Measuring, Analyzing, and Tailoring the Rotational Memory Effect in Multimode Fibers

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Keywords: multimode fibers, orbital angular momentum, memory effects, wavefront shaping

Multimode fibers (MMF) provide an attractive platform to perform minimally invasive imaging deep into the human body. However, the presence of mode dispersion and coupling scrabble the input image. While the image can be reconstructed with the knowledge of the transmission matrix (TM) [1], this requires us to have access to the distal end and for the fiber to remain static. These two conditions cannot be met in real life applications. An elegant way forward is to use statistical invariant properties and the resulting memory effects to reconstruct images without the knowledge of the TM [2].

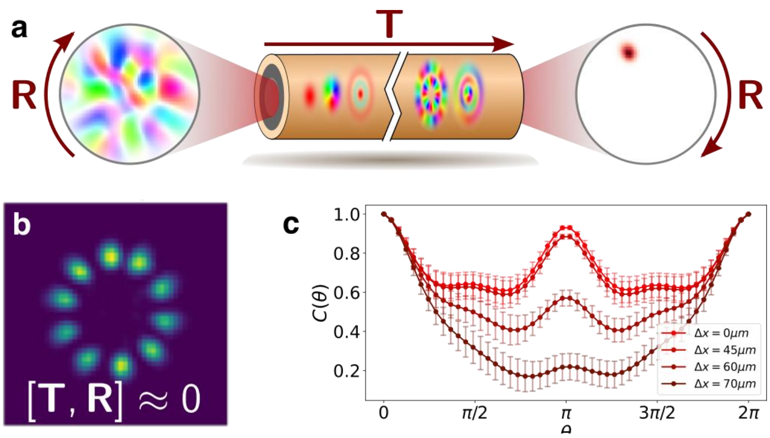

Fig. 1: Rotational memory effect in multimode fibers: **a**, Due to the rotational symmetry one expects that by rotating the input, the output should also rotate. **b**, This is approximately true as exemplified by rotating a focal spot. **c**, The effect of external deformations destroys the rotational memory effect in a predictable manner.

In MMFs with cylindrical symmetry, one has a rotational memory effect (RME) wherein a rotation of the input field leads to a rotation of the same amount at the output [3]. Said another way, the rotation operator commutes with the TM see Fig. 1a. Here, we demonstrate how the effect of aberrations can be compensated for [4] in order to accurately measure the RME (see Fig.1b-c). Moreover, we study how this effect is affected by intrinsic defects of the fiber and ultimately destroyed by external perturbations, such as bending, (see Fig. 1c) both of which lead to the coupling of neighboring modes in the orbital angular momentum space. We provide a theoretical framework in excellent agreement with both simulations and experimental results. Finally, we define operators that allow finding input wavefronts that maximize the RME for a given angle or over the full range of angles.

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