**Docket #:** S10-387

# Sensing and Imaging with Multimode Fiber for Spatial Scanning

A team of Stanford engineers have developed a fast adaptive optics system for scanning, 3D imaging and sensing with a small (50 µm) multimode fiber (MMF). This technology uses a spatial light modulator (SLM) to manipulate the modes coupled at the MMF input in order to change the spatial focusing of light at the fiber output. Then an efficient algorithm reconstructs the optical field output into a 3D image with a wider field of view and higher resolution that current techniques. The system has applications in biological imaging, microscopy, sensing and optical communications. Because of the extremely small fiber probe, the invention may be particularly useful for imaging hard to reach locations in vivo.

*This video shows a spot of light scanning across the output facet of a multimode fiber (MMF). When combined with a 3D image reconstruction algorithm, this adaptive optics system can be used for 3D imaging or sensor multiplexing.*

**Stage of Research**
The inventors have demonstrated this technique for scanning microscopy and were able to distinguish between stripes 3.50 µm apart with axial resolution of 90 µm and depth of field of 200 µm. This invention motivated the application of MMF to high-resolution single-fiber microscopy/endoscopy (see Stanford Docket S12-501).

## Applications

- **Imaging:**
  - in vivo microscopy or endoscopy for accessing hard to reach targets
  - atomic force microscopy (AFM) – attach multiple tips for faster measurements

- **Sensor multiplexing** - multiple sensors on one platform, for example to identify different target molecules or to uncouple effects from the environment (e.g. temperature and pressure)
- **Optical communications** - increase bandwidth by sending information in different spatial modes

## Advantages

- **3D imaging**
- **Fast** scanning with **efficient** reconstruction algorithm
- **Small, flexible** MMF probe that dramatically increases multiplexing – fiber is 50 µm, two orders of magnitude smaller than current confocal microscopy
- **Wide field of view** - axial resolution of 90 µm and depth of field of 200 µm
- **Inexpensive, robust** platform which is easy to use and has a simple design

## Publications


- K. J. Boucher, C. Jan, J. M. Kahn, J. P. Wilde and O. Solgaard, Spot Formation and Scanning Microscopy via Multimode Fibers, presented at 2011 IEEE Photonics Conference (PHO), 9-13 October 2011, pp. 713-714.
- Kristen J. Boucher, Catherine Jan, Jeffrey P. Wilde, Joseph M. Kahn, Olav Solgaard, Multimode Fiber Imaging via Scanning Microscopy, presented at The Stanford Photonics Research Center (SPRC) 2011 Annual Symposium, 12-14 September 2011, Stanford, CA.
- Reza Nasiri Mahalati, Daulet Askarov, Jeffrey P. Wilde, and Joseph M. Kahn, Adaptive control of input field to achieve desired output intensity profile in multimode fiber with random mode coupling, Optics Express, 2012 Jun 18;20(13):14321-37. doi: 10.1364/OE.20.014321.


## Patents

- Published Application: 2014-064654
- Issued: 9,280,003 (USA)

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