + NIR + SWIR

Fruit sorting and grading

Lane sorting

Fruits, nuts and vegetable sorting

- Simultaneous imaging of Color + up to two NIR bands
- Optical design compactness
- Less resource and competence intensive compared to self-developed beamsplitter-based solutions
- Grading is potentially even better with customized wavebands

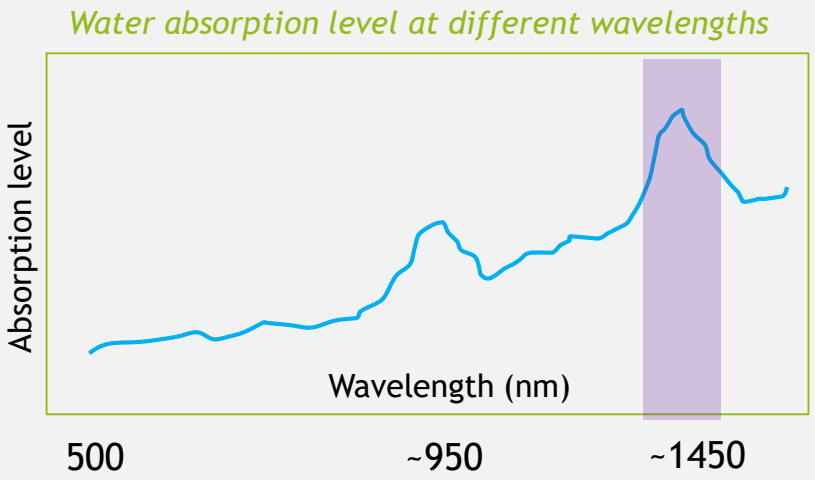
Potential inspections:

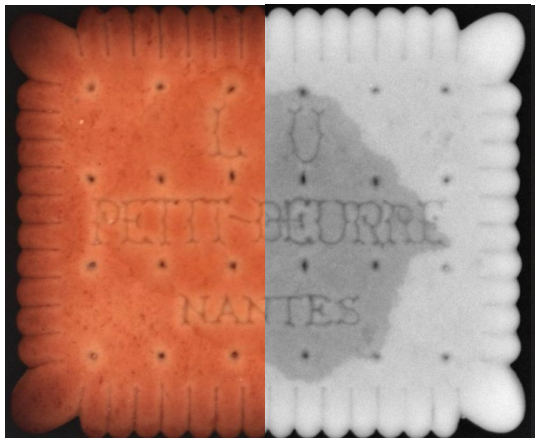
Visible R-G-B channel	NIR channel
Texture and color	Contamination, foreign materials
Unwanted shapes	Rot or signs of early decay under the skin

