Light-on-a-Chip
Group
Electrooptical Engineering

Presentation on the paper: Shaping the light amplified in a multicore fiber

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Outline

Introduction

- The interest in MM fiber is not limited to optical communications but spreads to other fields including spectroscopy, nonlinear optics, and imaging.
- The high degree of spatial freedom in the way light is trapped and transmitted through MM waveguides causes the delivered laser light to appear as a scattered beam with a random speckle pattern.
- Still control of light propagation through MM fibers can be achieved by use of a transmission matrix, digital phase conjugation, adaptive spatial shaping in combination with optimization routines.

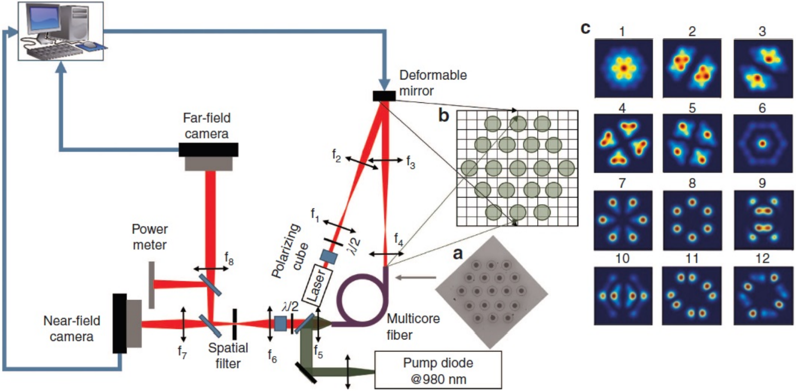
Introduction

What if the MM fiber or the scattering medium transmission is no longer considered as a lossless and gainless medium? Is it possible to shape the output field intensity pattern of an MM fiber in the amplification regime?

- The amplification is not uniformly shared by the guided modes.
- Linearity of the light-field transmission is generally lost in an amplifying MM fiber with the onset of gain saturation.

In this paper the ability of the adaptive wavefront shaping technique to tailor the output pattern of an MM fiber amplifier is investigated.

Experimetal setup



Schematic of the experimental setup including (a) an image of the MM-MC Yb-fiber (in gray), (b) a drawing of the downscale imaging of the DM surface on the fiber input face and (c) the 12 supermode patterns.

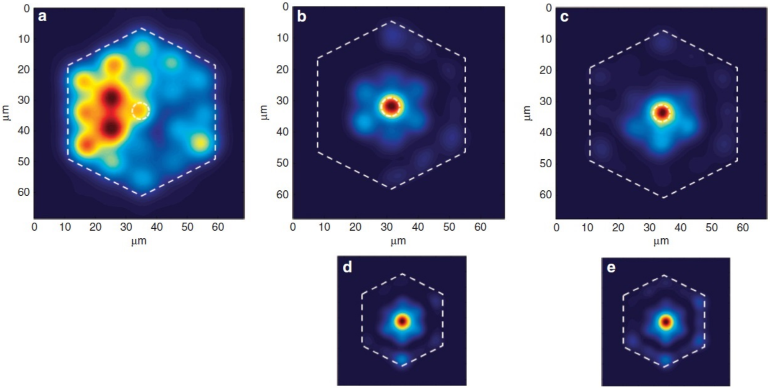
$$OF_1 = \frac{\int\int_A |\psi_{out}(x,y)|^2 dxdy}{\int\int_R |\psi_{out}(x,y)|^2 dxdy} \tag{1}$$

$$OF_2 = \frac{(\int\int_R \psi_{out}(x,y)\psi^*_{des}(x,y)dxdy)^2}{\int\int_R |\psi_{out}(x,y)|^2 dxdy \int\int_R |\psi_{des}(x,y)|^2 dxdy} \tag{2}$$

