Hyperspectral Photonics: an Overview

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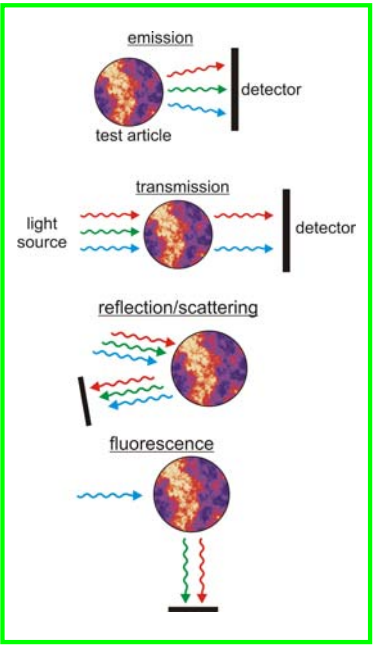
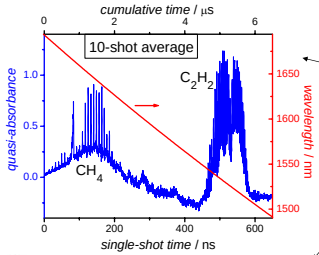
Generic Spectroscopy Arrangements:





Why hyperspectral?

MORE INFORMATION

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

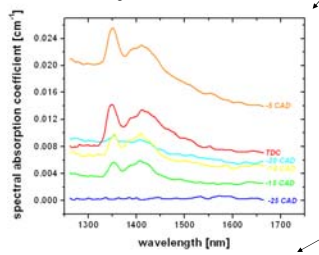
High-resolution (< 1 cm^{-1}):

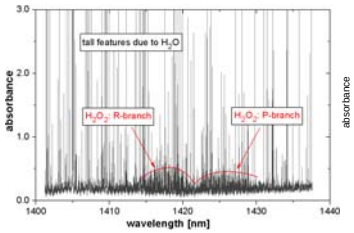
- higher SNR in gas spectroscopy
- discrimination of multiple species
- large possible ranging depth in OCT: 1 cm^{-1} resolution enables 3.7mm-deep images, 20 cm^{-1} resolution only allows 185μm-deep images

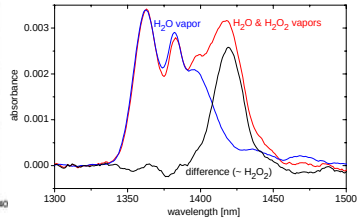
HIGHER INFO RATE

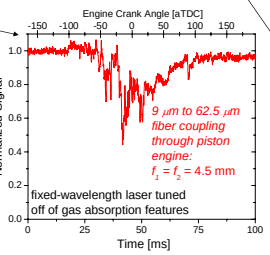
High-speed (> 1 spectrum every 50 μs):

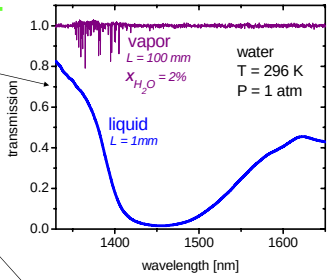
- Immunity to 'slow' noise sources: vibration, beamsteering, etc.
- Compatibility with transient experiments (explosions, shock tubes, pulsed magnetic fields, video-rate OCT, etc.)

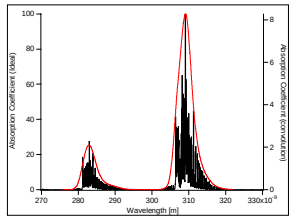


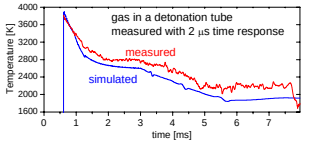












Why engineer hyperspectral sources?

(since most spectroscopic measurements can be made using only a light bulb and a spectrometer)

1. 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

2. 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

3. Compatible with simple detectors

- Not paced by camera technology (limited readout rates, usually optimized for visible range, etc.)

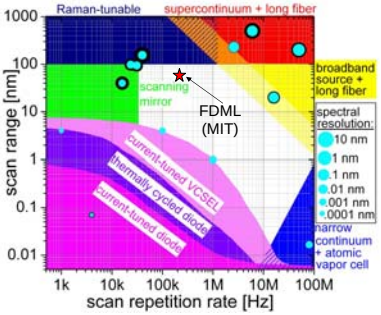
4. Can complement spectrometers

- Ultimately, may want to combine hyperspectral light sources and detectors (e.g., for combined excitation-emission fluorescence spectroscopy)

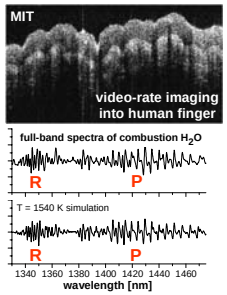
5. Ordered light reduces natural beating

- For 5 μs-duration measurement at 1 cm^{-1} resolution, thermal light has a fundamental peak-to-peak noise level of ~ 1%

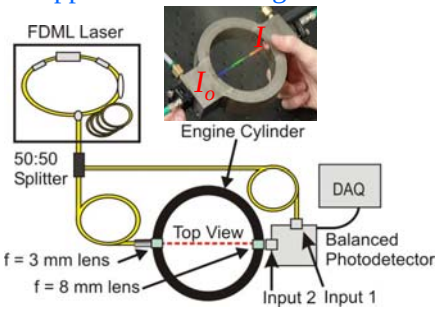
Some sources developed:



Key measurements:



Application in an engine:



HCCI Engine thermometry results: