Sorting blueberries

Acquiring impurities in blueberries by means of Hyperspectral Imaging

An optical sensor evaluating the spectral behaviour in the NIR (Near Infrared) range (up to 1.7µm) can make an extremely accurate distinction between blueberries and (organic) impurities, such as leaves, stems, worms or insects. If the overall system is designed suitably while considering the background, still other impurities, (which are anorganic), such as stones, can be detected.

As is known from literature, spectral analysis in the VIS (visual) up to the NIR range (e.g. 1.0µm) will also furnish information usable for this task. An optical sensor working in this wavelength range cannot only acquire the "material properties", such as the sugar or chlorophyll content, but also the colour of the blueberries.

This report shows that the ***Hyperspectral Imaging System HELIOS NIR made by EVK*** *is optimally suited for these tasks. Thanks to* ***HELIOS NIR****, the spectra can be acquired and evaluated on-line in sufficient quality and local resolution. The system* ***HELIOS Complete NIR*** *will deliver all the required information on-line and will even generate the control signals for ejecting the undesired parts.*

Keywords: *optical grading of food, optical sorting of food, spectral imaging, hyperspectral imaging, imaging spectroscopy, sensor based sorting*

Introduction

EVK develops and produces optical and inductive **sensor systems for sorting bulk material according to the "colour, shape, size and structure"** and has, by now, more than 15 years' experience.

The sensor technology that is available at EVK and has been established in the field of recycling and reusing bulk material and has, from the start, been used successfully for glass, plastics, paper and metal recycling plants **also is optimally suited for being used for sorting food** (fruit, potatoes, grain and corn, vegetable, etc.). Technology of imaging spectroscopy, which has the product name **HELIOS** at EVK, in particular, goes hand in hand with ever improving efficiency and performance and is outright predestined for applications in food industry due to its measuring principle.

EVK offers three product variants, namely **HELIOS Core, Class and Complete**. The functional differences of these variants are shown in Fig. 1.

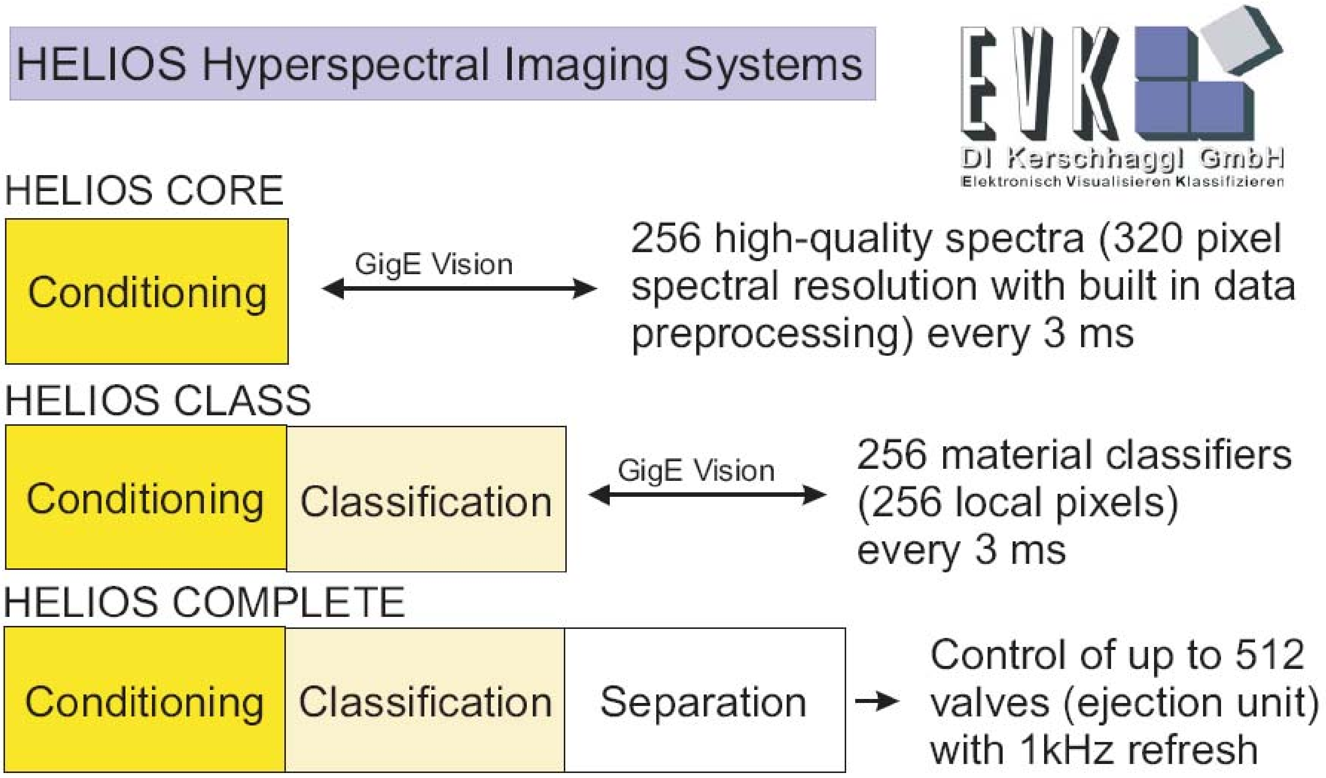

Fig. 1: Functionality of HELIOS Core, Class and Complete

Bases

In chemical terms, infrared radiation will incite covalent molecule bonds in (mostly) organic compounds. Detection usually occurs in the NIR range (up to approx. 2.0µm). Then there will be overtone or combination vibrations of the base vibration, which is in the medium infrared range (2.5µm – 10µm). This means NIR spectroscopy is a contactless method for determining organic compounds in various food products, which is almost ideal.

Tasks for sorting blueberries

After being harvested, the blueberries will be deep frozen unless they are processed at once. Before this, the majority of the impurities will be ejected by means of well established and matured (mechanical) processes. Before the further treatment of the (frozen) blueberries, the fruit processors would optimally have to minimize the share of the unripe (green) blueberries as well as the residual impurities contained – optimally to zero. Sorting out of green blueberries as well as removal of impurities, which differ from the blueberries in their colour, shape and size, are solved by means of colour cameras. As for such organic impurities as leaves, stems, beetles or other insects, there is no satisfactory solution yet. Colour cameras cannot detect these impurities safely enough. For as a rule, these impurities will be coloured in blue by the juice of the blueberries, and their shape cannot be clearly distinguished from that of the blueberry neither. In addition, such impurities as leaves or stems sometimes adhere to the blueberries and cannot even be seen in case of careful manual picking and screening.

Solution using Hyperspectral Imaging

In the NIR range, the shape of the spectra of blueberries, leaves, stems, worms, insects, etc., differs a lot. Therefore, these organic impurities can safely be detected and ultimately ejected automatically by using imaging spectroscopy – **Hyperspectral Imaging**.

In this report, **the classification of blueberries and impurities**, such as leaves, stems, worms and insects, using **the contactless optical Hyperspectral Imaging System "HELIOS Complete NIR"** will be described in more detail while reviewing its suitability for this use.

The recording technology and results will be presented below.

Description of the test configuration

The test configuration shown in Fig. 2 is suitable for static and dynamic recording of test material. In case of static recording, **HELIOS Complete** is standing vertically while the test objects are lying on the horizontal base. The overall unit consists of a transporting base, lighting and **HELIOS Complete**. This unit can be tilted so that the horizontal transporting base will be turned into a chute with a variable inclination, over which the test material can be fed via a feeder and led past **HELIOS Complete**. In this process, **HELIOS Complete** will always be standing vertically to the transporting base.

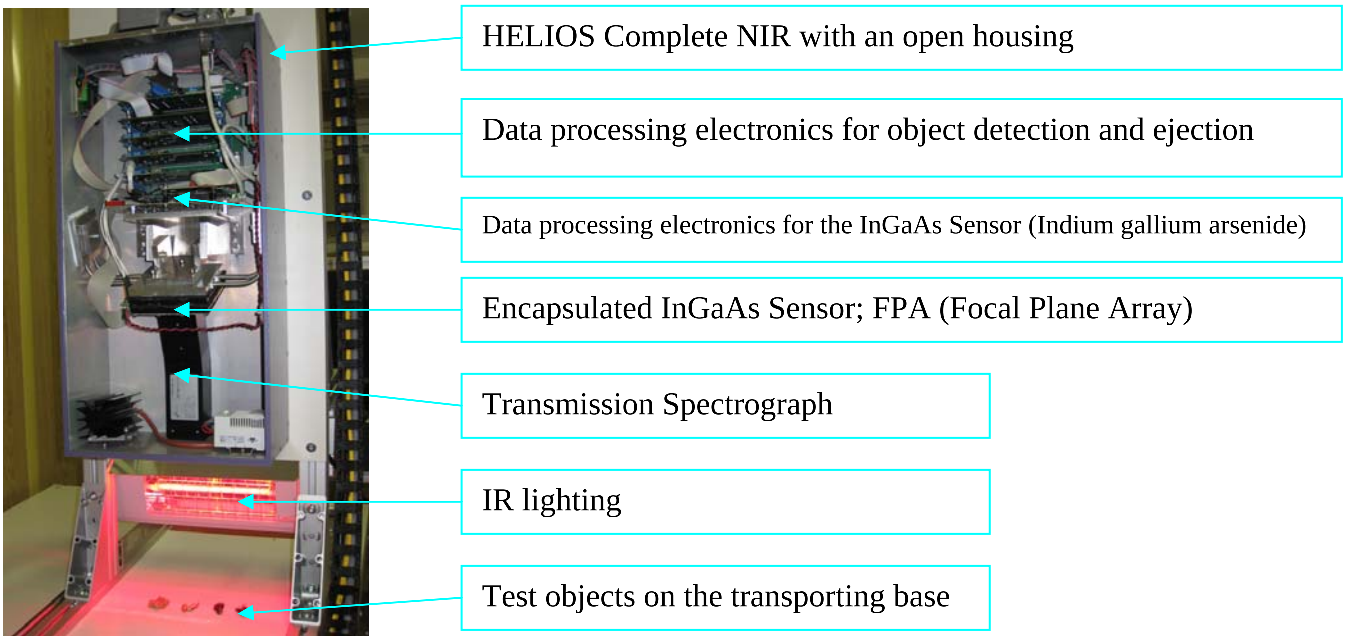

Fig. 2: Test configuration, which consists of a swivelling arrangement of a transporting base, IR lighting and HELIOS Complete

Recording technology

The test objects can be recorded statically or dynamically. As for static recording, the configuration will be horizontal, the test objects will temporarily be laid into the recording area of **HELIOS Complete**, and the scene will be recorded. One line will be recorded throughout the working width, and a spectrum will be acquired for each image point. As for dynamic recording, the configuration will be tilted, and the objects will be moved past HELIOS Complete over the chute thus created with a defined velocity. An image of the moved objects will be created by the time sequence of the recorded lines (line camera function).

In this process, **HELIOS Complete** will be operated as follows:

- wavelength range: 1.1µm – 1.7µm (HELIOS Complete NIR);
- 330 Hz scanning rate (Full Frame); at a transporting velocity of 1m/s, this means a local resolution of 3mm in the transporting direction;
- working width of 280 mm, which results in a local resolution of 1.17 mm crosswise to the conveying direction;
- lighting using incident light (reflection);
- adjusting HELIOS as to make sure the spectra are standardized and the 1st derivation of the spectra is generated so that the spectra taught in before will be allocated to two classes (Class 1: blueberries; Class 2: impurities) and the control signals for the ejector will be generated for Class 2.

