WHITE PAPER:

Revolutionizing Black Plastic Sorting: The Power of the Specim FX50 MWIR Hyperspectral Camera and Its Integration into Industrial Sorting Systems

SPECIM

A Konica Minolta Company

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Introduction

Plastics are ubiquitous in modern life, with global production exceeding 380 million metric tons annually. A significant portion of this production includes black plastics, which are favored for their aesthetic and functional properties, particularly in high-demand industries such as automotive manufacturing, electronics casing, and food packaging.

Currently, the recycling rate for black plastics remains very low due to the challenges associated with traditional sorting technologies. Near-infrared (NIR) imagers, commonly used for plastic sorting, struggle to detect black plastics because their carbon black pigmentation absorbs light rather than reflecting it. As a result, black plastics are often misidentified, leading to improper sorting, reduced recycling rates, and an increase in waste directed to landfills.

Across regions, stricter regulations are being enacted, requiring manufacturers to incorporate a certain percentage of recycled plastics into new products. Effective methods for sorting black plastics are needed to meet the targets.

Mid-wave infrared (MWIR) hyperspectral imaging (HSI) offers a solution to overcome the limitations of NIR-based systems and significantly improve black plastic sorting accuracy and efficiency. Optical black plastic sorting offers an efficient solution, enabling customers to sort black plastics accurately and free themselves from gravity-based sorting methods that rely on large amounts of water, salt, and other resources that contribute to environmental pollution.

This white paper demonstrates the capabilities of MWIR HSI - specifically the Specim FX50 camera - and how it can be integrated into industrial sorting systems to address this challenge. It aims to provide a comprehensive overview for industry decision-makers and technical professionals seeking to enhance their sorting processes and achieve greater efficiency in material recovery, especially in the context of black plastic sorting.

Introducing Hyperspectral Imaging (HSI) and Its Advantages in Material Sorting

HSI is an advanced technology that scans materials and captures and analyzes a wide spectrum of light across many narrow wavelength bands, far beyond what the human eye or conventional cameras can see.

This data forms a unique “spectral fingerprint” for each material, which can be analyzed using sophisticated algorithms to identify and differentiate between various materials with high accuracy.

HSI allows the differentiation of materials that would otherwise appear similar when utilizing other imaging technologies. Additionally, HSI supports real-time processing, enabling rapid, accurate, and automated sorting, making it particularly valuable for industrial sorting.

