Hyperspectral Fluorescence and Reflectance Imaging Instrument

A single system contains spatial-scanning, illumination, and spectral-imaging subsystems.

Stennis Space Center, Mississippi

The system is a single hyperspectral imaging instrument that has the unique capability to acquire both fluorescence and reflectance high-spatial-resolution data that is inherently spatially and spectrally registered. Potential uses of this instrument include plant stress monitoring, counterfeit document detection, biomedical imaging, forensic imaging, and general materials identification.

Until now, reflectance and fluorescence spectral imaging have been performed by separate instruments. Neither a reflectance spectral image nor a fluorescence spectral image alone yields as much information about a target surface as does a combination of the two modalities. Before this system was developed, to benefit from this combination, analysts needed to perform time-consuming post-processing efforts to co-register the reflective and fluorescence information. With this instrument, the inherent spatial and spectral registration of the reflectance and fluorescence images minimizes the need for this post-processing step.

The main challenge for this technology is to detect the fluorescence signal in the presence of a much stronger reflectance signal. To meet this challenge, the instrument modulates artificial light sources from ultraviolet through the visible to the near-infrared part of the spectrum; in this way, both the reflective and fluorescence signals can be measured through differencing processes to optimize fluorescence and reflectance spectra as needed.

The main functional components of the instrument are a hyperspectral imager, an illumination system, and an image-plane scanner. The hyperspectral imager is a one-dimensional (line) imaging spectrometer that includes a spectrally dispersive element and a two-dimensional focal plane detector array. The spectral range of the current imaging spectrometer is between 400 to 1,000 nm, and the wavelength resolution is approximately 3 nm. The illumination system consists of narrowband blue, ultraviolet, and other discrete wavelength light-emitting-diode (LED) sources and white-light LED sources designed to produce consistently spatially stable light. White LEDs provide illumination for the measurement of reflectance spectra, while narrowband blue and UV LEDs are used to excite fluorescence. Each spectral type of LED can be turned on or off depending on the specific remote-sensing process being performed. Uniformity of illumination is achieved by using an array of LEDs and/or an integrating sphere or other diffusing surface. The image plane scanner uses a fore optic with a field of view large enough to provide an entire scan line on the image plane. It builds up a two-dimensional image in pushbroom fashion as the target is scanned across the image plane either by moving the object or moving the fore optic.

For fluorescence detection, spectral filtering of a narrowband light illumination source is sometimes necessary to minimize the interference of the source spectrum wings with the fluorescence signal. Spectral filtering is achieved with optical interference filters and absorption glasses. This dual spectral imaging capability will enable the optimization of reflective, fluorescence, and fused datasets as well as a cost-effective design for multispectral imaging solutions. This system has been used in plant stress detection studies and in currency analysis.

Improving the Optical Quality Factor of the WGM Resonator

New iterative annealing and polishing increases the resonator's finesse over the fundamental limit.

NASA's Jet Propulsion Laboratory, Pasadena, California

Resonators usually are characterized with two partially dependent values: finesse ($\mathcal{F}$) and quality factor (Q). The finesse of an empty Fabry-Perot (FP) resonator is defined solely by the quality of its mirrors and is calculated as

$$\mathcal{F} = \pi R^{1/2}/(1 - R).$$

The maximum up-to-date value of reflectivity $R \approx 1 - 1.6 \times 10^{-6}$ is achieved with dielectric mirrors. An FP resonator made with the mirrors has finesse $\mathcal{F} = 1.9 \times 10^{6}$. Further practical increase of the finesse of FP resonators is problematic because of the absorption and the scattering of light in the mirror material through fundamental limit on the reflection losses given by the internal material losses and by thermodynamic density fluctuations on the order of parts in 10^{9}. The quality factor of a resonator depends on both its finesse and its geometrical size. A one-dimensional FP resonator has $Q = 2 \mathcal{F} L/\lambda$, where L is the distance between the mirrors and λ is the wavelength. It is easy to see that the quality factor of the resonator is unlimited because L is unlimited. $\mathcal{F}$ and Q are equally important.

In some cases, finesse is technically more valuable than the quality factor. For instance, buildup of the optical power inside the resonator, as well as the Purcell factor, is proportional to finesse. Sometimes, however, the quality factor is more valuable. For example, inverse threshold power of intracavity hyperparametric oscillation is proportional to Q^2 and efficiency of parametric fre-