Washington University in St. Louis
Office of Technology Management

MINIATURE, HIGH RESOLUTION MULTI-SPECTRAL IMAGING FOR LABEL-FREE IMAGE GUIDED SURGERY AND OTHER APPLICATIONS

Garcia Hernandez, Nimrod Missael, Gruev, Viktor

Carter, Paul

T-016872

Technology Description

Engineers in Prof. Viktor Gruev's laboratory have developed a compact 27-band hyperspectral imaging system for high resolution, label-free, real-time imaging. This system can distinguish spectral signatures in image guided surgery (IGS) and other applications. The technology integrates specialized filters on a 3 x 3 grid of stacked photodiodes in a single sensor that detects 27 different spectral observations in a single snapshot. This flexible imaging system can be tailored for desired applications by tuning the spectral range of the components to different wavelengths.

In the case of IGS, conventional technologies help physicians thoroughly remove tumors during surgery by differentiating tumor tissue from surrounding healthy tissue with dyes and molecular markers. However, these markers require lengthy and costly regulatory approval, limiting the widespread adoption of IGS. Alternative label-free imaging approaches are unsuitable for surgical use due to their bulky, complex electromechanical architectures, low image resolution and slow speeds. This new 27-band hyperspectral image sensor offers an alternative by using the spectral response of tissue as a reliable predictor of tissue type even under harsh surgical lighting. The simple construction and fast image processing of this technology make it well-suited for cameras used in operating rooms or other demanding environments, where low cost, small size, minimal complexity and maximal performance are prized.

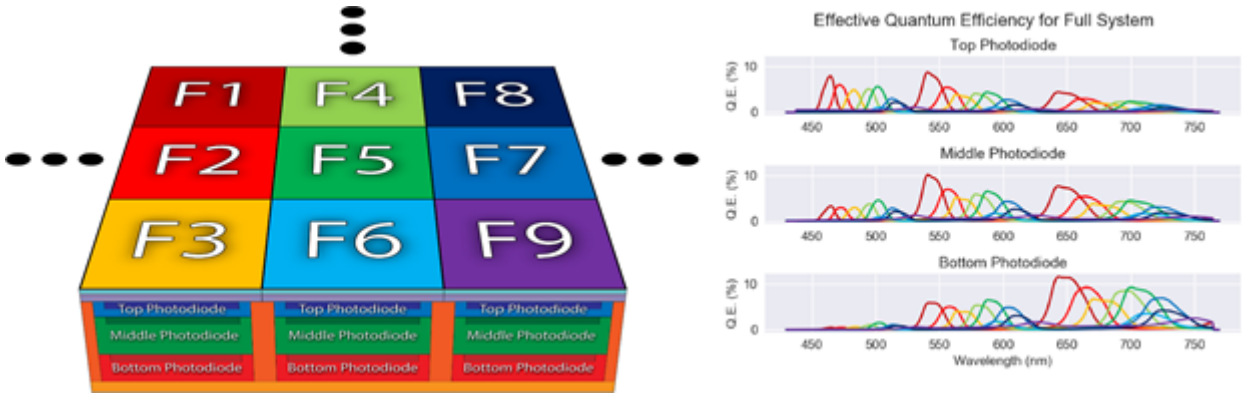

Diagram of the pixel pattern in the hyperspectral imager. *(Left) Layout of the filters on the stacked photodiodes: 9 different filters with distinct transmission spectra and 3 different photodiodes with distinct quantum efficiencies provides a total of 27 different spectral observations in each 3-by-3-pixel block. (Right) Quantum efficiencies for each pair of filter and photodiodes, spanning the visible spectrum from ~450 nm to ~750 nm.*

Stage of Research

- **Prototype** – The inventors fabricated a prototype camera with a compact 27-band hyperspectral imaging system that achieved a resolution of 1252 x 852 pixels at a rate of 17.2 frames per second while avoiding co-registration error. It had a signal-to noise ratio of ~55dB and a dynamic range of ~62dB.
- **Proof of concept** - The inventors used the prototype camera on a mouse model to differentiate between cancerous and noncancerous tissue and discriminate between distinct cancer types.

Applications

- **Image guided surgery** – label-free surgical guidance for distinguishing healthy tissue from disease (e.g., cancerous) tissue
- **Other imaging application –** disease tissue imaging, seed imaging/quality control, crop imaging

Key Advantages

- **High resolution, label-free imaging:**
  - 1252 x 852 pixels at a rate of 17.2 frames per second for image guided surgery demonstration
  - directly visualize spectral differences in tissue without dyes or imaging reagents that need regulatory approval
  - single chip architecture eliminates co-registration errors
- **Highly compact:**
  - miniature architecture to eliminate bulky, complicated equipment
  - lightweight image sensor can be integrated into a wearable goggle for image guided surgery application
  - low power consumption
- **Flexible, real-time imaging:**
  - filters and photodiodes can be tailored to select wavelengths that are optimized for specific applications
  - fewer selected wavelengths enables faster, easier deconvolution and processing
- **Broad band light source –** image sensing from standard surgical light source (does not require polarization)

Publications

- Blair, S., Garcia, M., Konopka, C., Dobrucki, L., & Gruev, V. (2019, March). A 27-band snapshot hyperspectral imaging system for label-free tumor detection during image-guided surgery. In *Label-free Biomedical Imaging and Sensing (LBIS)* 2019 (Vol. 10890, p. 108900G). International Society for Optics and Photonics.

Patents

- Multispectral imaging sensors and systems (Patent No. US 11,223,783)