High-dimensional quantum key distribution based on multicore fiber using silicon photonic integrated circuits

Quantum key distribution provides an efficient means to exchange information in an unconditionally secure way. Historically, quantum key distribution protocols have been based on binary signal formats, such as two polarization states, and the transmitted information efficiency of the quantum key is intrinsically limited to 1 bit/photon. Here we propose and experimentally demonstrate, for the first time, a high-dimensional quantum key distribution protocol based on space division multiplexing in multicore fiber using silicon photonic integrated lightwave circuits. We successfully realized three mutually unbiased bases in a four-dimensional Hilbert space, and achieved low and stable quantum bit error rate well below both the coherent attack and individual attack limits. Compared to previous demonstrations, the use of a multicore fiber in our protocol provides a much more efficient way to create high-dimensional quantum states, and enables breaking the information efficiency limit of traditional quantum key distribution protocols. In addition, the silicon photonic circuits used in our work integrate variable optical attenuators, highly efficient multicore fiber couplers, and Mach-Zehnder interferometers, enabling manipulating high-dimensional quantum states in a compact and stable manner. Our demonstration paves the way to utilize state-of-the-art multicore fibers for noise tolerance high-dimensional quantum key distribution, and boost silicon photonics for high information efficiency quantum communications.