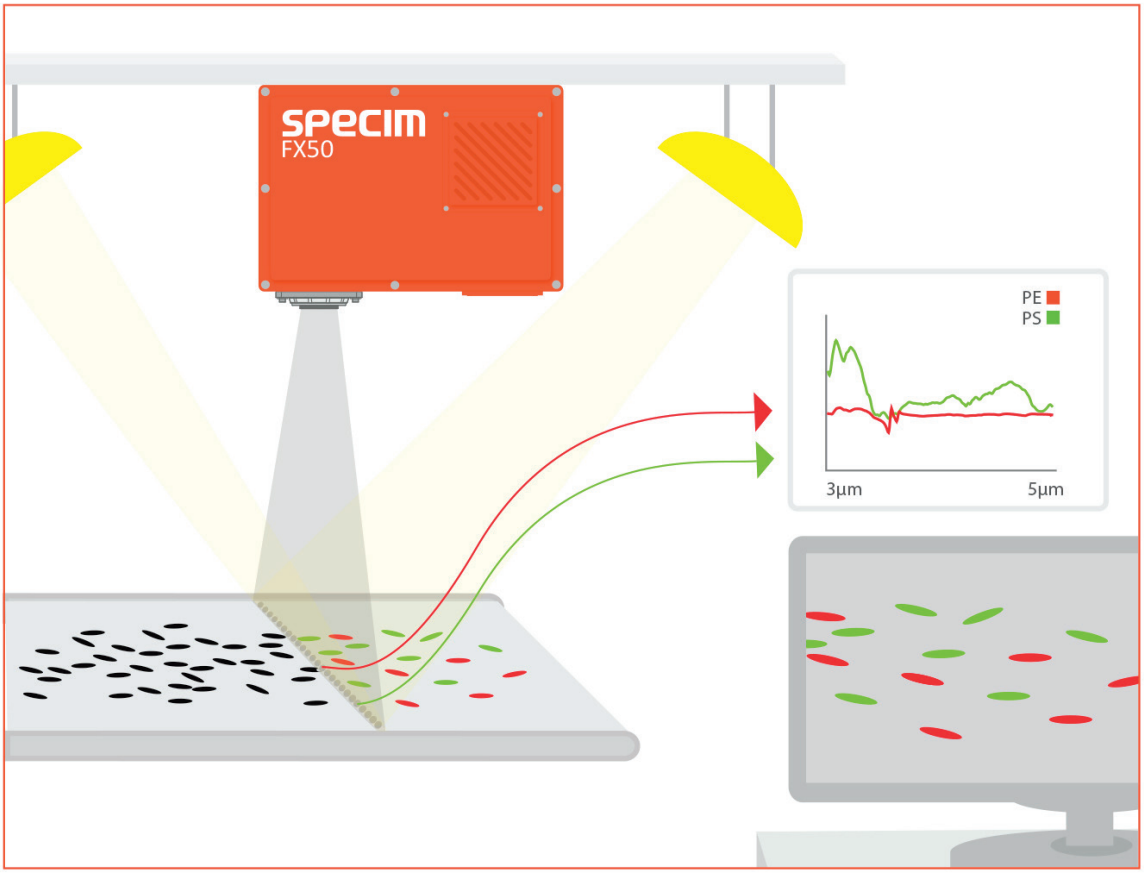

Image 1. Typical setup for inline differentiation of various black plastics using MWIR hyperspectral imaging technology

Overcoming Black Plastic Sorting Challenges with MWIR HSI

Until recently, no reliable sensor technology existed to sort black plastics for reuse. Traditional Near Infrared (NIR) sorting technologies rely on the reflection of infrared light to identify and sort plastics. However, most black plastics are colored with carbon black pigments that absorb infrared light rather than reflecting it, making them “invisible” to NIR sensors. This often leads to misidentification or exclusion from the recycling stream.

However, MWIR HSI is transforming this challenge. While Near Infrared (NIR) captures spectral information in the range of approximately 0.9 to 2.5 micrometers (µm), MWIR hyperspectral imaging captures detailed spectral information across the MWIR wavelengths from 3 to 5 micrometers (µm).

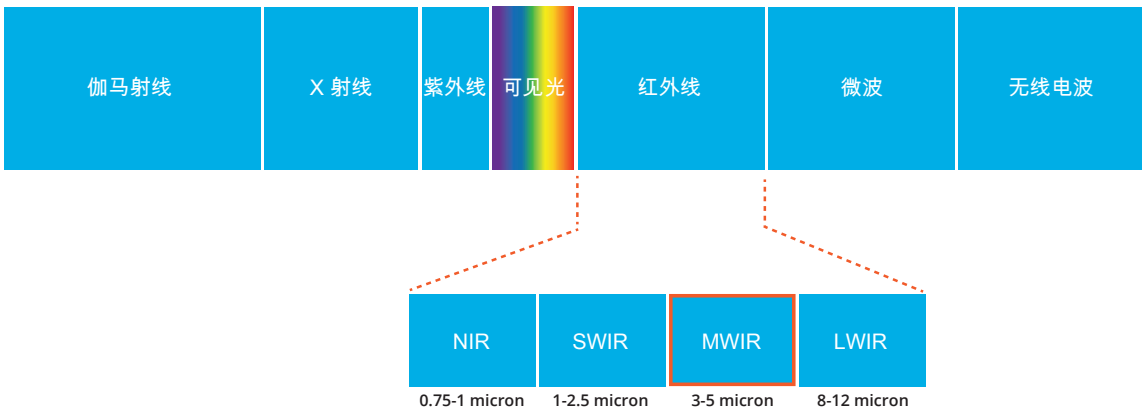

Image 2. Mid-wave infrared (MWIR) spectral range 3–5 µm

In this range, different plastics display unique spectral features due to their molecular composition (see image 3 below). As a result, when operating in the MWIR range, HSI can distinguish between different black plastic types, regardless of their color - even if black.

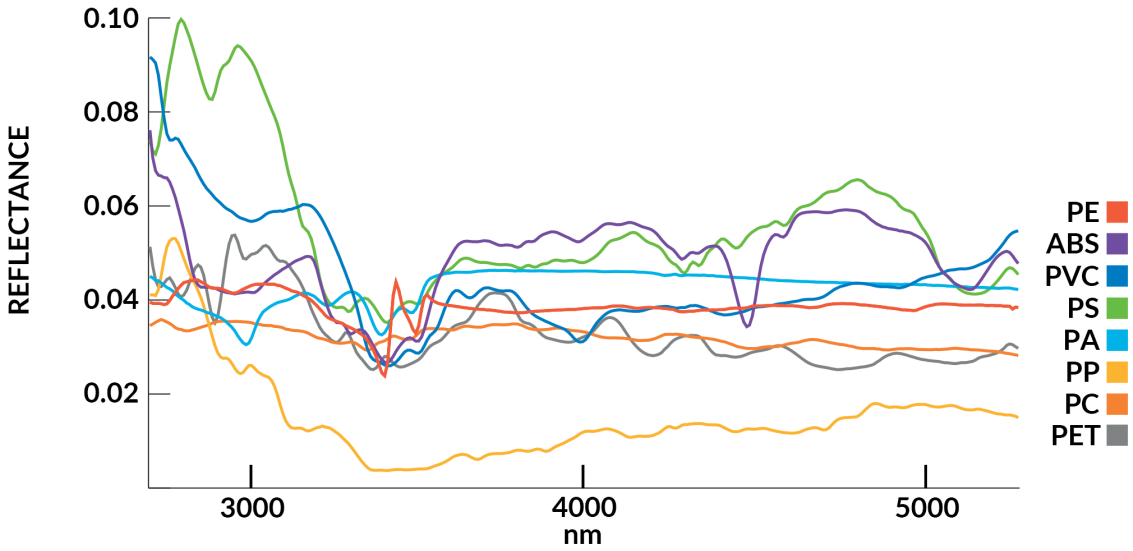

Image 3. Unique spectral signatures of different plastics in the MWIR range, measured with Specim FX50

Image 4. Common types of black plastics used in industry and sortable with HSI

Specim FX50 - A breakthrough in black plastic sorting

The Specim FX50 MWIR addresses the challenge of “invisible” black plastics by operating in the mid-wave infrared (MWIR) range. It is the first hyperspectral camera on the market to cover the full MWIR spectral range of 2.7 – 5.3 µm, which is crucial for sorting black plastics. This capability allows it to detect spectral features that traditional NIR cameras simply cannot see.

Specifically designed for industrial sorting applications, the Specim FX50 offers the speed, resolution, sensitivity, and durability required for reliable inline sorting. Utilizing its MWIR capabilities, the Specim FX50 can effectively identify black plastics, rubbers, and non-black plastic compositions.

Image 5. Specim FX50 MWIR hyperspectral camera

Specim FX50 allows fast and reliable sorting of:

- Black plastics
- Rubbers
- Non-black plastics and rubbers

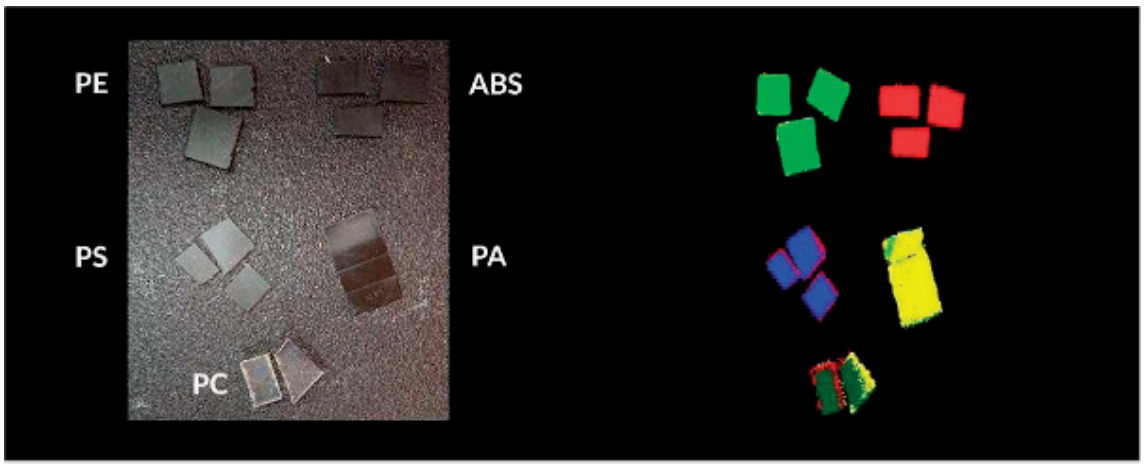

Image 6: Example of RGB and HSI images of different black plastics measured in a laboratory using the Specim FX50 camera

The Specim FX50 uses push-broom technology, which is highly advantageous in industrial sorting applications. Its rapid scanning and detection capabilities allow accurate real-time identification of moving objects on conveyor belts, reducing costs associated with identification errors.

For example, the Specim FX50's fast frame rate and high spatial resolution allow it to sort 300 kg of 2x2 cm plastic flakes per minute on a 1-meter-wide conveyor belt running at 2 m/s with nearly 99% accuracy. (*)

This high throughput and precision make the Specim FX50 a highly competitive option for the recycling industry, where speed, precision, and cost efficiency are crucial.

(*) Final speed and output are subject to variation based on operational conditions and the types of plastics being sorted.

HSI and X-Ray Sensor Fusion for Sorting Flame-Retardants (FR)

Flame-retardant (FR) compounds can influence plastic detection because they alter certain properties of the material. However, the presence of FR does not prevent plastics from being identified. Flame retardants may or may not be visible during detection, and in most cases, they are not.

The Specim FX50 can detect various types of plastics, even those containing some flame-retardant compounds. Although it may not always detect the FR itself, this limitation can be mitigated through sensor fusion by combining hyperspectral imaging (HSI) with X-ray technology. While the FX50 identifies plastics accurately, X-ray technology complements it by detecting the presence of flame retardants based on differences in material density. This integrated approach provides a more comprehensive solution for sorting black plastics, particularly in sectors where flame-retardant compounds are increasingly used, such as automotive manufacturing.

How to integrate FX50 with Sorting Systems

There are two primary ways to integrate the Specim FX50 with an industrial sorting system: using the SpecimONE platform or through the SDK (Software Development Kit) option, depending on the needs and resources of the customer.

1. Integration with the SpecimONE Platform

The SpecimONE platform offers a complete solution for integrating the Specim FX50 camera with sorting systems, from data collection to real-time processing.

Image 7. The SpecimONE spectral imaging platform includes industry-proven Specim FX50 hyperspectral camera, SpecimCUBE processing hardware, and SpecimINSIGHT HSI data-analysis software tool

Data Analysis and Classification with SpecimINSIGHT:

SpecimINSIGHT software can be used to analyze the spectral data captured by the FX50 camera. This software allows users to examine the unique spectral signatures of different materials and create classification models based on the data.

Real-Time Processing with SpecimCUBE:

Once classification models are created using SpecimINSIGHT, they are transferred to the SpecimCUBE real-time processing platform. SpecimCUBE is designed for high-speed, inline processing, converting spectral data from the Specim FX50 into real-time sorting decisions. This platform ensures fast and precise sorting performance in demanding industrial environments.

SpecimCUBE is compatible with GigE Vision, a global standard for high-speed image data transmission, enabling seamless integration of the Specim FX50 with a wide range of sorting machines and industrial automation systems.

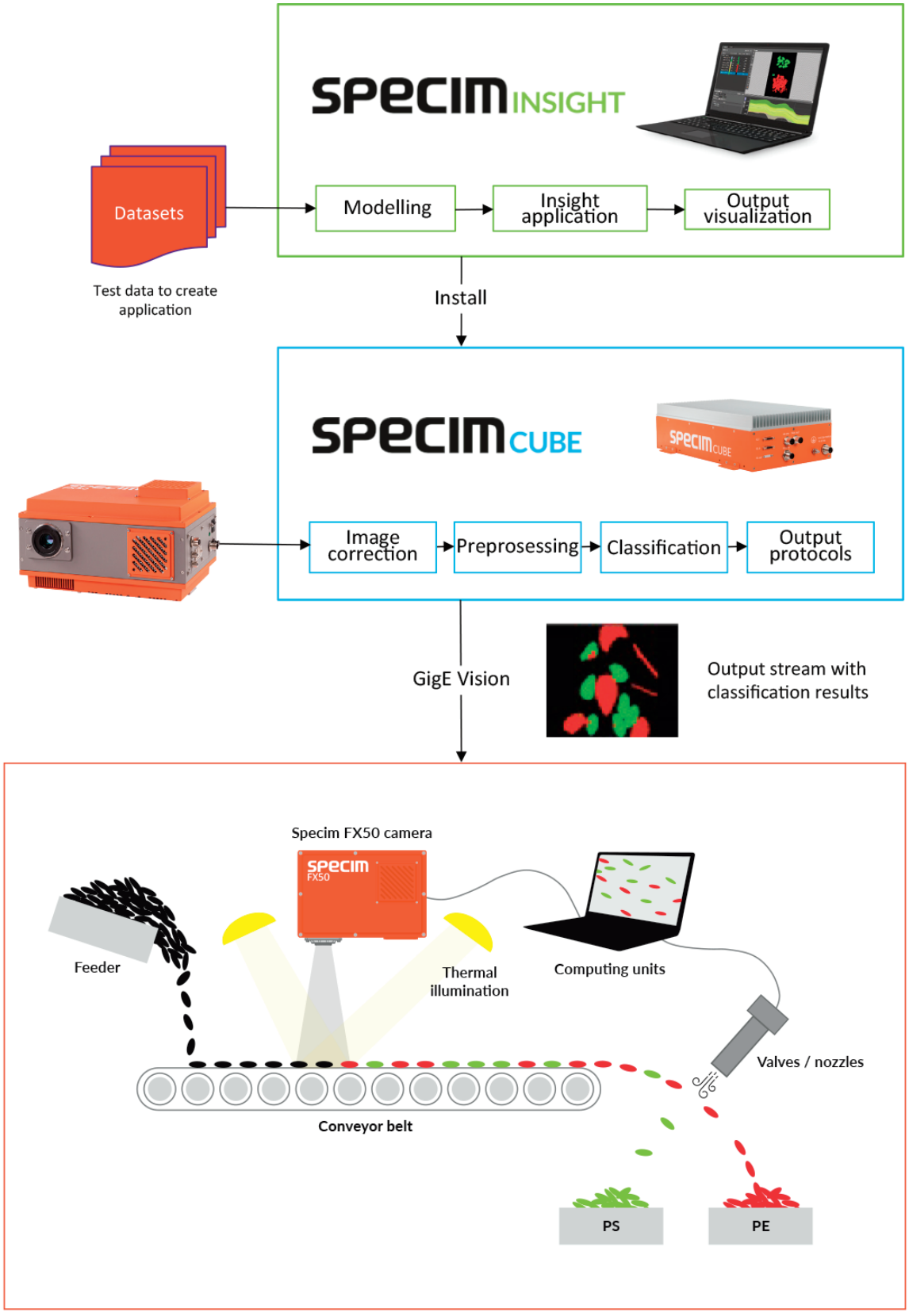

Image 8. Integration of the Specim FX50 with sorting systems for real-time black plastic sorting

2. Integration via SDK (Software Development Kit)

The second option is integrating the Specim FX50 camera using the SDK, which offers more flexibility for customers who prefer to develop their own processing hardware and software.

With the SDK, customers are provided with the tools needed to access the camera's raw data and develop custom algorithms for material sorting. In this approach, the customer is responsible for building the entire processing pipeline, from data collection to real-time processing, using their own hardware and software infrastructure. This option is ideal for users with specific or highly customized requirements and in-depth knowledge of HSI.

MROI Functionality to Optimize Sorting Algorithms

The MROI (Multiple Regions of Interest) functionality in the Specim FX50 allows users to select specific parts of the spectral data most relevant to their application. This means you can focus the camera's processing power on certain wavelength ranges that are important for identifying specific materials while ignoring other irrelevant parts of the spectrum.

For example, CO2 interference affects the spectral data in the mid-wave infrared (MWIR) range, typically around the wavelengths of 4.2 to 4.4 micrometers (µm). CO2 strongly absorbs infrared light in this range, which can confuse the spectral readings when sorting materials like plastics.

By removing this irrelevant data, the system reduces confusion in the analysis, ensuring a more precise and accurate hyperspectral picture and the sorting process becomes more efficient in several ways:

- **Faster Processing:** With fewer spectral bands to analyze, the camera can process data more quickly.

- **Reduced Data Load:** The system processes only the relevant data, lowering the demand on processing memory.

- **Improved Robustness:** By focusing only on meaningful spectral data, the algorithm becomes more robust and less prone to errors caused by irrelevant spectral information

Overall, MROI enhances the performance of sorting systems by streamlining data processing and ensuring more accurate and efficient sorting.

Consistent Results Across Cameras with Unified Spectral Calibration

Regardless of the integration approach, one of the key advantages of the Specim FX50 is its unified spectral calibration. The Specim FX50 cameras are all calibrated to the exact specifications during production. This standardized calibration eliminates the need for software adjustments for wavelength variability, ensuring consistent spectral data across all units.

This unified spectral calibration means that users can build sorting models with one Specim FX50 camera and transfer them to other FX50 (or any Specim FX model cameras) without additional recalibration, saving time and ensuring consistent results across different systems.

Recommended operating conditions

Illumination requirements

Illumination plays a critical role in the performance of the Specim FX50 MWIR hyperspectral camera. The camera requires a strong, uniform, and stable thermal light source. Proper illumination ensures that the spectral features of the materials are clearly visible, even at high conveyor speeds. The illumination system must emit light in the MWIR range (3 to 5 micrometers).

Tips for Optimizing Illumination:

- A thermal illumination source with a temperature range of 900 – 1,000 Kelvin is typically used, providing sufficient intensity for the camera to capture accurate spectral data.

- We recommend using a heating element made from an alloy, as it ensures the light source remains durable and stable over time, providing consistent thermal radiation.

- Specim offers different illumination options and can also recommend suitable third-party solutions based on your specific needs and application setup.

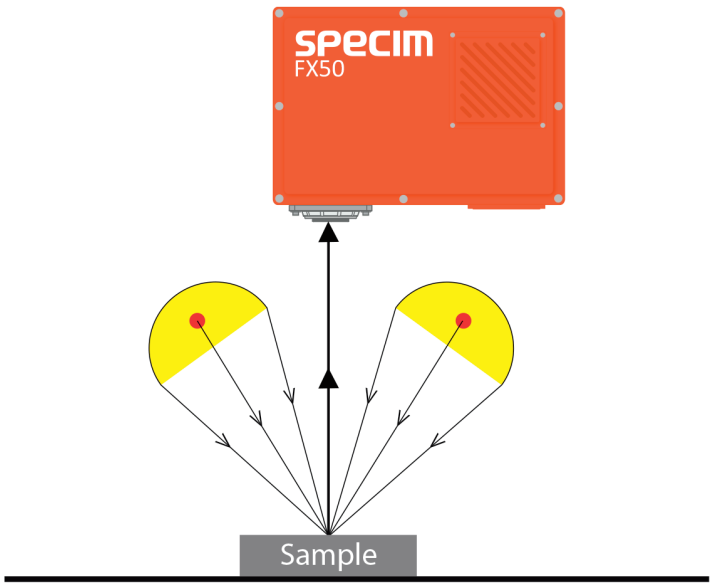

Image 9. Specim FX50 requires uniform and stable thermal illumination

Operating Temperature and Vibration

Maintaining a stable operating temperature and controlling vibration are critical for maximizing the performance and longevity of the Specim FX50. You can optimize the FX50's performance and extend its operational life with the following considerations.

