SPECTROSCOPY

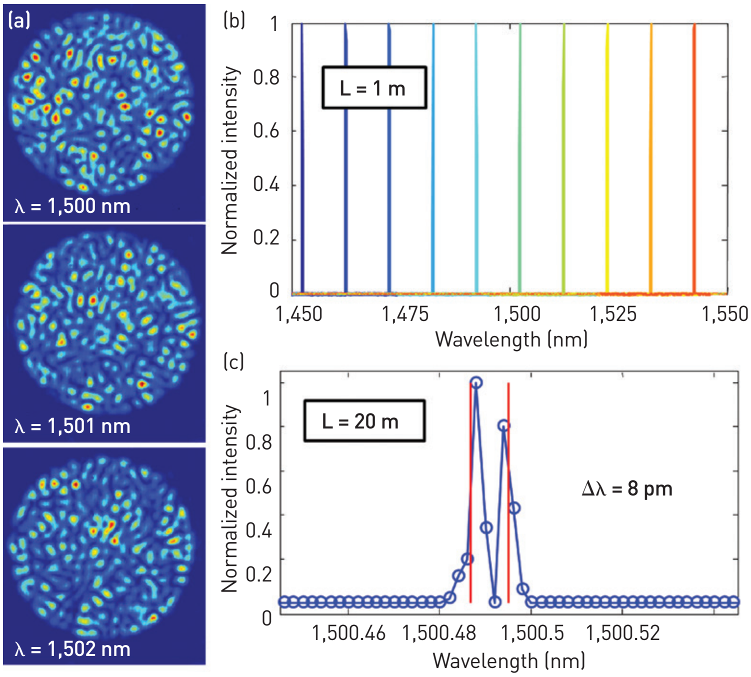
Multimode Fiber as a High-Resolution, Low-Loss Spectrometer

Spectrometers are widely used tools in chemical and biological sensing, material analysis and light source characterization. Traditional spectrometers use a grating/prism to disperse light. The spectral resolution scales with the optical path length from the grating to the detectors, imposing a trade-off between device size and resolution. The recent development of miniature spectrometers has enabled a host of new applications, owing to their reduced cost and portability. However, these implementations are still based on grating dispersion, and therefore the spectral resolution is lower than large bench top spectrometers. As a potential solution to this problem, we proposed and demonstrated that a single multimode fiber can function as a high-resolution, low-loss spectrometer.[1]

Our fiber spectrometer is compact, lightweight and low-cost. It also provides resolution that is competitive with the top commercially available grating-based spectrometers. It utilizes the speckle pattern from a multimode fiber for spectral reconstruction. The speckle pattern, generated by interference among the guided modes, is unique for each wavelength and can be used as a fingerprint to identify the spectral content of input light. We used a camera to record the speckle patterns at individual wavelengths and stored them in a transmission matrix. After calibration, we retrieved an arbitrary probe spectrum from the speckle pattern by matrix inversion and non-linear optimization.[1–5]

The spectral resolution of the multimode fiber spectrometer scales with the fiber length. A standard 1-meter-long multimode fiber (105 μm core diameter, NA = 0.22) provides 100 nm bandwidth with 0.15 nm resolution at about 1,500 nm wavelength. Using a 20-meter-long fiber, we could resolve two lines separated by 8 pm. The fiber spectrometer can also recover broadband spectra.[2]

In addition to providing fine spectral resolution and broad operation bandwidth, our fiber spectrometer has low insertion loss. The signal-to-noise ratio can exceed 1,000. Furthermore, the fiber can be coiled to provide a compact, lightweight and low-cost spectrometer that will enable a host of new spectroscopic applications. OPN



(a) Speckle patterns at the end of a 1-meter-long multimode fiber for three input wavelengths. Small changes in the input wavelength produce uncorrelated speckle patterns, enabling high resolution. (b) Spectra reconstructed using a 1-meter-long fiber. The probe for each is a narrow laser line. (c) A 20-meter-long fiber is used to reconstruct a spectra consisting of two narrow lines (red) separated by only 8 pm.

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