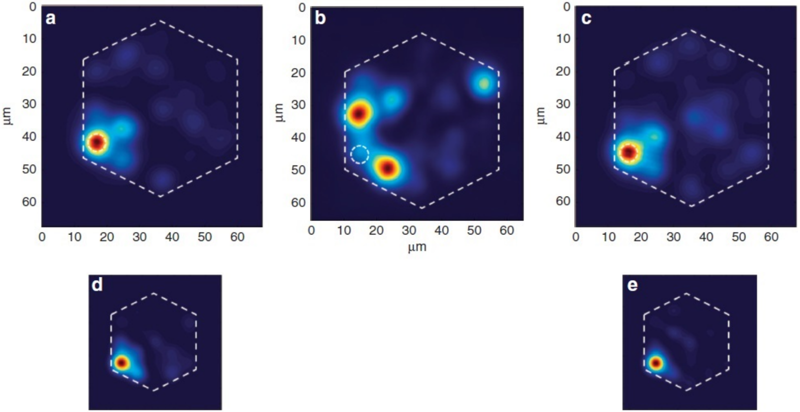
where:

- ψ_{out} - the current output field pattern,
- ψ_{des} - the desired mode,
- A - area covered by the desired profile,
- R - fiber core complete cross-section.

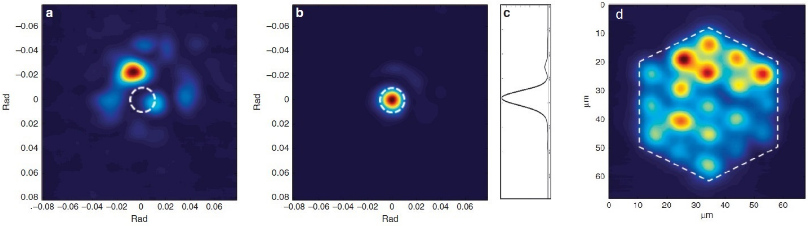
1. The eigenmode fields (supermodes) and propagation constants have been computed.
2. Laser beam was supposed to have an initial plane wavefront and almost uniformly covered the DM, whose surface was discretized in 12×12 elements.
3. The wavefront shaped by the DM was imaged onto the MM-MC fiber and expanded on its eigenmode basis.
4. The transverse profile of the output beam was built up by coherent summation of the transmitted modes and served to derive the value of the OF.
5. The final intensity pattern at the fiber amplifier output was computed.



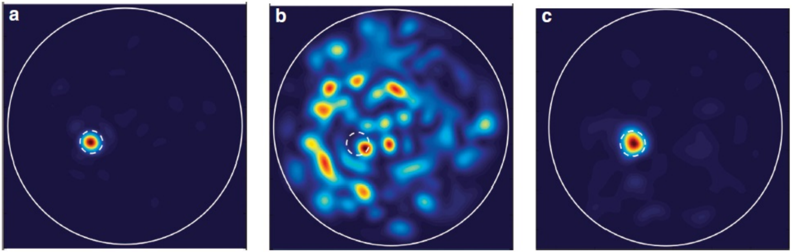
Output patterns recorded on the exit face of the MM-MC Yb-doped optical fiber: (a) without wavefront profiling, (b) after wavefront shaping for focusing on the central core without gain and (c) after wavefront shaping with 17-dB small signal gain. Insets show numerical results of the modeling of the whole system for the passive (d) and active (e) regimes, in good agreement with the observations.



Concentration of the output power in a bright spot on the outer ring of the multicore fiber. Typical recordings of the MM fiber output pattern (a) in the passive regime; (b) in the amplification regime maintaining the same input wavefront as in the passive case, in which the shaping is lost; and (c) in the amplification regime after a new round of adaptive shaping, in which the focus is restored. The experimental results are in agreement with the numerical results (d) and (e) given in the two insets.



Experimental far-field pattern of the multicore fiber amplifier before wave-front shaping (a), final pattern after optimization of the DM surface to obtain, in the desired orientation (dashed white circle), a single narrow diffraction lobe (b) cross-sectional profile (c) and near-field intensity at the MM fiber amplifier output recorded after optimization in the far field corresponding to (b).



Highly multimode fiber amplifier, experimental output patterns (a) after adaptive structuring of the input wavefront to obtain maximum power in the small target area bounded by the white dotted line without gain; (b) after switching on the gain, while maintaining the mirror profile with the passive case setting; and (c) after a restart of the adaptive profiling for shaping with a gain of 20 dB.

Conclusions:

- The adaptive wavefront shaping approach works for the control of the near-field pattern at the exit of a strongly multimode amplifying medium.
- The shaping capability of the technique was preserved despite the mode coupling, the inhomogeneous gain among the guided modes and the gain competition occurring in the saturation regime.
- Profiling of the amplified beam in the far field was demonstrated.