Thermal Emission Sensitivity and Stabilization

- **Operating Temperature:** To ensure the camera's components, including the optics, stability and achieve the longest possible lifespan, the ambient operating temperature should be kept between 5 – 25°C.

- **Temperature Stability:** For the most accurate spectral readings, the camera's optics should maintain temperature fluctuations within +/- 1°C, as larger variations may affect material identification accuracy.

- **Temperature-Stabilized Optics:** The Specim FX50 features temperature-stabilized optics, with tightly controlled internal temperatures of the optical components, minimizing thermal drift and providing consistent, reliable hyperspectral images.

- **Advanced Cooling:** The Specim FX50 has an advanced cooling system that keeps the sensor at an optimal temperature, reducing dark noise (interference) and maintaining high sensitivity for clear, accurate spectral readings.

- **Temperature-stabilized casing:** We also recommend using a temperature-stabilized casing to protect the camera from fluctuations, dust, and debris. Customers typically design their own casings following our recommendations, but there are also specialized casing providers who can offer tailored solutions.

Vibration Control

Vibration is a common challenge in industrial environments, especially in conveyor systems used for sorting. Excessive vibration can not only affect the camera's stability and compromise the accuracy of spectral data but also shorten the camera's lifespan over time, which is why it needs to be limited.

To minimize the impact of vibration and extend the camera's operational life, we recommend mounting the camera separately from the conveyor system. Additionally, using vibration dampers on the apparatus feet can further reduce the transmission of vibrations, helping to protect the camera and ensure consistent data accuracy.

Summary and Conclusions

The Specim FX50 hyperspectral camera tackles one of the biggest challenges in modern recycling: sorting black plastics. Unlike traditional NIR-based systems, the FX50 leverages unique spectral signatures in the MWIR region, enabling precise identification of different plastics - even the most challenging black plastics – and rubbers.

With high-speed processing and nearly 99% sorting accuracy, the Specim FX50 offers a reliable inline solution for industrial sorting. Its design ensures seamless integration into existing systems, optimized for high-throughput operations.

By adopting the Specim FX50, industries can significantly improve recycling rates and meet regulatory requirements.

Contact us today to learn more or get additional technical details. Our experts are ready to support you in implementing this advanced technology into your operations.

Contact us

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Specim is a global leader in hyperspectral imaging solutions, offering an extensive range of hyperspectral cameras across VNIR, NIR, SWIR, MWIR, and LWIR wavelength ranges, along with spectrographs, software, and accessories designed to meet diverse industrial and scientific requirements.

As part of the Konica Minolta Group, Specim operates worldwide, with headquarters in Oulu, Finland, and sales offices in Germany, Spain, China, and the United States. Through a strong global distributor network, we provide localized support to our customers around the world.

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Appendix i. Specim FX50 technical specifications

Spectral range	2.7 – 5.3 µm
Spatial resolution	640 pixels
Frame Rate	377 fps
Dynamic Range	2000:1 (1.5ms); 5000:1 (0.2ms)
Max SNR	1300:1 (1.5ms); 1800:1 (0.2ms)
Sensor material	MCT
Full well capacity	5.0 Me- (IWR), 6.36 Me- (ITR)
Connectors	Ethernet, Aux, Power, Trig In, Trig Out
Cooling	Optimized thermal management for enhanced cooler lifetime
Dimensions (L x W x H)	280 x 202 x 161 mm
Weight	7.0 kg

You can download the Specim FX50 datasheet from https://www.specim.com/products/specim-fx50/