NEXT GENERATION SPECTRAL DEVICE
and performance testing

NOW AVAILABLE
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**Introduction**

Almost all material has their optical “fingerprint”, or spectrum. Different compounds can be identified based on their ‘fingerprints’. Near Infrared (NIR) spectrometers are widely used in many fields to measure material content, such as moisture, fat, protein, hydrocarbons, textiles, polymers and pharmaceutical ingredients. Infrared spectrometers are already in widespread use, thanks to their great accuracy and flexibility compared to chemical detectors.

So far their drawback has been price and size, but the new generation of spectrometers changes all that. And what’s more, many industrial applications require highly miniaturized and robust NIR device to meet industrial operators’ expectations. So there is clear need for new innovative sensors which are small, robust, inexpensive and intelligent to bring measurements from laboratories to the field use.

Spectral Engines introduced the new NIRONE platform in June 2017. NIRONE technology platform is based on small-sized high-performance core sensor (25x25x20 mm, 15 g) and the device level solution which will expand the use of spectroscopy also out of laboratory. In this white paper, we present the performance evaluation these new spectral sensors and a new portable pocket-size wireless NIR reflection device. Spectral Engines’ wireless device is battery-powered and wireless that can be operated with a tablet computer or mobile devices. We also shortly describe how to realize cloud connectivity to operate simultaneously and seamlessly multiple spectral sensors.

**Wireless Food Scanner**

Spectral Engines FoodScanner is pocket-size device which measures nutrition facts from different food ingredients.

NIR spectroscopy is broadly used technology for material sensing particularly in laboratories.
Short introduction to Near Infrared spectroscopy

Near Infrared (NIR) spectroscopy is well-known in material sensing. It is still mainly used in laboratories. Benefit of Near-Infrared spectroscopy is that it doesn’t need any sample preparation. Silicon based sensors (CCD, CMOS) are used many times for spectroscopy applications but though sensor technology is offering high SNR the sensitivity of measurement is not sufficient for many applications. Though sensitivity of InGaAs detectors are not that good compared to silicon based detectors, the selectivity and sensitivity are typically better at true NIR range beyond of 1700 nm.

Figure below shows wood material spectrum measured with a laboratory analyzer. We can see e.g moisture peaks at 1450 nm and 1940 nm region and cellulose peaks in many different regions. As we can see the absorptions band of moisture at 1940 nm is roughly 3-4 times stronger compared to 1450 nm band. This means higher sensitivity. Another additional benefit is that absorption peaks are more separate at longer wavelengths. This will make it easier to develop chemometrical models for different materials.

We can change many industries through material sensing:

Moisture, Textiles, Polymer analysis, Grain analysis, Fuel quality, Biofuel and biogas monitoring, Pharmaceuticals, Food scanner, Fat, Protein, Carbohydrates, Alcohol, Adulterants, Methane, Ethane, CO2, Hazardous gases, Mud logging, Engines optimization, Lubricants, Skin quality, Blood glucose, Health monitoring, Well-being…and many more…

NIRONE technology platform provides laboratory analyser performance

Spectral Engines introduces new spectral sensors, NIRONE

Spectral Engines new portable wireless NIR reflection device brings spectroscopy to pocket size. The NIR device is battery-powered and wireless that can be operated with a computer or mobile devices. Spectral Engines wireless device is based on a diffuse reflectance measurement geometry. Device consists of a broadband illuminator and a tunable Microelectromechanical (MEMS) Fabry-Perot Interferometer with a single pixel extended InGaAs detector.

The illumination and detection units with electronics are packaged to a cubic inch size with a weight of less than 15 grams. The operation wavelength ranges cover from 1350 nm to 2450 nm.

We present the sensor design, its building blocks, operation principle and easy-to-use algorithms to adapt the sensor to number of applications. In addition, we show how the algorithms are used to adapt the sensor to applications and how the sensor is powered with meaningful intelligence. We also present some practical NIR applications carried out with truly portable NIR device. Such miniature spectral sensors open up substantial new application and business opportunities by offering small footprint, high performance and intelligent connectivity.

We’ll present comprehensive testing results of NIRONE devices. Test results illustrate the performance parameters of the devices which are most relevant when selecting the right technology for industrial or portable measurement applications. Tests includes e.g. one-to-one variations, signal-to-noise, resolution, signal stability and accuracy. Finally in this paper, we show how spectral sensors can be used in complete solution. We present Spectral Engines’ portable NIR device, FoodScanner. Our FoodScanner received EU Horizon Prize award as the best Food scanner technology by European Union, March 2017. As a main prize Spectral Engines got 800'000€ from this competition.
MEMS based Fabry-Perot Interferometer offers high performance at affordable price point

There are several ways under investigation to miniaturize NIR spectrometers and integrate them into existing devices or products. Spectral Engines technology is based on tunable Fabry-Perot interferometer. Interference filters are traditionally used for fixed wavelength filtering; and our Fabry-Perot technology is based on the same principle. But instead of having only one single wavelength, Spectral Engines optical filter is fully programmable and robust sensor which can be operated only with few points or scanning across the whole wavelength region. Spectral Sensor utilise only single detector instead of array detector and this makes it very affordable also beyond silicon region. Also the size of detector and optical aperture are high and filter transmission is typically 80-90%. All these mean that Spectral Engines NIR sensors are very powerful spectrometers at true NIR range which offers high sensitivity from the application point of view.

Typical specifications of Spectral Engines, NIRONE sensors are shown in the table below. Spectral Sensors are available at four different versions:

- **NIRONE 1.7** (1350-1650 nm)
- **NIRONE 2.0** (1550-1950 nm)
- **NIRONE 2.2** (1750-2150 nm)
- **NIRONE 2.5** (1950-2450 nm)

Main benefits:

- Compact
- Fully programmable
- High SNR and accuracy
- Mass-production allows low price point
- Robust
- Easy to integrate to process or portable devices

<table>
<thead>
<tr>
<th>SPECs</th>
<th>NIRONE</th>
</tr>
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<tbody>
<tr>
<td><strong>Wavelengths</strong></td>
<td>1350-2450 nm</td>
</tr>
<tr>
<td><strong>Detector type</strong></td>
<td>Single element ext. InGaAs</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>15-25 nm</td>
</tr>
<tr>
<td><strong>Switching time</strong></td>
<td>1 ms</td>
</tr>
<tr>
<td><strong>SNR (int. time 0.1 ms)</strong></td>
<td>&gt; 10'000</td>
</tr>
<tr>
<td><strong>Wavelength Temp drift</strong></td>
<td>&lt; 0.1 nm/°C</td>
</tr>
<tr>
<td><strong>Illumination source</strong></td>
<td>2 tungsten vacuum lamps</td>
</tr>
<tr>
<td><strong>Sample working distance</strong></td>
<td>2-25 mm (with reflectance optics)</td>
</tr>
<tr>
<td><strong>Operation temperature range</strong></td>
<td>10-+50°C (non-condensing)</td>
</tr>
<tr>
<td><strong>Power consumption</strong></td>
<td>&lt; 1.1 W (peak), &lt; 300 mW (nominal)</td>
</tr>
<tr>
<td><strong>Optical interface</strong></td>
<td>Micro reflection optics SMA-connector</td>
</tr>
<tr>
<td><strong>Electrical interface</strong></td>
<td>UART (3.3V), i²C (3.3V) and digital trig in/out (3.3V)</td>
</tr>
<tr>
<td><strong>Size (W x L x H)</strong></td>
<td>25 x 25 x 17.5 mm³</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>ca. 15 g</td>
</tr>
</tbody>
</table>

Spectral Sensor is based on fully programmable optical filter.

Spectral Sensor typical specs.
**NIR ONE Spectral Sensor module**

**is very compact and works at true NIR region**

**Spectral Sensor Module**

The spectral module has a single pixel ext-InGaAs detector stacked with the MEMS Fabry-Perot Interferometer. The module contains two integrated Tungsten lamps to provide broad-band illumination that resembles black body radiator. With the reflectance optics, the measurement principle is a diffuse reflectance. The front optics is shielded by a protective window. However, the front optics can be replaced with an SMA connector or custom designed to fit different applications. The input optics is limited by a circular aperture providing +7 degree cone angle which makes the diameter of the measurement area ca 1-3 mm depending on the measurement distance which can be up to 10 mm.

