

# High dimensional information transmission via multimode fibers exploiting physics-informed deep learning towards classical and quantum communication

Juergen W Czarske<sup>1,2</sup>, Qian Zhang<sup>1</sup>

<sup>1</sup>Laboratory of Measurement and Sensor Systems, TUD Dresden University of Technology,

Helmholtzstraße 18, 01062 Dresden, Germany

<sup>2</sup>Adjunct Professor of Optical Sciences, Wyant College of Optical Sciences, University of Arizona, Tucson

Email: [juergen.czarske@tu-dresden.de](mailto:juergen.czarske@tu-dresden.de); [qian.zhang@tu-dresden.de](mailto:qian.zhang@tu-dresden.de)

Multi-mode fibers (MMFs) have attracted numerous studies for boosting the transmission capacity in classical and quantum communications, but also biomedical imaging with endoscopes. One potential approach is to use the transverse modes as spatial sub-channels transmitting information through them simultaneously, including orbital angular momentum and light spin. However, the distortion caused by modal crosstalk limits the deployment of MMF-based information transmission. To undo the scrambling, digital optical phase conjugation can be used, where the wavefront launched at the input should be manipulated using a spatial light modulator to obtain a desired field at the output. However, wavefront modulation techniques rely on phase, amplitude, and polarization measurements. We propose a novel approach for referenceless phase retrieval based on the mode decomposition using AI approaches, which are applied for 12 km long MMF. Using this technique, we can realize high-fidelity mode transmission over MMFs towards advancements in capacity and security of data transmission. The proposed intelligent photonics using physics-informed neural networks will facilitate MMFs towards classical and quantum communication.



## Short Bio:

**Juergen W Czarske** (Fellow EOS, OPTICA, SPIE, IET, IOP) is director and full chair professor of the TU Dresden, Germany. His awards include the 2019 OPTICA

Joseph-Fraunhofer-Award/Robert-M.-Burley-Prize in Optical Engineering and the 2024 SPIE Dennis Gabor Award in Diffractive Optics. Juergen fosters talented

students early. The students and members of his lab have won over 100 prizes, including Bertha-Benz award of Daimler Benz Foundation. Juergen is Vice President of International Commission for Optics, ICO, and was the general chair of the world congress ICO-25 with 3 Nobel laureates and attendees from 55 countries. Juergen also serves on the editorial boards of Light Science and Applications, Advanced Photonics and Light Advanced Manufacturing.



**Short Bio:**

**Qian Zhang** is a Ph.D. student at the Laboratory for Measurement and Sensor Systems/Czarske Lab Tech-nique. He received his Diploma degree in Electrical Engi-neering from the TU Dresden in 2020. He won the Faculty Award of the Gisela and Erwin Sick Foundation for his thesis. His research focuses on the application of artificial intelligence in optical measurement systems.