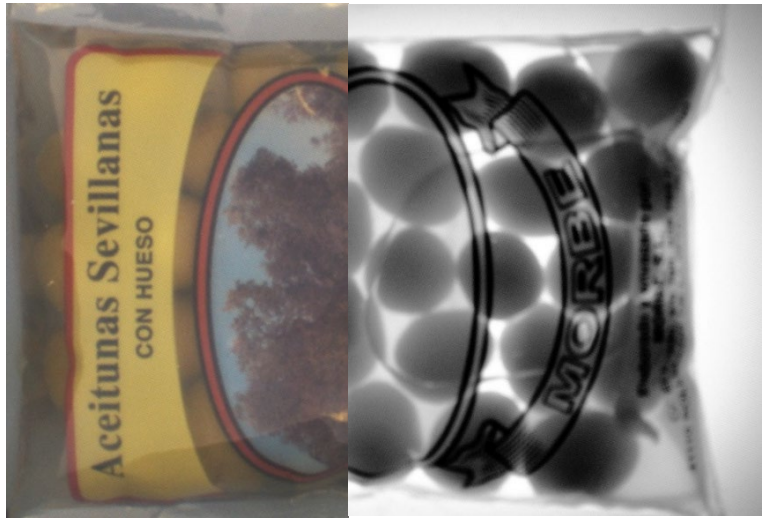
Food, Beverages and Packaging

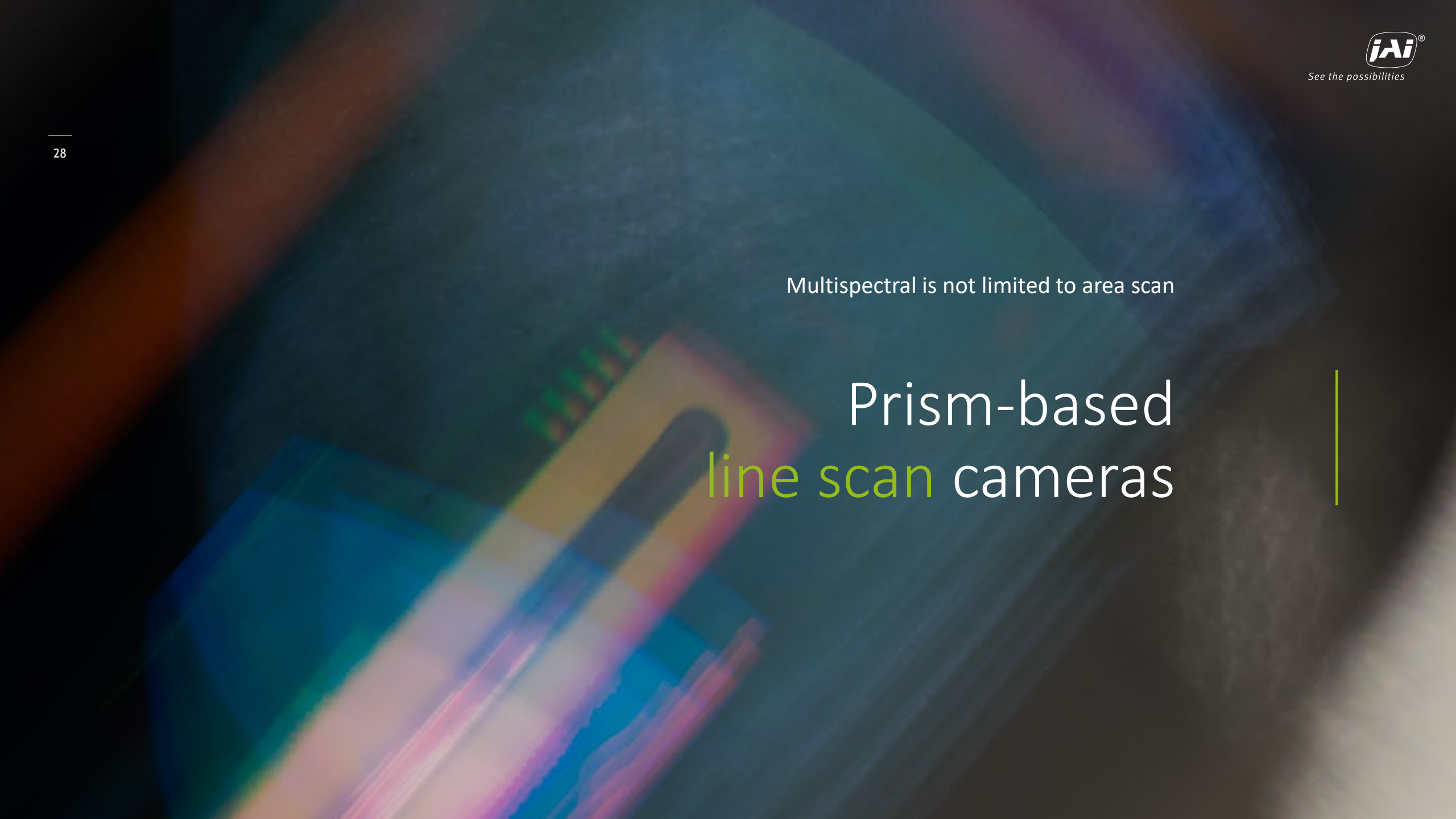
Inspection of food and beverages
and their packaging

- Water absorption peak at ~950 nm (and also at ~1450)
- Transparency of materials in NIR
- Simultaneous imaging of content and labels
- Separation of contaminations with similar visible colors





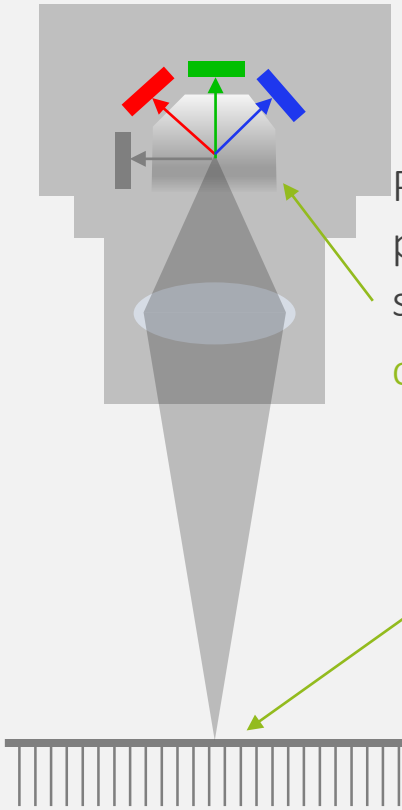




Multispectral is not limited to area scan

Prism-based line scan cameras

Prism-based imaging

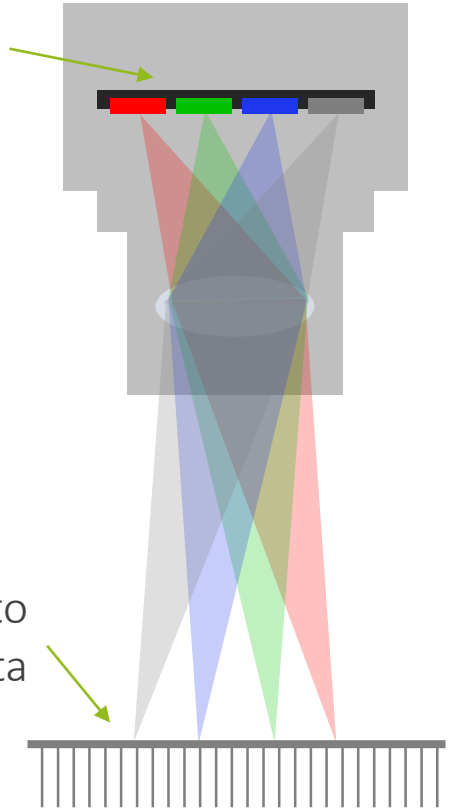


Prism splits light to precisely-aligned sensors with common optical path

No compensation required

Quadlinear imaging

Line spacing creates different optical paths



Compensation required to match all color data

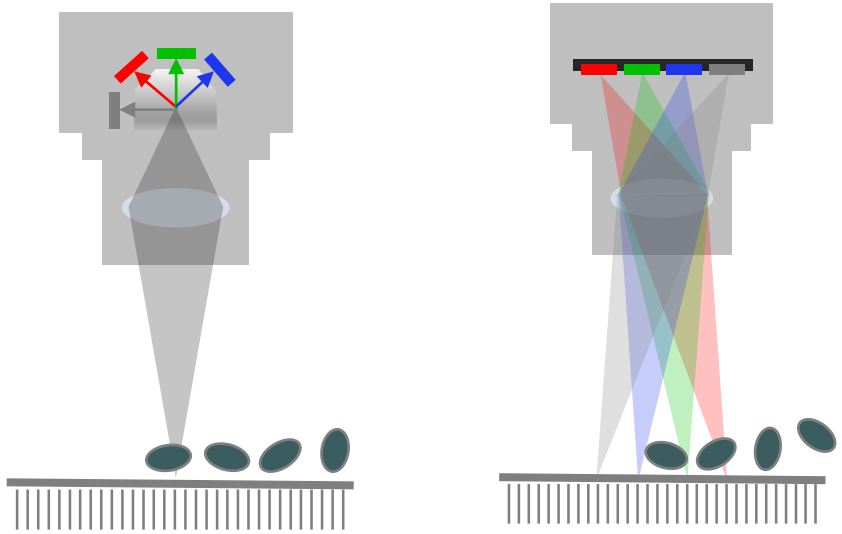
Grain, nut and vegetable sorting

Belt and Chute (free-fall) sorting

Grain, nut and vegetable sorting

Belt sorting