The module electronics design is divided on two separate PCB’s. Interface PCB handles the communication with the customers application board through I2C or UART interface. This interface can be connected to external board to add for example USB and/or Bluetooth connectivity. The interface PCB contains microcontroller, light source drive electronics, and AD- and DA- converters that handles the conversion between digital and analogue signals. Detector board contains the light sources, detector module in TO-can and amplifier stages for FPI control and detector readout.

**Firmware functionalities**

The module contains ARM Cortex-M3 microcontroller to implement higher level functions for the spectrometer unit. This includes automated measurement sequences, spectrum post processing and possibility to use chemometric models integrated directly to the microcontroller. It is also possible to save up to 4 different sets of measurement parameters to the module. These functions make the usage of the module easier and allow faster implementation of end application for many customers.

The module firmware is responsible for handling the low-level control of the AD and DA converters as well as performing mid-level functions which include the FPI drive voltage compensation. Higher level functions are also provided to make spectral measurements more convenient. These functions allow the whole spectrum to be measured according user selectable parameters which minimizes the communication with the module during the measurement scan.

Microcontroller is also capable to perform post processing functions for the spectrum. These include division, scaling, averaging, logarithm, derivation and linear regression calculations (e.g. PLS models) over the measured spectrum. In addition, the dark level compensation measurement can be automated for the measurement to achieve better control of the baseline at varying temperature conditions.
The two PCB boards are packaged inside aluminum enclosure to form a Faraday gage over sensitive parts of the electronics and to provide a mounting interface for different optical interfaces. Together with the enclosure the device forms a PCB surface mountable component with a single connector for power and communication and two screws to fasten the device on the application board. Two integrated light sources allow easy implementation of different optical configurations.

To provide broadband IR illumination for the spectral measurement a miniature tungsten lamp was chosen as a light source. The heated tungsten filament is emitting broad-band light that is quite close to black body radiator. The glass enclosure of the lamp is creating some minor deviations to the spectrum but the most dominant absorption bands of the glass are over 2.5 μm which is outside the measurement range and therefore the lamp is well suited for the purpose.

Communication with the sensor can be handled either through UART- or I2C communication bus. Both interfaces are 3.3V compatible. The sensor module uses Hirose DF12-20DS-0.5V(86) connector receptacle that can be used to interface the board with the customer base board. The mating connector plug for the base board is DF12(5.0)-20DP-0.5V(86) from Hirose.
Cloud computing is essential part of meaningful intelligence

Pocket-size wireless portable NIR sensors

Based on the Spectral Sensor Module, a wireless reference design is easy to make. This gives a practical demonstration on how to integrate and utilize the core module. The housing contains only an additional PCB that holds a Bluetooth radio and a battery. Also USB connection is used for the charging and communication. This makes it very fast to design and develop the sensor for different applications.

Challenges

The challenge for using future spectral sensors broadly is not only related to the price of hardware but also on how to build complete sensor network solutions. NIR spectroscopy is still mainly used by professional users in central laboratories. But the real challenge is when there will be hundreds or thousands sensors in the field to make real-time analysis. This will need sophisticated new cloud based tools to optimize the performance of individual sensors but also enable easy. New cloud computing technologies, like machine learning and other parts of Artificial Intelligence, will open new opportunities to update fast new applications for field sensors. Through cloud computing it is possible to create meaningful intelligence for sensor networks.

Cloud Concepts

Web based tools are used to manage the sensor fleet. E.g. device condition can be seen and possible repair needs are indicated. The raw data is processed so that the smart analysis algorithms can be easily be deployed to the multiple sensors which will speed up the field deployment of the sensors. New applications are build so that the few sensors are used to gather the reference data. which is used to build the models for the application, and those can be deployed to the whole sensor fleet. These tools give the used a free access to the data, model building steps and the deployment of the sensor at the field.

MODULE INTERFACES AND MAIN SOFTWARE MODULES.

COMMUNICATION CONCEPT WITH WIRELESS COMMUNICATION.
Bluetooth with AES128 encryption.
Performance testing

Resolution

Resolution is one critical feature which can be used in comparison of different spectrometers. We need to remember that it is not always crucial and specification for the resolution should be estimated also from the application point of view, i.e. what is required. Typically resolution between 10-30 nm is adequate to the most of well-known NIR applications. Application performance is also many times combination between resolution and SNR. In other words, high resolution won’t help if SNR is not adequate. So it is important to test the performance with real samples.

Spectral Engines NIRONE sensors resolution is better than 1% from the operating wavelength. I.e. Resolution of NIRONE 1.7 version is under 13-17 nm (operational range 1350-1650 nm). The resolution of the modules is always measured and analysed during the calibration phase at the factory. Figure above shows spectral resolution as a function of wavelength for each four different module types. Due to nature of the Bragg reflectors in the MEMS FPIs the resolution is higher at the central wavelengths than at the edges. That’s because the Bragg reflectors have been optimized for a single wavelength and there the resolution is smallest, and it gets lower when the distance from this optimization wavelength gets higher. The variation of the resolution between the modules is caused by two phenomena: first it’s due to manufacturing variability on the MEMS fabrication process, second assembly and placement variability of the all optical components. This is one-to-one variation is roughly +/-5% from the average resolution. We have to remember that resolution is also partly function of optical configuration. In other words resolution of fiber connected system is typically better when the angle of light is better controlled than in reflection measurements.
Thermal Cycling

One of the most critical performance attributes for spectrometers, in general, is the wavelength accuracy. It can be tested in standard temperature or by using different temperatures, thermal cycling. We did wavelength stability test by using temperature cycling in order to get maximum instability to be detected.

We used temperature cycling from +5°C to +65°C and monitored the wavelength drift of the NIRONE sensor. The data from each sensor is saved in every 1 minute to the database. Figure x shows a typical temperature behavior during the calibration cycling. The inaccuracy of the wavelength peaks are better than ±0.5 nm over the whole operation temperature range. The maximum peak-to-peak shift is on average 0.6 nm, which means 0.01 nm/°C as a temperature drift in wavelength axis.

Signal Repeatability

Another interesting quality parameter for spectral sensors is signal repeatability. It can be tested by measuring the same object several times and calculating the difference of the measurement signals vs. wavelength.

NIRONE sensor signal repeatability was tested by measuring 45 consecutive measurements with one single sensor. Wavelength reflectance calibration standard from Avian Technologies LLC (FW-WC-VisNIR-02c) was used. One spectral point was averaged 150 times (measurement time 4ms per wavelength) and wavelength step was 2 nm (totally 200 points across whole wavelength region). As a result, we got a standard deviation of 5.2 LSB’s (16-bit system) for raw signal. Average SNR in the measurements was 3200. By increasing light, the maximum SNR would be >10'000.
Wavelength uniformity of sensors

Wavelength uniformity of different devices is very important parameter, because the uniformity will influence the algorithm transferability from device to device. One-to-one accuracy in wavelength axis was tested by using Krypton calibration lamp.

Wavelength uniformity was tested by using 80 devices. Single emission peak of Krypton lamp at 1816.7 nm was used. Standard deviation of 80 devices was +/- 0.3 nm, which is really good result when remembering that the resolution of device is roughly 15 nm. So deviation is only +/- 2% from resolution.

Response uniformity of sensors

We made also tests for totally 35 sensors to find out response uniformity of NIRONE sensors. Signal uniformity means how big variations of intensity can be detected between different units.

Wavelength reflectance calibration standard from Avian Technologies LLC was used for these tests. Totally 1500 spectra were acquired from the 35 sensors. Absorbance data was calculated by using so called SNV correction. This indicates that an efficient algorithm transfer from device to device can be done.
Lamp stability

NIRONE sensor has two illumination sources, micro tungsten sources. The stability of illumination source has impact to the performance of the sensor in reflection measurements. These effects can be compensated by measuring white reference now and then. The bigger changes are the more often white reference should be measured to compensate the effect of light source instability away.

We made 7 months stability test for NIRONE sensor. Total signal variation observed in this test was +/- 0.5%. This will give good understanding about potential variations in illumination signals over long time. The initial intensity change in figure x is due to lamp burn-in phase.
Technology comparison between different microspectrometers

There are a few microspectrometer technologies for the NIR out in the market, some more traditional and some newer. VTT Technical Research of Finland and Valmet Oyj, have carried out impartial test measurements on several devices on their main characteristics (Paaso et al. Microspectrometers for paper, plastic and pharmaceutical applications, OPD2017, 2017). The instruments selected into tests were laboratory FTNIR (Bruker), Micro FTIR (Si-Ware), Diode Array spectrometer (Zeiss) and MEMS-based FPI sensors (Spectral Engines NIRONE).

