Superiority of a Square-core Multimode Fiber for Imaging and Spectroscopy

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An optical fiber is a promising tool for remote imaging [1]. A multimode fiber (MMF) offers multiple advantages: compactness, flexibility as well as the ability to transmit a large amount of information via multiple spatial modes. There are several methods to do optical imaging through a MMF. One can use wavefront shaping (WFS) to compensate for the modal dispersion and mode mixing so that the incident light can converge to a desired pattern at the fiber output [2]. By using WFS, we can sequentially generate focal spots at the distal fiber facet to scan the sample. Another imaging method through a MMF is compressive imaging (CI). The interfering fiber modes create a speckle pattern, which varies with wavelength and input light position, which. can be used as a basis for CI [3]. CI allows to reconstruct the image with a resolution beating the Abbe limit with fewer measurements than the number of pixels [4]. Finally, the decorrelation of the speckle patterns with wavelength encodes the spectral information of input light, which enables MMF spectroscopy applications [5].

For all the above applications almost always a conventional *round-core* MMF is used. Here we experimentally and theoretically demonstrate that a *square-core* MMF has superior potential for WFS-based imaging, compressive imaging, and optical spectroscopy [6,7]. The quality of focal spots launched from the MMF, the orthogonality and the decorrelation of the speckle patterns are the most important characteristics for WFS-based imaging, CI, and optical spectroscopy. A principal sketch of our experimental setup is shown in Fig 1(a). Via a digital micromirror device (DMD) the light is coupled to a MMF. A CCD camera is used as detector. In the WFS-based imaging mode, the DMD projects different phase patterns to provide holographic control of light. A focal spot grid is generated at the distal facet for round- and square-core MMFs as shown in Fig. 1(b). We characterized and carefully analysed the quality of the focal spots generated by the different MMFs. In a second set of experiments, the DMD couples light into a MMF at different input postions to generate speckle patterns. The orthogonality, uniformity and randomness of the speckle patterns for CI have been investigated. In a last set of experiments, we analyze the decorrelation of speckle patterns with wavelength.

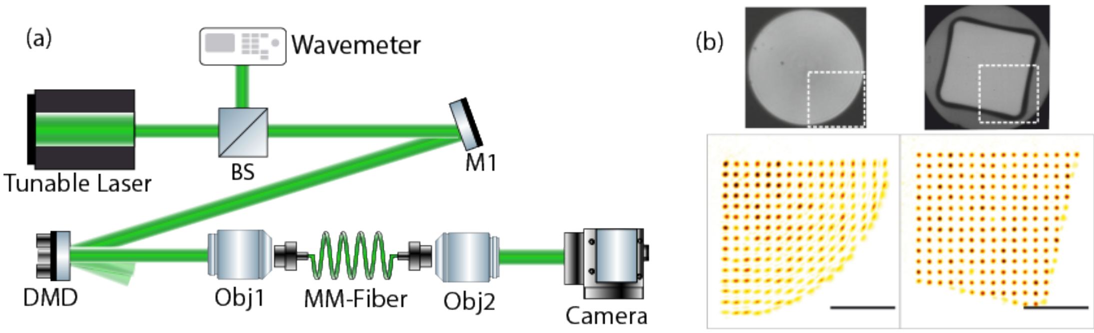

Fig. 1 (a) Experimental setup. (b) Composite image of focal spots generated on the output of a round-(left) and square-core (right) MMF. Pixel color represents the maximum value over all wavefront shaping runs. Scale bars are 20 μm.

To summarize, we have demonstrated that for imaging and spectroscopy a square-core MMF is superior to a round-core MMF because of its small focal spot aberration in WFS, a uniform speckle pattern and independence of its speckle pattern decorrelation from the input light position.

References

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