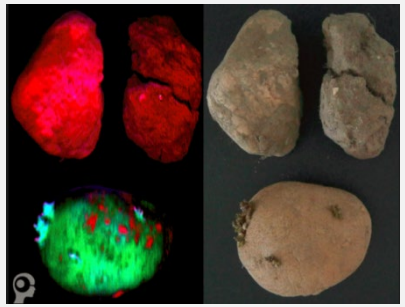
Variable object speeds, rolling objects



- Multispectral cameras with 3 or 4 seperate wavebands
- Single optical plane for all wavebands
- Immune to random changes in speed, direction, or orientation of the object
- No need for image correction algorithms to match the pixel position or wavebands

Surface defects

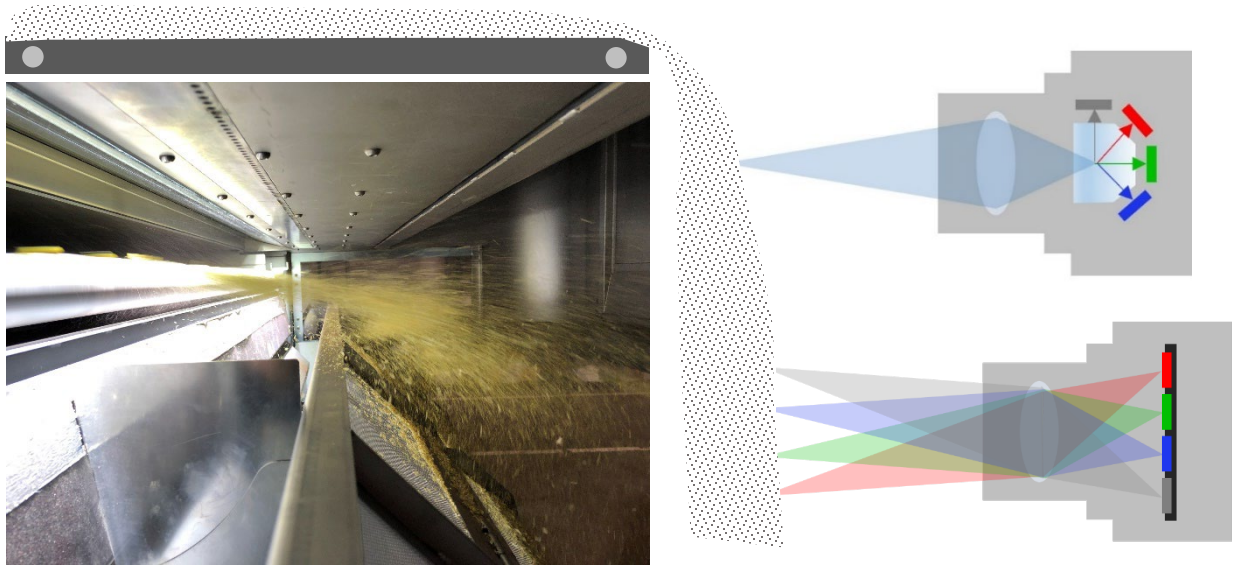
Wrong shape and size



Foreign objects

Grain, nut and vegetable sorting

Chute (free-fall) sorting



- Superior color differentiation
- Identification of foreign objects in the NIR channel

Rice before/after sorting

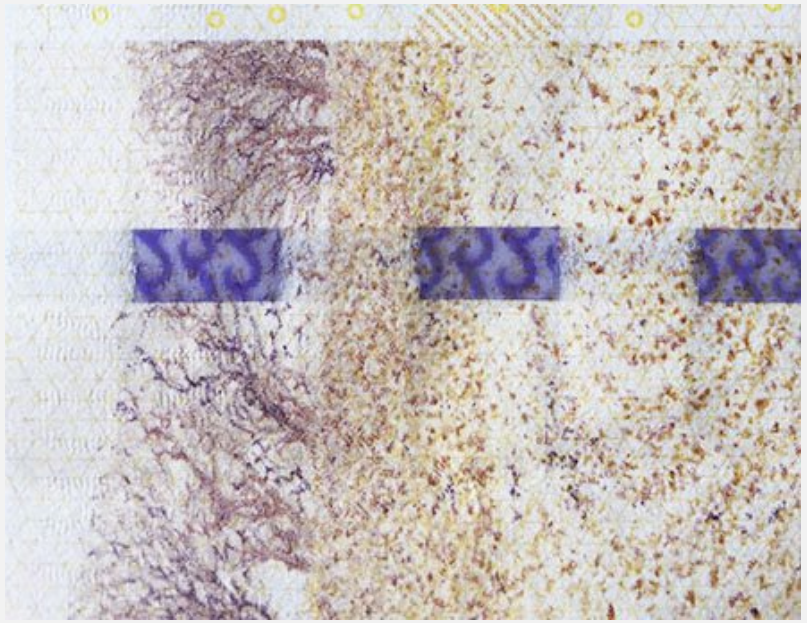
Foreign objects in tea leaves

Imperfect beans in coffee production

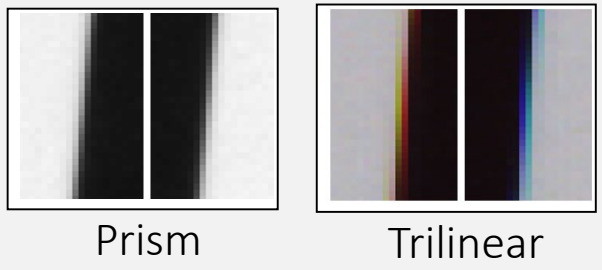
Print Inspection

Print Inspection

Banknote Inspection



Close-ups of image details



- Edges without „halo” effect
- Multiple color and NIR wavebands definable to match unique requirements of security applications
- High speed inspection in multiple wavebands simoultaneously with the same optical axis
- Immune to wave-like undulations, speed or vibration changes

Customized?

Customization

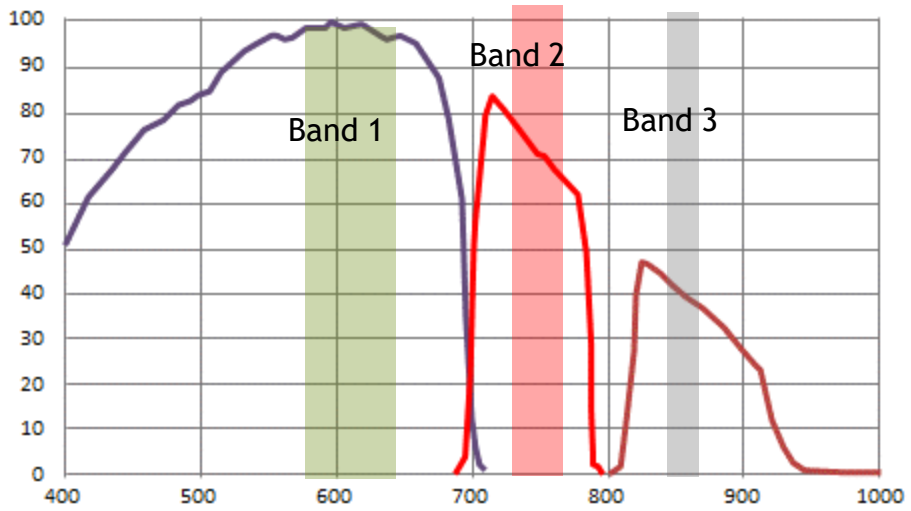
Special prisms

- Custom main bands
- Neutral density (HDR)
- Polarization

+

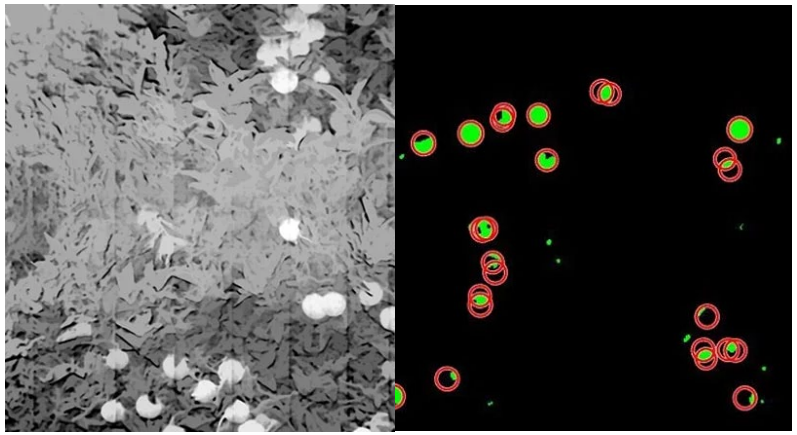
Combined with color filters for each band

- Bandpass
- High OD
- Etc.