SNR

First tests were carried out concerning Signal-to-Noise. The measurement was done by using same measurement set-up and same measurement total time. One second measurement time was selected to give relatively good SNR for all spectrometers. The sample was white paper. Zeiss spectrometer has 2-stage TEC cooling when Si-Ware and Spectral Engines had uncooled sensors in tests.

The best SNR was achieved with Spectral Engines sensor. It was almost 50 times better than the micro FTIR sensor and 5 times better than diode array spectrometer. High SNR is needed when the measurement time is short and if very sensitive measurement should be realized.

Spectral Engines SNR can be even improved by reducing the measurement points. NIRONE sensor offers the opportunity to reduce points in case where only single or a few substances are analysed. Then the points can be reduced from 40 down to e.g. 4 points and this will increase the SNR by factor square root 10, roughly 3.
Sensitivity of different spectrometers

Same spectrometers were tested also by measuring coated paper samples and moisture samples. Polyethylene coated paper samples with 15, 30, 40 and 50 g/m² PE content was used. Paper moisture samples had 0.3%, 5.8% and 9.1% moisture concentrations. Light source in the measurement had 20W power and the same light source was used for all spectrometers. Light was coupled with fiber optical probe (NA 0.22, 1 collection fiber and 6 illumination fibers). Integration time was 1 second, like in SNR measurements. Calibration experiments were carried out to estimate how spectrometer noise and resolution will affect the results. The spectrometer prices and some key feature are shown in table below.

<table>
<thead>
<tr>
<th>COST *)</th>
<th>SPEED **)</th>
<th>RESOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTNIR</td>
<td>20-100 k€</td>
<td>&gt;&gt; 1 sec</td>
</tr>
<tr>
<td>Diode arrays</td>
<td>5-10 k€</td>
<td>milliseconds</td>
</tr>
<tr>
<td>Micro FTIR</td>
<td>3 k€</td>
<td>&gt; 1 sec</td>
</tr>
<tr>
<td>Micro FPI</td>
<td>1 k€</td>
<td>ms ... sec</td>
</tr>
</tbody>
</table>

The results are shown in figures below. From this picture we can see that resolution of NIRONE Spectral Sensor is not as good as FTIR devices. But thanks to higher SNR, Spectral Engines NIRONE was able to achieve the best sensitivity for moisture analysis which was 20 times better than micro FTIR device. For coated paper the performance was almost equal compared to Diode array spectrometer which cost almost 10 times more even in small quantities.

These measurements proves that high SNR can compensate lower resolution. Thanks to higher SNR Spectral Engines NIRONE sensors don’t need expensive TEC cooling or high resolution in order to offer sensitivity equal or even better than 10-20 times more expensive laboratory analyzers. What’s even more important, NIRONE sensors are fully programmable which makes them perfect sensing technology for fast monitoring process measurement or portable inspection.

<table>
<thead>
<tr>
<th>NOISE 2σ</th>
<th>PE [g/m²]</th>
<th>MOISTURE [moi%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro FTIR</td>
<td>0.44</td>
<td>0.100</td>
</tr>
<tr>
<td>Micro FPI</td>
<td>0.02</td>
<td>0.005</td>
</tr>
<tr>
<td>Diode Array</td>
<td>0.01</td>
<td>0.017</td>
</tr>
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</table>
Flour moisture content measurements in Smart Agriculture and Smart Industry

The content of the flour can vary considerably in its protein quality, protein quantity, ash, moisture, enzymatic activity, color, and physical properties when obtained from different sources. The purpose of the flour measurements is to detect specific properties or characteristics of a flour such as moisture. The results of these measurements affect flour’s performance in food industry and farming, and therefore these quality variations of the flour composition need to be detected.

The Near-infrared spectroscopy (NIR) method of estimating protein and moisture contents is widely used in the milling and baking industries. These devices are easy to use, generate instant results, and can be operated by non-technical personnel. The method’s accuracy is dependent upon its calibration but the procedure for carrying out an analysis is quite simple.

Case study

Wheat flour samples with varying amounts of moisture were measured with our Spectral Sensor NM module. NM-series is a new compact and powerful tool for realizing Near Infrared (NIR) spectroscopic measurement applications between 1350 and 2150 nm. In our measurements, the reference method for moisture was the oven-drying method. The simple air-oven method is sufficiently accurate for the routine analysis of flour moisture for example at the flour mill or bakery.

