Growing Quantum Communication Capacity with Spatial Modes of Optical Fiber

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Quantum communication links and networks are needed for secure information exchange and for interconnecting future quantum computers. However, their capacity decreases exponentially with distance due to the effect of fiber attenuation that cannot be undone by amplification (although quantum repeaters are an active area of research, they are almost as hard to build as quantum computers). Hence, the only way to increase the quantum communication capacity is by employing more degrees of freedom (optical modes) over which this information can be encoded and transmitted. While frequency (WDM), temporal, and polarization modes have already been exploited for this purpose, the use of many spatial modes has only recently become possible owing to the development of low-loss few-mode fibers (FMFs).

This talk will present the work of Prof. M. Vasilyev's research group on the development of two key enablers of quantum communication over spatial modes of FMFs: 1) generator of spatially-entangled photon pairs and 2) receiver sub-system that can perform projective measurements that alternate between two sets of mutually unbiased bases in a given spatial mode space (this sub-system can also perform dynamically reconfigurable de-multiplexing of spatial modes of the FMF).

Both of the above devices / sub-systems are based on the spatial-mode-selective quantum frequency conversion process, implemented in a medium with either second-order nonlinearity (multimode lithium niobate waveguide) or third-order nonlinearity (custom-made FMF). The talk will introduce the principles of their operation, as well as the recent experimental results obtained in both media.

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Prof. Michael Vasilyev received the M.S. degree in Physics from Moscow Institute of Physics and Technology, Russia, in 1993, and the Ph.D. degree in Electrical Engineering from Northwestern University, Evanston, IL, in 1999. During his doctoral work, he has demonstrated the first noiseless image amplifier, first noiseless fiber amplifier, and tomography of multimode quantum states. In 1999 Dr. Vasilyev joined Corning Inc. (Somerset, NJ) as a senior research scientist, where he performed experimental and theoretical studies of noise and nonlinearities in optical fibers and amplifiers to optimize them for ultra-long-haul transmission systems. Since 2003 he has been with the Department of Electrical Engineering, University of Texas at Arlington, TX, where he is currently a Distinguished University Professor. Prof. Vasilyev's research interests include novel optical amplifiers, nonlinear-optical signal processing, quantum communications, and nanophotonics. He has served as a member or a chair of the technical program committees for IEEE Summer Topicals, CLEO, FiO, OFC, OAA, Photonics West, and other conferences, and as an Associate Editor of the Journal of Lightwave Technology. Dr. Vasilyev was a recipient of 2008 DARPA Young Faculty Award and 2019 UTA Outstanding Research Achievement Award, and was inducted into the UTA Academy of Distinguished Scholars in 2020. He has published over 60 journal and over 170 conference papers, and holds 10 U.S. patents. Dr. Vasilyev is a Fellow of the OSA and SPIE and a Senior Member of the IEEE.