Following, please find recordings that have been made by using the configuration above and are shown by means of the programme **HELIOS Viewer** and/or **RefSpecMan** on the PC screen.

HELIOS Viewer

HELIOS Viewer makes it possible to set the operating parameters of the camera and visualize the data delivered by **HELIOS Complete** on the screen of the PC.

As can be seen from Fig. 1, this may be the spectra of the individual image points (or their derivation) (HELIOS Core Function), the classified data for each image point (HELIOS Class Function, which corresponds to the function of a line camera) or ultimately the control signals for the ejector.

Fig. 3 shows the spectra of the individual image points (HELIOS Core Function) as a two-dimensional, colour coded image (live image of the recorded scene). On the vertical axis, there is local allocation. On the horizontal axis, there is the wavelength. If a spectrum deviating from the background (shown in magenta) is detected, it will be shown in a colour coded way on the corresponding local coordinate (line). The colour scale ranges from blue (low intensity) to red (high intensity). If blueberries and leaves are led past HELIOS over the conveyor, an image as is shown in Fig. 4 can be recorded. On the basis of the spectra recorded for each image point, **HELIOS Class** will acquire a classifier, which is shown in a colour coded way, on-line. This means **HELIOS Class** works like a line camera.

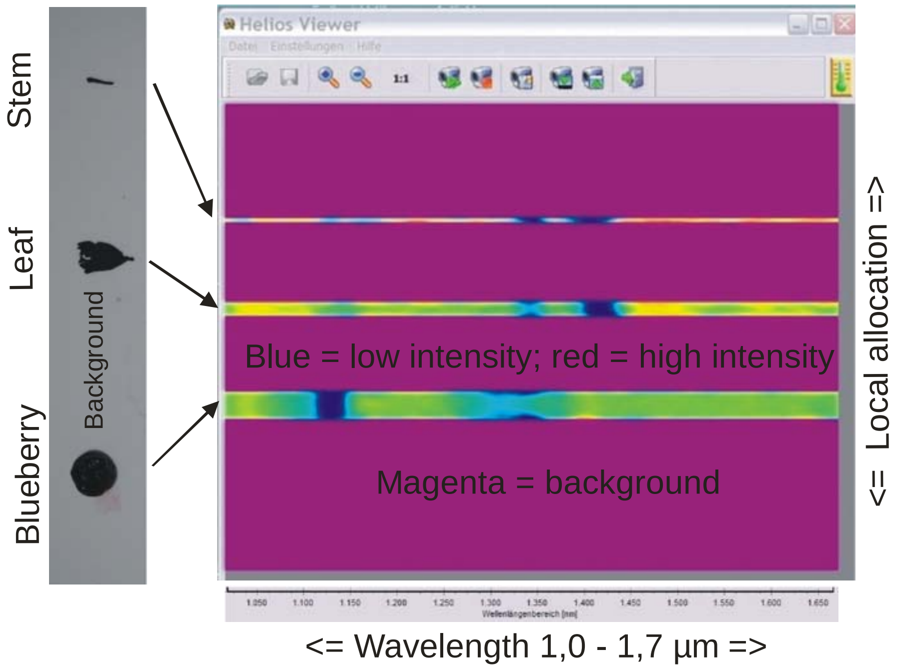

Fig. 3: Visualization of the spectra of the scene in HELOS Viewer, which is shown on the left side. The local allocation (256 local points) is entered vertically, and the wavelength (320 data points) is entered horizontally. The intensity of the spectra (here the 1st derivation is shown) is colour coded, blue corresponding to a low intensity and red corresponding to a high intensity.

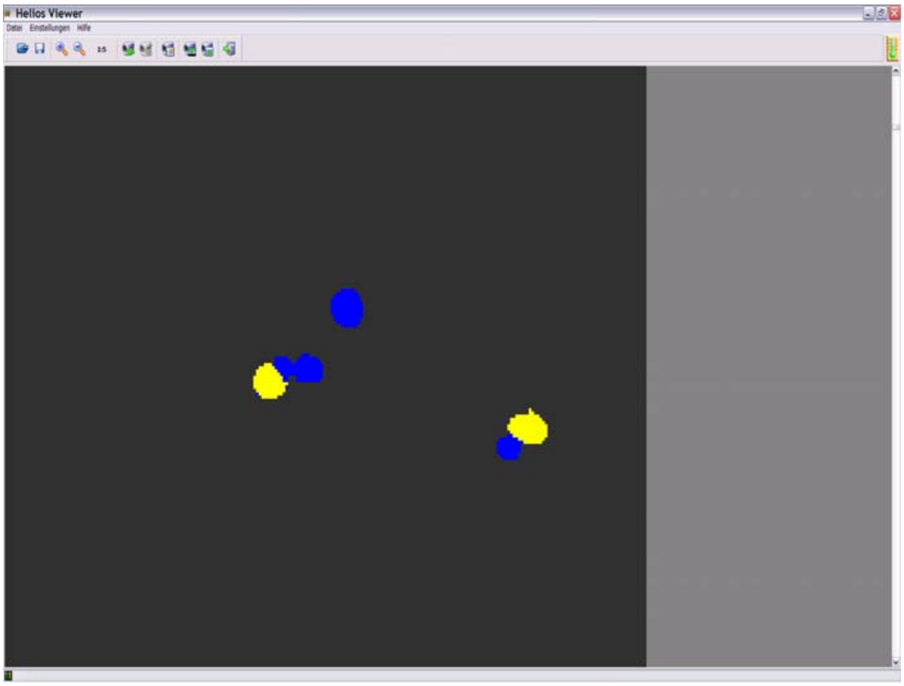

*Fig. 4: Live recording of blueberries and blueberry leaves. The classified data acquired by **HELIOS Class** are shown (blueberries in yellow and blueberry leaves in blue). For the objects to be ejected (blueberry leaves), **HELIOS Complete** would additionally fade in the control signal for the ejector in the right part of the image.*

Interpreting the spectra

In Fig. 5, one chosen spectrum is shown as a histogram for three test objects (stem, leaf and blueberry) in order to improve visibility. As can be seen, the three spectra differ significantly and can therefore easily be classified by **HELIOS Class** and **HELIOS Complete**. In this context, it is possible to use the same matured classification algorithms as they have been used successfully by EVK for recycling plastics for some years.

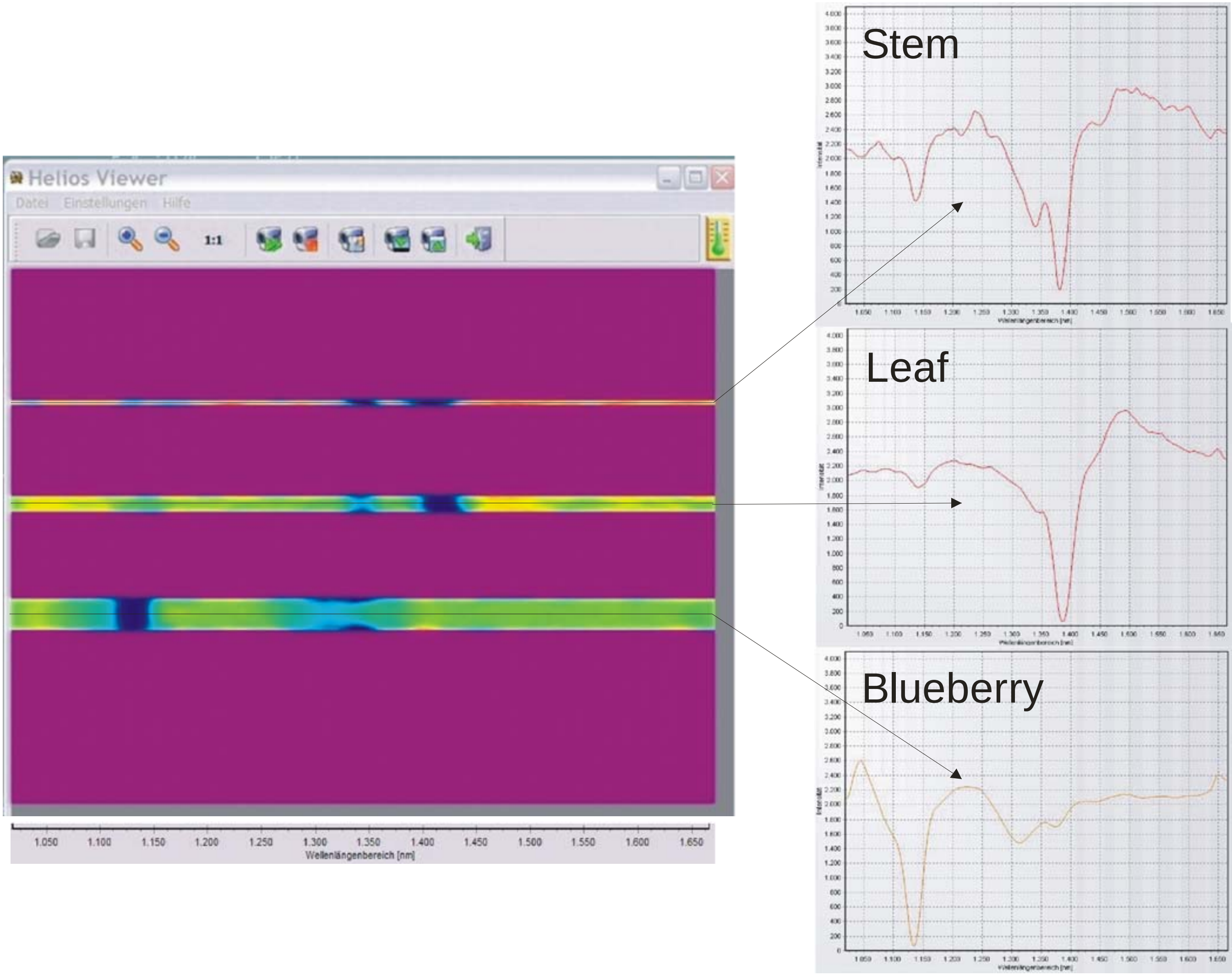

Fig. 5: left: Colour coded visualization of all the spectra (1st derivation);
right: Histogram of one chosen spectrum (1st derivation) of the stem, leaf and blueberry