The moisture content of the flour is important for two reasons. First, the higher the moisture content, the lower the amount of dry solids in the flour. Flour specifications usually limit the flour moisture to 14% or less. It is in the miller’s interest to hold the moisture as close to 14% as possible. Secondly, flour with greater than 14% moisture is not stable at room temperature. Biological activity at high moisture levels produces off odors and flavors in the flour.
Portable NIR sensors expand business of NIR spectroscopy

NIR is proven technology for material identifications in central laboratories. The challenge related to laboratory instruments is related to their price, size and also the fact that they are used mainly by professional laboratory personnel. NIR portable analyzers have partly solved the challenge of using NIR spectroscopy in out-of-lab applications. But still, the main challenges in these portable devices are related to their rather big size and high price point which limits existing device use only for specific cases.

Plastics material classification with Spectral Engines NIR sensor

Identification of plastics and polymers in general is necessary for proper sorting of materials in recycling. The recycling and sorting requires a fast, cost-effective, high-accuracy analyzer.

We measured a selection of typical plastics found in household appliances and consumer products. These included latex rubber, polystyrene (PS), polyvinyl chloride (PVC) nitrile rubber (NBR), polyethylene (PE), and acrylic or polymethyl methacrylate (PMMA). We used Spectral Engines NIRONE 2.0 Sensors to measure the reflectance spectra from 1550 to 1950 nm range. This range is excellent for the identification and classification of materials, thanks to C-H bonds which absorb IR radiation in this region. Each material has a unique spectral fingerprint, which enables classification and identification of the materials.

Spectral Engines wireless portable NIR analyzer fits very well to field inspection applications.

- Fast and reliable detection of counterfeits, illegal drugs and explosives
- Rapid, non-destructive measurement without a need for sample preparation
- Cost-efficient
- Connectivity and portability
- Easy-to-upgrade libraries via cloud-based tools

![Absorbance (AU) vs Wavelength (nm)]
Example of complete measurement device: FoodScanner

The European Commission has awarded Spectral Engines the main Horizon 2020 prize of 800 k€ for cracking the challenge of developing an affordable and non-invasive mobile food scanner solution that enables users to measure and analyse their food intake.

The evaluating expert panel saw that our solution provides a major step towards better food-sensing devices and will play a significant role in the emerging field of the “Internet of Food” and smart personal nutrition. We were able to differentiate from our competitors by developing both food scanning hardware and software, enabled by our NIRONE platform tools.

FoodScanner platform
- Bluetooth-connected, battery-powered Scanner device
- Result: Energy, fat, carbohydrate and protein content
- Cloud platform enables to update calibration very fast
- Advanced pre-treatment methods could be implemented
- Mobile phone app to run the device and get analysis results from cloud
- Fast measurement (less than 0.5 s)
- 14 food categories, multiple scan possibility

Intelligent Algorithms
- Learning algorithms
- Application-specific models
- Sensor management database
- Reference library with over 10,000 spectra

Cloud connectivity
- Linux based cloud service
- Secure SSL connection
- REST architecture for efficiency and scalability
- 350 ms response time

Wireless, portable Spectral device
- Compact and easy to integrate
- True NIR wavelengths
- Typ. measurement time < 0.5 s
Conclusion

We have introduced in this white paper new revolutionary spectral sensor platform, the NIRONE. NIRONE products are available as Sensors, ready-made wireless Devices or it is possible to make a dedicated Scanner device for process, portable or even consumer markets. We have shown in this paper that despite the small-size or low price point, NIRONE products have excellent performance equal or better than expensive and bulky laboratory instruments. So we are able to expand the use of NIR spectroscopy to many real field or process applications.

If you would like to know more about technology or business opportunities concerning our next generation technology, do not hesitate to contact us or our distributors in your own region.

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USE CASE

Heptagon’s RF Digital, GreenTropism, and Spectral Engines Team Up to Deliver Complete Spectrometer Solution for Consumer and Industrial Applications 1.

“We have identified spectrometry as a new technology that may eventually enable a new wave of innovation in mobile phones.”  
Dr. Peter Roentgen, Manager of Advanced Research at Heptagon

Heptagon launched a new material sensor product for consumer markets at CES2017, Las Vegas, powered by Spectral Engines.