



NIR Trends: The Growing Impact of Light Measurement On Our Lives

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The interaction between an electromagnetic wave and a material can tell us a great deal about the chemistry and physical makeup of the material in question. We are all familiar with this interaction — for example, visible light in electromagnetic wavelengths reflects off plant leaves and enters our eye as green light, due to absorption of other wavelengths by the dominant photosynthesis chemical, chlorophyll. Many of us coat our bodies with sunscreen to absorb ultraviolet (UV) wavelengths of light to protect our skin from damage by these higher energy wavelengths. We are also aware that when X-rays, with wavelengths even shorter than UV light, are sent through our body, they are mostly absorbed by bone (and not as much by tissue), enabling medical professionals to diagnose broken bones or decayed teeth.

Fewer people, however, are aware that wavelengths in the infrared (IR) bands are also being used for product quality control and the detection of health problems. Just as the absorbance spectral profile of chlorophyll identifies its presence in leaves, the profile of fatty deposits (lipids), proteins, sugars, and moisture reveals their presence in foods and beverages through the use of near infrared (NIR) spectroscopy and the computer analysis of those spectra using a method known as chemometrics. By placing wavelength-selective filters in front of line scan or 2-D cameras, manufacturers can improve the purity of incoming raw materials by identifying — and rejecting — contaminants like packaging materials, stones, twigs, and stems. On combine harvesters, NIR diode array spectrometers are being used to monitor crop health and ripeness. These and other applications are helping to reduce both consumer costs and environmental impact.

Similarly, IR imaging is being used to monitor the chemical signatures of drugs in pharmaceutical packaging lines to ensure that the right pill is in the correct package, or in mixing lines to ensure proper composition, quality, yield, and efficacy. Infrared tags are increasingly used to prove the authenticity of a manufacturer's product, protecting retailers and consumers from counterfeit or substandard products.

In the medical arena, hospital patients (and even some treadmill users) may be familiar with the pulse and blood oxygen monitors that are applied to the finger or ear lobe. These devices transmit light wavelengths, which are just beyond the red that the human eye can perceive, through the skin. By

comparing two of these wavelengths, the oxygen content of the patient's hemoglobin can be computed. In addition, these wavelengths can make surface veins more apparent, as seen in *Figure 1*. This technique can also be used to image arteries through the wrist, helping nurses locate them for administering intravenous (IV) therapy or other medical procedures.



Figure 1: Forearm viewed in the short-wave IR with an InGaAs (indium gallium arsenide) camera

Though near-infrared (NIR) and shortwave-infrared (SWIR) light passes through biological tissues, it is highly scattered, since the molecules are similar in size to the wavelengths of light. This makes imaging difficult. However, interferometric techniques now allow physicians to perform “optical biopsies” on living tissue without cutting, staining, or otherwise preparing the tissue before imaging. Known as optical coherence tomography (OCT), this technique ignores the majority of scattered light rays bouncing around the tissue, and selectively amplifies the light bouncing directly back into the fiber optic probe that delivers the source light. Different depths of structures in the tissue that reflected the light are decoded by analyzing the interferogram vs. spectral wavelength. Meanwhile, mirrors sweep the fiber probe in both the X and Y directions over a section of tissue so the computer can build a 3-D image dataset of the living tissue volume. After further processing takes place to clean up the image, doctors can manipulate the data to see all of the cellular structures at a single depth across the scanned section. Alternately, a vertical slice through the volume can be displayed and swept left to right, or top to bottom, to show how multiple layers of tissue relate to each other (*Figure 2*).

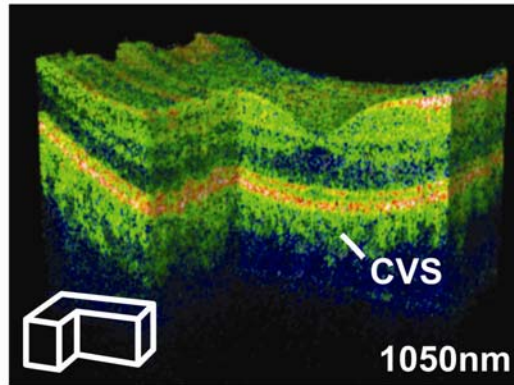


Figure 2: The layers of the retina in a human eye are clearly delineated. (Image courtesy of Dr. Wolfgang Drexler, Cardiff University)

A 5-second video demonstrating this technique can be viewed at <http://www.photonicsonline.com/download.mvc/SWIR-Retinal-Scan-0001>, courtesy of Dr. Wolfgang Drexler of Cardiff University. (Figure 3 is a still from this video.) The OCT video shows a high-speed, high-resolution, flythrough of a wide angle fundus area. The video images were captured using Sensors Unlimited's SU-LDH SWIR linescan camera (Figure 4).