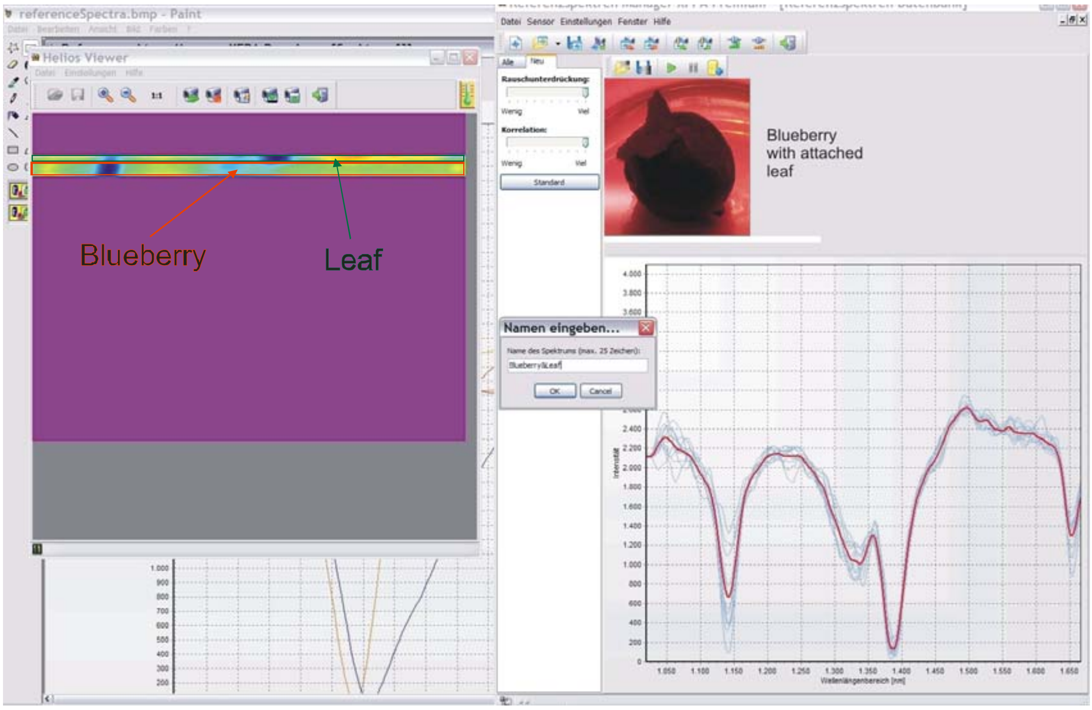

Fig. 6: Recording of a blueberry to which a leaf, whose colour does not differ from that of the blueberry, adheres. In the left part of the image, the different spectra of the leaf (top) and blueberry (bottom) can be identified clearly. As described above, "top" and "bottom" go hand in hand with different local coordinates on the test object "Blueberry with leaf".

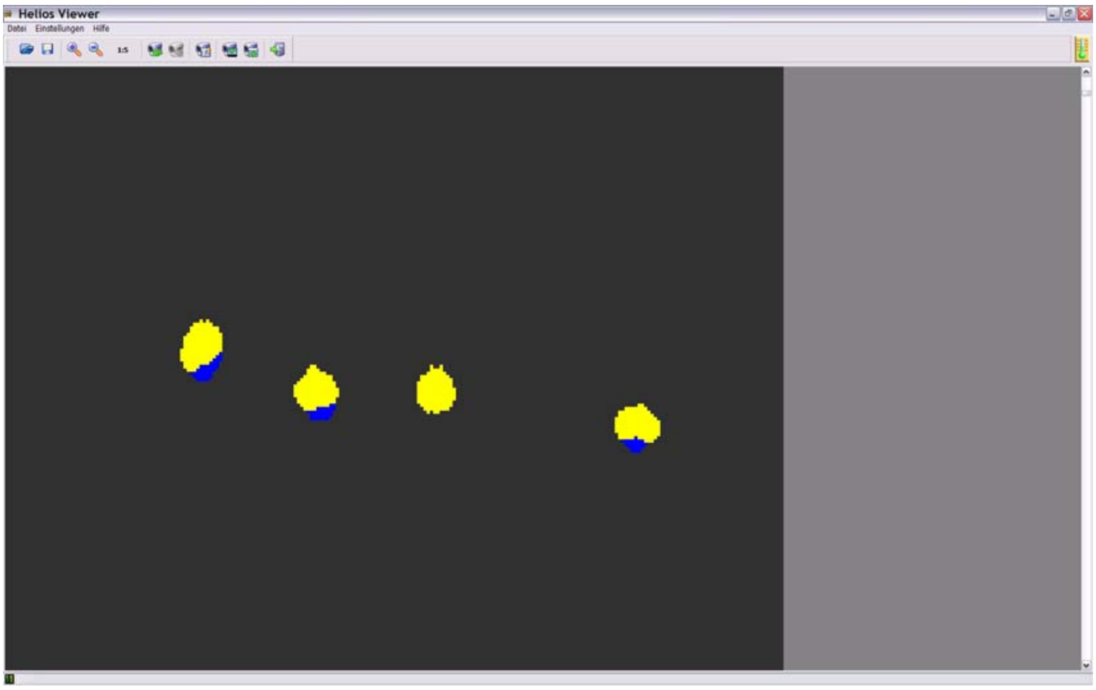

Fig. 7: Live recordings of blueberries with stems (blue), which are made by using ***HELIOS Class****. Even though the stems are so small, they can be detected because the background does not generate any useful signal while the stem does.*

Images of different spectra

The following spectra that have been recorded and shown give even more insight and make it possible to estimate the efficiency and performance of the Hyperspectral Imaging System HELIOS NIR in connection with sorting of blueberries.

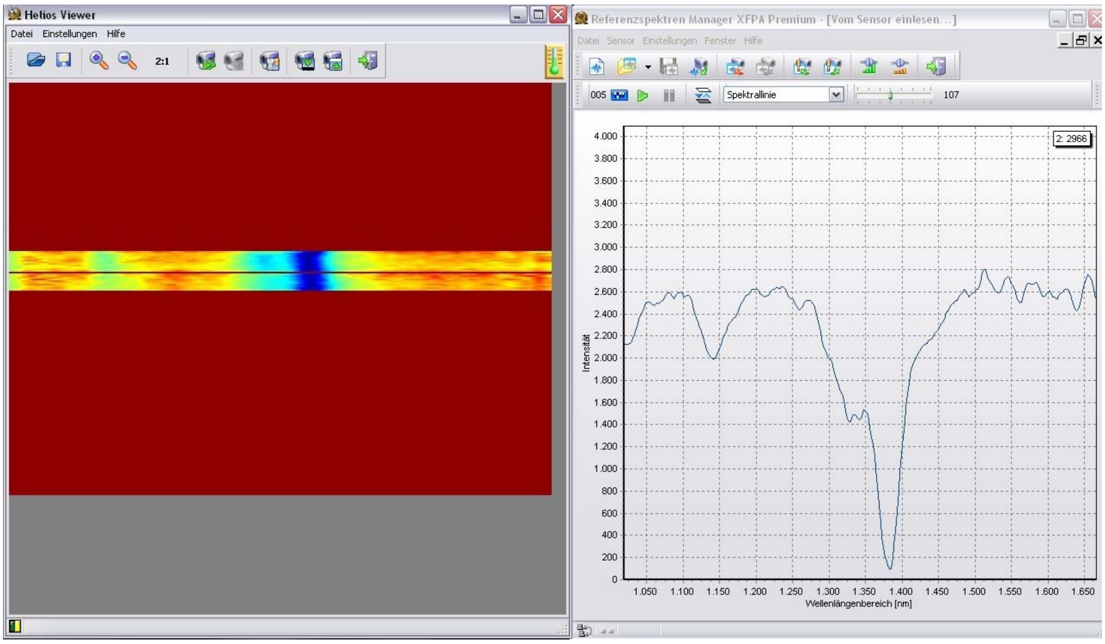

Fig. 8: Spectra (1st derivation) of a larva. Larvae can also be clearly distinguished from blueberries and thus ejected as impurity.

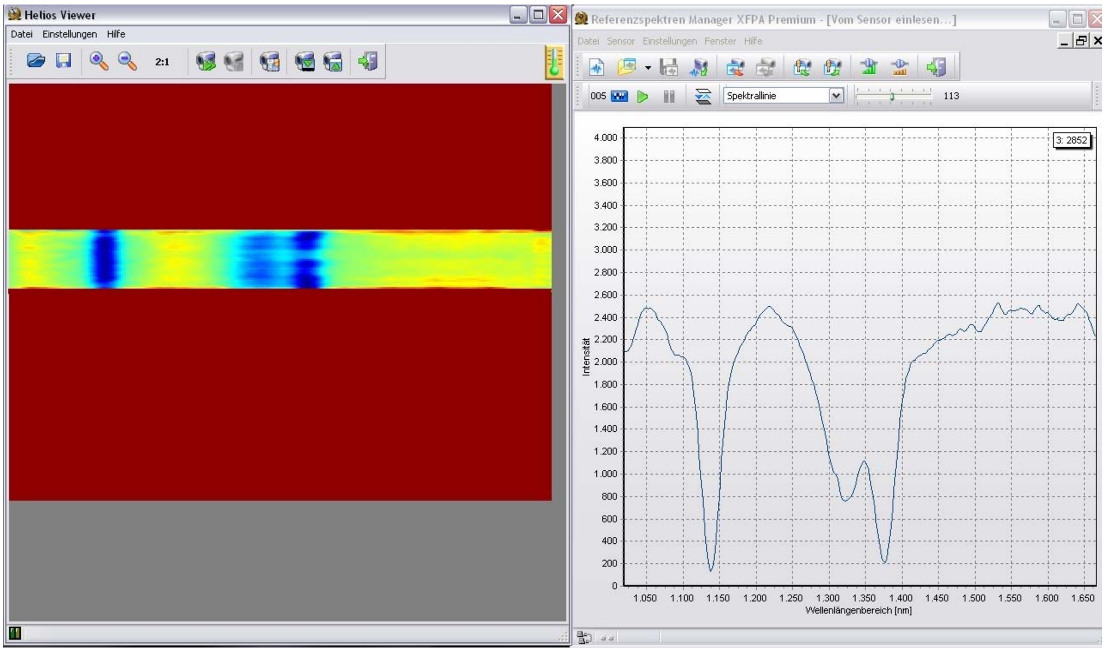

Fig. 9: Spectra (1st derivation) of a worm. Worms can also be clearly distinguished from blueberries and thus ejected as impurity.

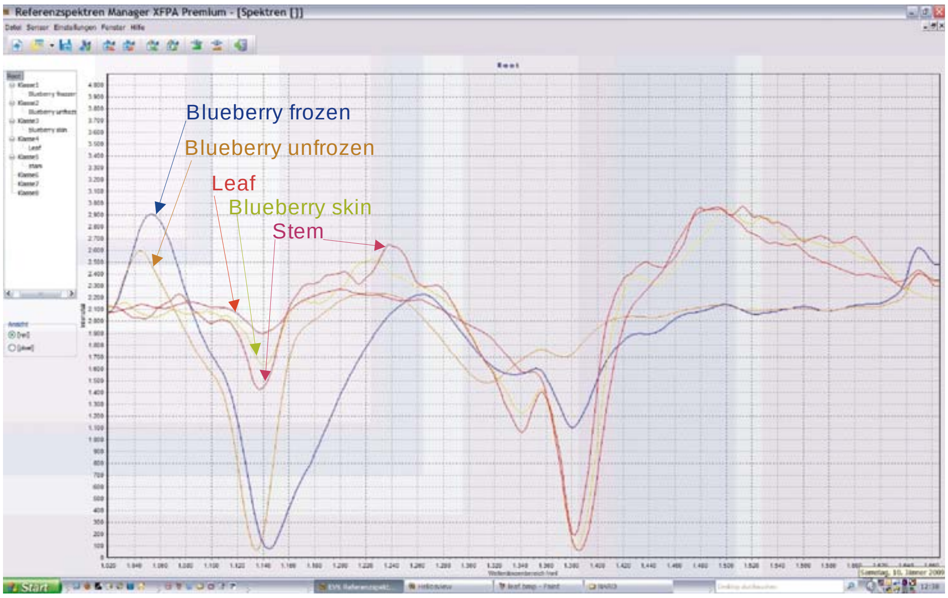

Fig. 10: Summarizing visualization of the spectra (1st derivation) of frozen and unfrozen blueberries, the skin of blueberries as well as blueberry leaves and stems

