



Hyperspectral Photonics: an Overview

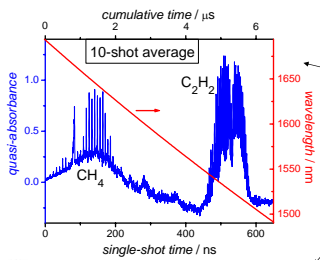
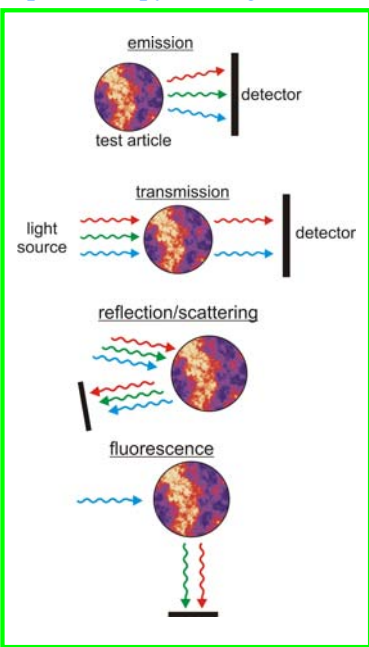
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Generic Spectroscopy Arrangements:



Why hyperspectral?

Broad spectral coverage (> 200 cm⁻¹):

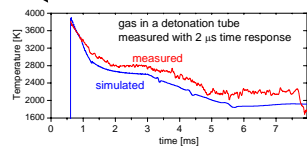
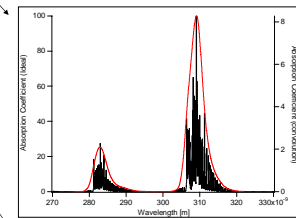
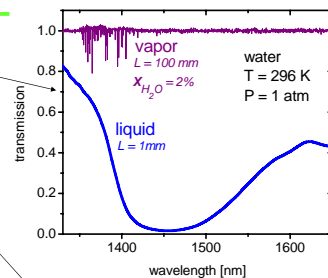
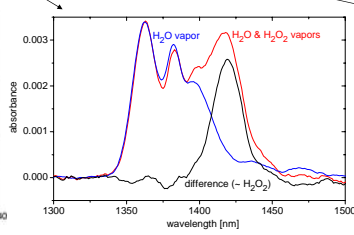
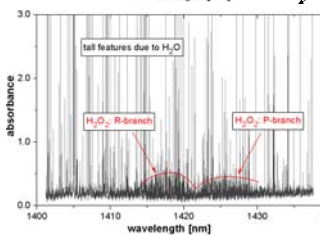
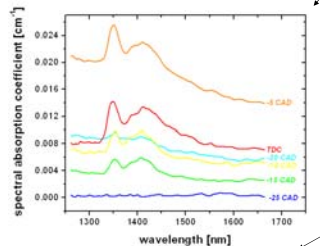
- multiple species with a single source
- ability to monitor broad spectral features (heavy or high-pressure gases, supercritical fluids, liquids, solids, etc.)
- reality checks (are you really measuring what you think you're measuring?)
- high-resolution OCT: 1300-1500 nm (1025 cm⁻¹ range) provides 3.7 μm resolution whereas 1300-1310 nm (59 cm⁻¹ range) provides 64 μm resolution

High-resolution (< 1 cm⁻¹):

- higher SNR in gas spectroscopy
- discrimination of multiple species
- large possible ranging depth in OCT: 1 cm⁻¹ resolution enables 3.7mm-deep images, 20 cm⁻¹ resolution only allows 185μm-deep images

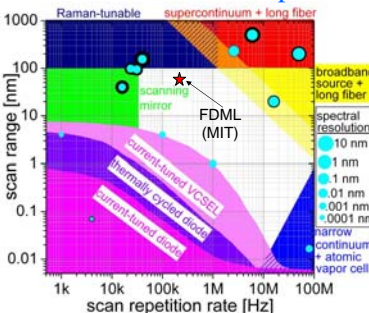
High-speed (> 1 spectrum every 50 μs):

- Immunity to 'slow' noise sources: vibration, beamsteering, etc.
- Compatibility with transient experiments (explosions, shock tubes, pulsed magnetic fields, video-rate OCT, etc.)

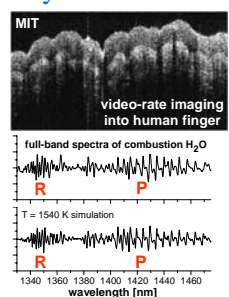


- ## Why engineer hyperspectral sources?
- (since most spectroscopic measurements can be made using only a light bulb and a spectrometer)
- Efficient at high-resolution**
 - Spectral resolution decoupled from collection etendue. Examples: in fluorescence, collect > 1 Sr from a 1-mm emitter and still maintain < 1 GHz spectral resolution in an excitation scan; likewise in absorption, beamsteering does not compromise spectral resolution
 - Simple, rugged, compact, all-fiber...**
 - Hyperspectral lasers more readily multiplexed than hyperspectral detectors, e.g. for multi-beam tomography, multi-channel sensors to cover ultra-broad spectral ranges
 - Compatible with simple detectors**
 - Not paced by camera technology (limited readout rates, usually optimized for visible range, etc.)
 - Can complement spectrometers**
 - Ultimately, may want to combine hyperspectral light sources and detectors (e.g., for combined excitation-emission fluorescence spectroscopy)
 - Ordered light reduces natural beating**
 - For 5 μs-duration measurement at 1 cm⁻¹ resolution, thermal light has a fundamental peak-to-peak noise level of ~ 1%

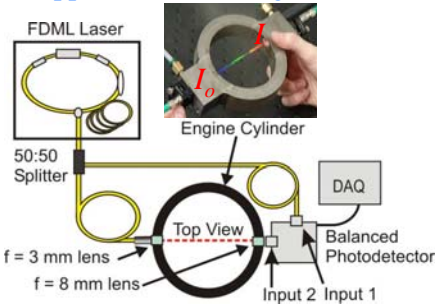
Some sources developed:



Key measurements:



Application in an engine:



HCCI Engine thermometry results:

