Hyperspectral Photonics: an Overview

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Why hyperspectral?

1. 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 3.7 mm-deep images, 20 cm⁻¹ resolution only allows 185 μm-deep images

2. 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.)

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

4. Ordered light reduces natural beating

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Why engineer hyperspectral sources?

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%