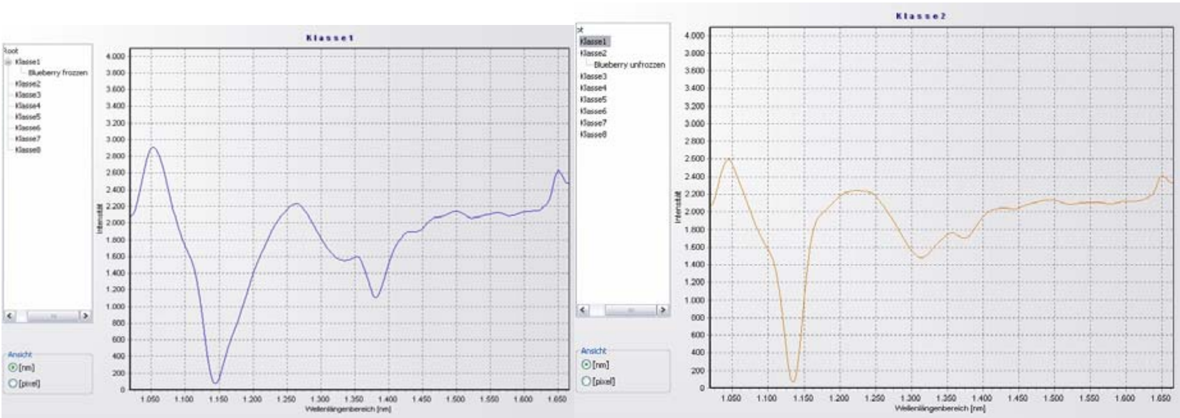

Fig. 11: Differences in the spectra (1st derivation) of frozen blueberries (left) and unfrozen blueberries (right)

Fig. 12: Spectrum (1st derivation) of the skin of a blueberry

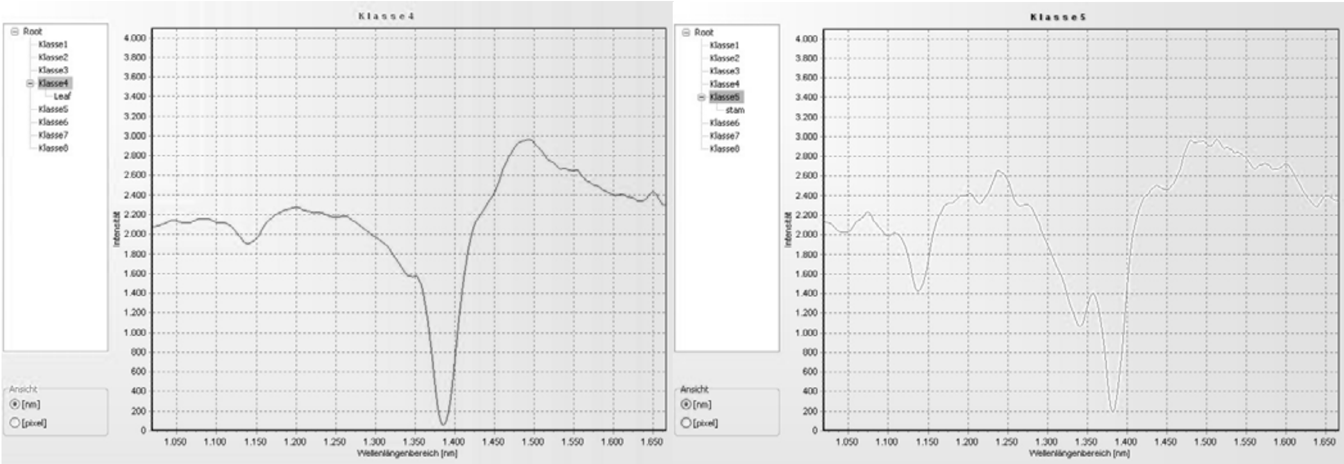

Fig. 13: Differences in the spectra (1st derivation) of blueberry leaves (left) and blueberry stems (right)

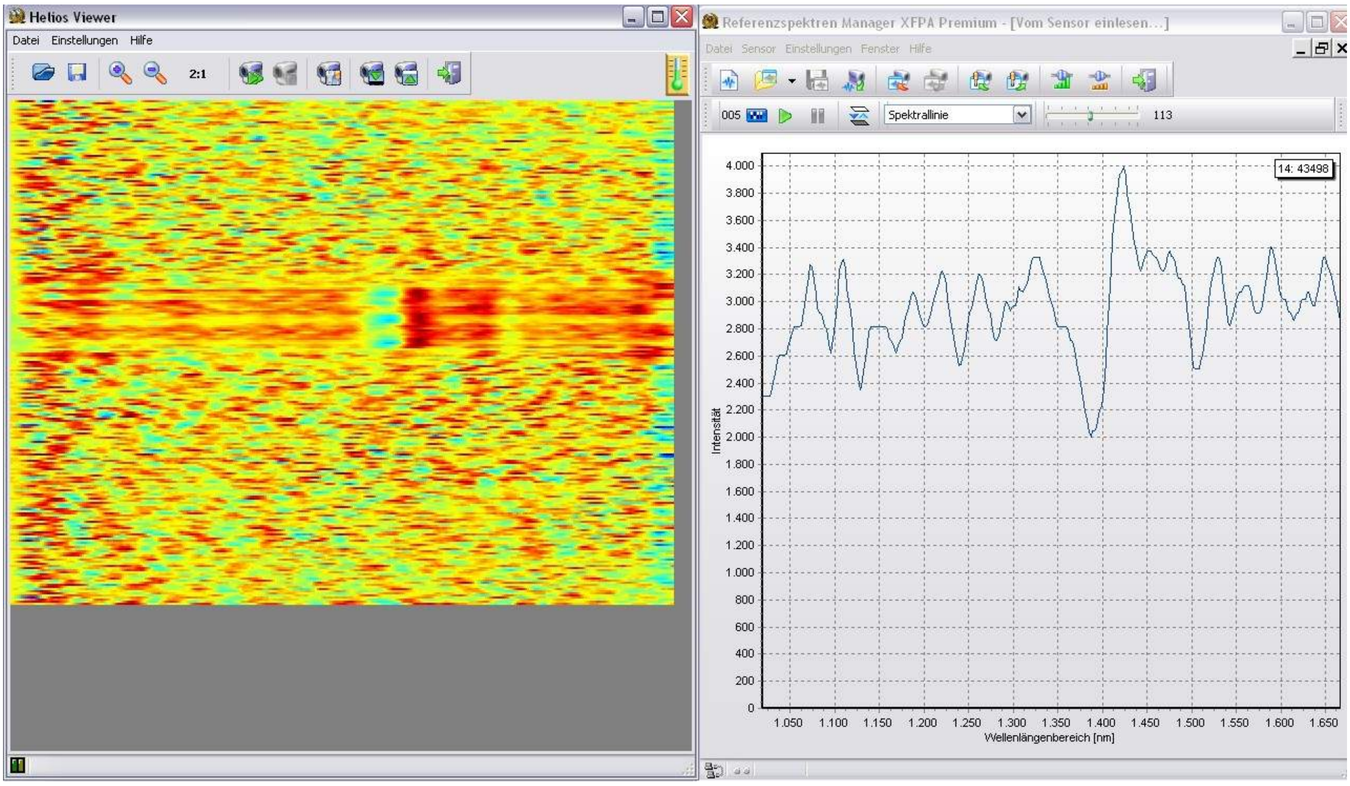

Fig. 14: Recording of the spectra (1st derivation) of a stone. The spectrum of a stone is very weak and only insignificantly stands out against the background, (which is not coloured in magenta for illustrative purposes). Perfect classification will only be possible if an "NIR active" background is chosen. This means the background delivers a sufficiently good spectrum in the NIR range. If the spectrum significantly differs from that of the blueberries (e.g. plastics), parts that do not furnish any sufficient useful signal can also be detected as "holes".

Result

As could be expected, there are distinct differences between blueberries, blueberry leaves, stems, larvae, worms and similar organic impurities in the analyzed NIR range (1.1 – 1.7µm). The spectra (1st derivation) have a distinctly different shape and can be distinguished one from another “with the naked eye”. This makes it possible to keep data processing simple, which directly means that the system can be designed as to be robust, resistant to disturbance and stable on a long-term basis. No calibration that is time consuming and needs to be repeated at regular intervals will be necessary. Furthermore, the known methods for recycling plastics, which are matured and have stood the test, can also be used for sorting blueberries almost one by one.

The suitability of **HELIOS NIR** (1.1 – 1.7µm) for sorting blueberries has been reviewed. **HELIOS Complete NIR** may also be expected to yield good results for sensor based sorting of blueberries (ejecting impurities) at rough field use. If the system is adequately equipped with an “NIR active” background, it will also be possible to detect impurities that do not provide any useful signal. Only parts that are “NIR transparent”, such as glass, cannot be detected by this system.

Resolution and scanning rate

HELIOS NIR (1.1µm – 1.7µm) has a sensor with 320 x 256 pixels, spectral resolution amounting to no more than 320 points and local resolution to no more than 256 points. Full resolution (place and spectrum) goes hand in hand with a scanning rate of 330Hz.

In principle attempts will be made to ensure local and spectral resolution is as good as possible. The more measuring points are acquired, the better verified will the results be. Ultimately, however, a well verified spectrum (i.e. only one image point) of the impurity will be sufficient for its detection. If the objects are isolated well and there is an “NIR inactive” background, i.e. a background that does not generate any useful signal, it will even be possible to detect parts that are significantly smaller than local resolution. Based on our tests, we assume a resolution of 1 – 2 mm is sufficient for sorting blueberries. Therefore, it is, e.g., possible to think about an arrangement with a working width of approx. 600 mm and a transporting velocity of approx. 1m/s and regard it as being a good compromise.

As the last third of the spectra does not contain any relevant information, it can be done without. This helps to increase the reading rate by approx. 1/3, i.e. to approx. 440Hz, which improves local resolution in transporting direction and/or makes it possible to increase transporting velocity.

Possible HELIOS products for sorting blueberries

- **HELIOS Class NIR** (1.1 – 1.7µm) or **HELIOS Complete NIR** (1.1 – 1.7µm) or
- **HELIOS Class VISNIR** (450 nm –1.0µm) or **HELIOS Complete VISNIR** (450 nm – 1.0µm)

Sorting blueberries by using HELIOS, comparison NIR and VIS/NIR range

HELIOS NIR (1.1 – 1.7µm)	**HELIOS VISNIR (450 – 1000nm)**
(+) There is a distinct useful signal and thus safe information in the NIR range (significantly different spectra of blueberries and most impurities).	(-) The useful signals are smaller than those for HELIOS NIR. Therefore, they will have to be intensified a lot. This is to the detriment of signal quality.
(+) This system was introduced by EVK as early as 2006 and has stood the test relating to recycling of plastics.	(+) It is possible to use the same data processing as that of HELIOS NIR, which is established well and has stood the test, for classification and ejection.
(-) Information for simultaneous colour sorting is missing. However, maturity might be derived from the sugar content.	(+) Information in the VIS range can be used for simultaneous colour sorting.
(-) Price	(+) Price