Multispectral Imaging to Improve Cancer Surgery Outcomes

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Technological advances continue to drive multispectral imaging (MSI) from expensive custom solutions to affordable commercial products. Component costs continue to decrease while capabilities increase exponentially, providing fertile ground for a variety of commercially viable products that only a few years ago were prohibitively expensive, if available at all. Areas that have seen the most growth are research, security, and healthcare.

Humans see only a small portion of the electromagnetic spectrum, that of "visible light". (Blacus, 2016) (Figure 1). This visible spectrum, about 400-700 nm, is what we humans see as colors, with shorter wavelengths perceived as blueish and the longer ones as reddish. Even shorter wavelengths enter the ultraviolet (UV) range; longer wavelength the infrared (IR) range. Although we are unable to see beyond visible light with the unaided eye, the use of special cameras, optics and software can expand human "sight" to these normally imperceptible wavelengths. Sight beyond the visible opens vast new horizons. We've all seen images taken through the Hubble telescope that reveal previously hidden secrets of the universe- heavenly bodies radiate not only visible light, but also short and long wave radiation. A microscopic universe illuminated with infrared radiation with MSI reveals hidden attributes of living tissues and organisms.

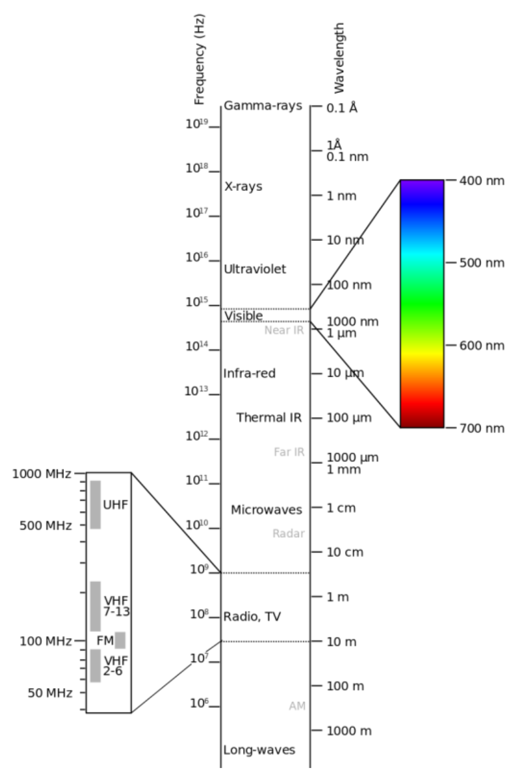

Figure 1: Electromagnetic Spectrum Source: Wikipedia

This tissue response to various wavelengths is the principle behind an exciting technology developed for cancer surgery. Fluorescence-Assisted Resection and Exploration (FLARE) was developed by John V. Frangioni, M.D., Ph.D. Cancer surgery outcomes are best when all cancerous tissue is removed with minimal removal of healthy tissue. The challenge for the surgeon is that it is difficult and, at times even impossible, to differentiate between the two. A surgical tool employing intravenously injected, targeted near-infrared (NIR) fluorophores and MSI can make a difference. FLARE enables surgeons to "see" with visible light what he is accustomed by training to seeing and also the difference between cancerous and normal tissue. This is done with an MSI system employing image fusion.

Security camera systems often provide daytime, visible light color images, and nighttime NIR images. The same sensor and optics are used, but the illumination is different. Image fusion is an extension of this technique where multiple wavelengths are collected and then the information from each is transmitted or enhanced to a video display. FLARE employs a visible light source, two excitation lasers, and chemical reagents that cause tissues to emit radiation in the (NIR) region between 700 nm and 900 nm. The result is four independent, but related video streams. A color video image provides the field of view that the surgeon is accustomed to seeing; two NIR images, one at 700 nm and one at 800 nm present images of tissue to be removed and tissue to be avoided; a fourth video stream contains all three channels, with pseudo-color added to the NIR images to make them visible to the surgeon. All of this occurs via image fusion in real time with multiple image correlation. Images are also magnified by the system for higher resolution than is available to the unaided eye. The result is that the surgeon is able to see cancerous and healthy tissue information superimposed upon a “normal” field of view.

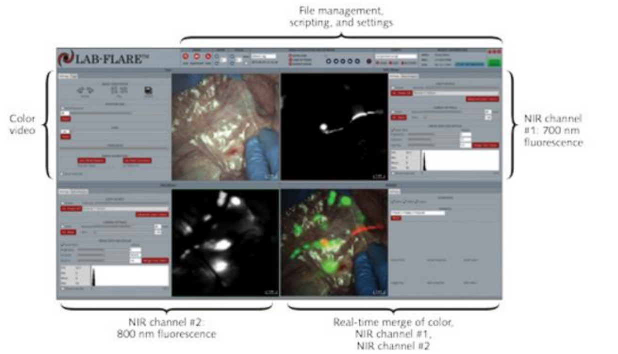

Figure 2: Four independent video streams provided in real time. 700nm and 800nm are pseudo colored red and green (respectively) in the merged image. Source CURADEL

Although not experienced in the aforementioned security systems, MSI systems present a potential challenge to the optics engineer because different wavelengths refract differently through the lens material. In fact, many MSIs are equipped with multiple apertures, one for each sensor wavelength band. Multiple sensors and optics imply additional cost. FLARE addresses this with chemical reagents that enable the use of a standard optics product manufactured by Computar that enable a common path for all wavelengths.

FLARE employs a CCD sensor to provide high dynamic range across a broad spectral band. Its white light source emits >= 20,000 lux at a working distance of 15” at >=85 CRI and 4500K. The laser excitation source generates 4 W total power at 666nm and 10W at 760nm. NIR Excitation fluence rate is >= 4mW/ cm2 at 660nm and >= 10 mW/cm2 at 760nm. FLARE is housed in a portable cabinet with two high-resolution monitors and an articulated arm to allow the surgeon to precisely position the imager and light source head to an exact location.

The purpose of FLARE is to someday empower surgeons to do better surgery. It will soon be offered to the market by Curadel Surgical Innovations (CSI) of Marlborough, MA. Efforts are currently underway to obtain authorization from the relevant regulatory bodies.

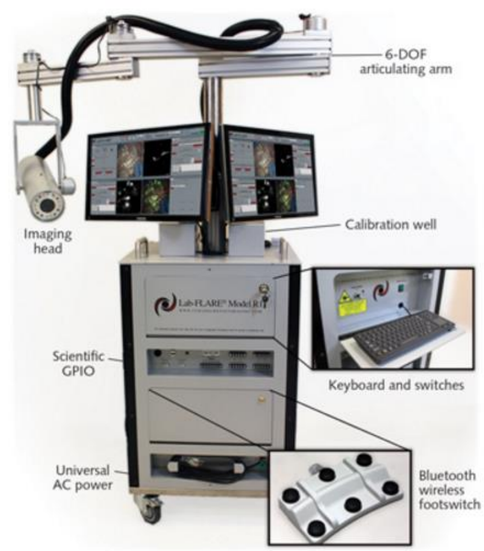

Figure 3: FLARE. Source: CURADEL

We are on the threshold of massive innovation in multispectral imaging. As component costs continue to decrease with increasing capabilities, more applications will continue to be developed in research, agriculture, security and healthcare. FLARE is another example of how this science might favorably impact thousands of lives.

Acknowledgements

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