Agriculture

Fruit yield estimation



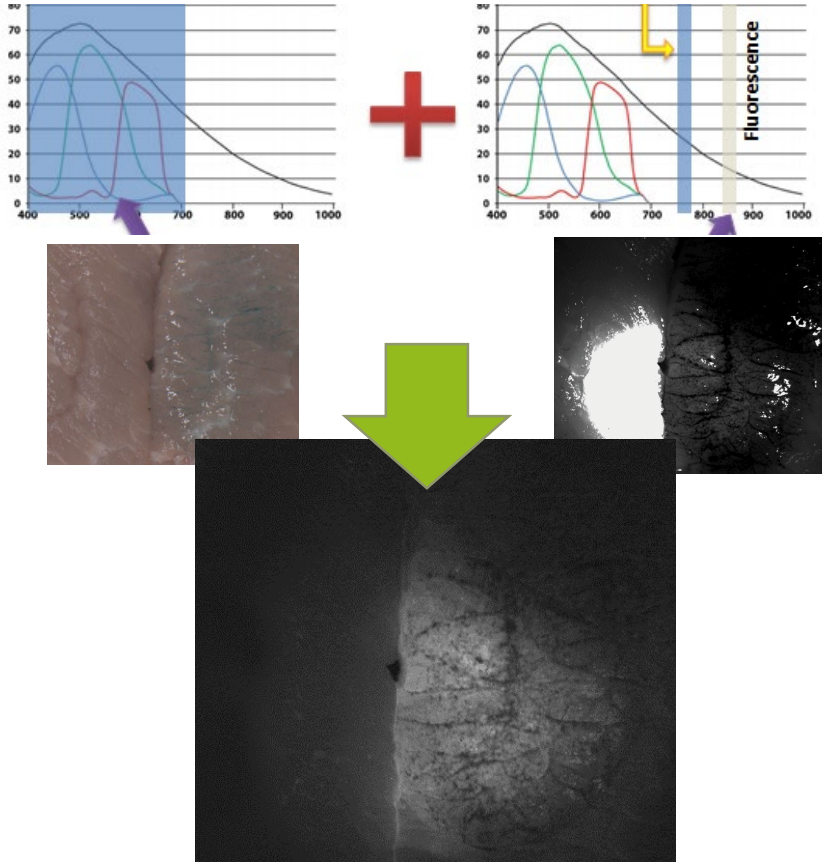
- A single optical axis for color and NIR bands (without parallax error)
- Custom wavebands to optimize the separability of fruit from leaves

Images from a leading customer in the Yield Inventory Management sector

Medical & Pharmaceutical

Medical & Pharmaceutical

- Endoscopy/Surgical Imaging
- Digital Pathology
- Medical Microscopy



- Guide to exact location of area to be operated based on flourescence (tissue with ICG dye injected)
- Custom wavebands required to match the fluorescence band of the used substance

Further applications
for Prism-based linescan

Further potential applications

Waste & Material sorting

- Incl. Waste & Plastics sorting, Textile and Raw material sorting
- Technology-based solutions to unlock new applications

Semiconductors

- Wafer and Semiconductor device inspection and alignment
  - Si crystal and ingot brick inspection for impurities
  - Defect detection within the Si wafer
  - Wafer Alignment
- Solar Panels (Si, CIGS, CIS)
  - Photoluminescence based defect inspection at 1150nm, 1300 and 1550nm
  - Micro crack detection beneath the surface
- Battery Inspection
  - Imaging through the Li:Ion separator
  - Particle Inspection betweed electrode-separator interfaces

See the possibilities

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Thank you!

For further discussion, please feel free to reach out or visit our booth: mib@jai.com

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