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In contemporary society, communication security has become increasingly important. The security of the current cryptosystems, based on mathematical assumptions, will not be guaranteed when quantum computers become available [1]. This has spurred investigations into new security technologies based on quantum physics. In order to exchange secure information between users, quantum key distribution (QKD), a branch of Quantum Communications (QCs), provides good prospects for ultimate security based on the laws of quantum mechanics [2–7]. Most of QKD systems are implemented in a point-to-point link using bulky, discrete and expensive devices. Consequently, a large scale deployment of this technology has not been achieved. In a future scenario, where QCs will become standard technology, and where infrastructures like banks and government buildings, will be connected through a quantum network, different requirements in terms of key generation are needed. A solution may be represented by new technologies applied to quantum world. In particular multicore fiber (MCF) open a new scenario for quantum communications, from high-dimensional (HD) spatial entanglement generation, to HD QKD and multi-user key generations, to HD-entanglement distribution. Furthermore, MCFs are expected as a good candidate for overcoming the capacity limit of a current optical communication system, as example the record capacity of 661 Tbits/s was obtained last year with a 30-cores fiber [8]. Proof of concept experiment has already proved the coexistence of classical and quantum communications transmitted into different cores of MCF [9].

On the other hand, photonic integration has played a critical role in recent quantum information revolution by integrating functionalities of traditional discrete bulky components into ultra-compact chips [10, 11]. In fact, integrated photonic circuits provides excellent performances (compacts, good optical phase stability, access to new degrees of freedom), and are particularly suitable for the manipulation of quantum states. Some recent experiments have already demonstrated conventional binary QKD systems, using polarization and phase reference degrees of freedom [12, 13]. Moreover, by using integrated solution new high-dimensional quantum states can be generated and propagated. Based on compact silicon photonic integrated circuits, we here show how a MCF can be used for quantum communications protocols by proving decoy-state HD-QKD and multi-users quantum key generations.

General information
State: Published
Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Fiber Optics, Devices and Non-linear Effects, Sun Yat-Sen University
Number of pages: 3
Publication date: 2017
Peer-reviewed: Yes
Event: Abstract from 7th International Conference on Quantum Cryptography, Cambridge, United Kingdom.
Electronic versions:
Th23.pdf
Research output: Research - peer-review › Conference abstract for conference – Annual report year: 2017