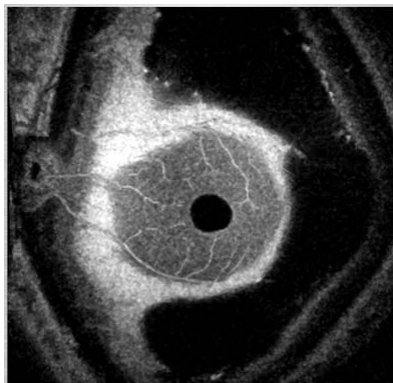


Figure 3: SD-OCT image of human retina in vivo, centered on the fovea and data captured with Goodrich/SUI SU1024-LDH SWIR line scan camera (Figure 4) acquiring at 47,000 kHz A-line rate per B-scan at the center wavelength of 1060 nm and 72 nm spectral bandwidth (512x512x512 voxel original). (Image courtesy of Dr. Wolfgang Drexler, Cardiff University)



Figure 4: Sensors Unlimited's SU-LDH linear digital high-speed InGaAs camera increases line rates for 1024 rectangular pixels to >47,000 lines per second, making it ideal for spectral-domain OCT (SD-OCT). (Image courtesy of Goodrich Corporation)

While the OCT technique has become a standard of care in eye clinics, new higher-speed methods are making it possible to capture blood flow and mechanical stress in tissue in real time. Longer wavelengths are being used, shifting from 0.8 to 1 micron wavelengths in the eye (and even 1.3 microns in other tissues), to penetrate deeper than 1 mm below the surface. These longer wavelengths experience reduced scatter, due to the size of the molecules in the tissue.

Researchers are now working to bring this technique into the operating room, in an attempt to speed analysis of regular tissue biopsies. Optical microscopy techniques are being combined with OCT to quickly deliver high-resolution images of cells in the biopsy. This will eliminate the time delay experienced with traditional pathology analysis, which is dependent on slicing the tissue, mounting it on slides, staining it, and methodically examining it to determine if any abnormal cells are present. Using this method, surgeons can immediately determine whether or not they cut deep enough. This prevents them from sewing up the patient only to later discover that another biopsy operation will be necessary, or from removing too much tissue and potentially damaging the patient's quality of life.

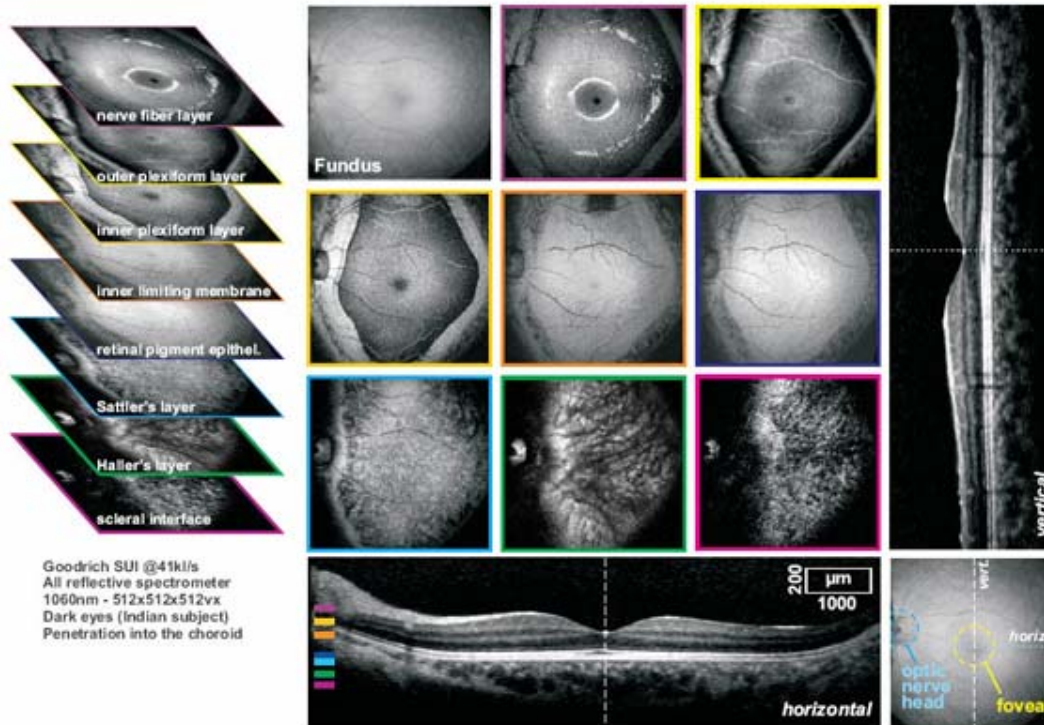


Figure 5: Video screen captures showing the layers of the retina.

As the examples above clearly demonstrate, the near-infrared portion of the electromagnetic spectrum is becoming more and more important in helping us live healthier, and longer, lives.

About the Author:

Doug Malchow is business development manager for industrial products at Sensors Unlimited, Inc., part of Goodrich Corporation, pioneers in the field of shortwave and near-infrared imaging based on indium gallium arsenide (InGaAs) technology. Malchow has a BS/BA in marketing from Rider University and 20 years experience in instrumentation, imaging, and spectroscopic applications.

