Flattened Switching Node with Flexible Co-propagation of Quantum and Optical Signals

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Abstract: We propose a flattened switching node with flexible co-propagation of quantum and optical signal that could combine the quantum key distribution network and optical network into one. And we exhibit a stable experimental platform that could show the Practicality of this structure.

OCIS codes: (060.5565) Quantum communications, (060.1810)Co-switching devices

1. Introduction

Quantum key distribution provides an unconditional physical layer for secure communication [1] and uses non-orthogonal coded single photon states, such as single photon polarization, phase or angular momentum, to provide secure information. These all can be transmitted and switched as same as optical signal in the fiber. So far, the study on point-to-point co-fiber transmission for QKD communication has been quite mature. More and more researchers have turned into studying large-scale and multi-user QKD network based on optical network. In 2003, Paul Toliver made an experiment of an optical switching system for QKD communication based on the 4x4 2-D MEMS switch array and reached a transmission distance more than 10 km [1]. But this system couldn't support the case of the co-switching of multiple wavelengths that have different destination. In 2010, Shuang Wang et al. of USTC proposed a wavelength-saving quantum switching device composed of a three-port looper and WDM [3] and it has low power loss and high stability. However this scheme adopted the real-time full connection and increased the complexity of the network. The schemes above neither considered to integrate the quantum network into the existing optical network. This paper will present an flattened low-loss switching node scheme supporting the co-propagation of quantum signal and optical signal, the node is based on WSS and coupler and could provide abilities of flexible spectrum allocation and non-blocking switching.

2. Difference between quantum communication and classical optical communication

To integrate quantum communication with optical communication, we should consider similarities and differences between quantum signal and optical signal. The quantum signal can't be amplified, it needs the link loss to be extremely low, while the optical signal is not sensitive to the link loss. When passing through the beam splitter, quantum signal only appear in one branch of the beam splitter at a specific probability, while optical signal appear in all branch of the beam splitter at a specific ratio of the input power. In the process of QKD, the delay time between quantum signal and synchronization signal has an important effect on key generate rates.the synchronization signal is needed to have the same path with quantum signal on the link layer to keep the signal synchronized. However, the classical optical signal doesn't require additional synchronization signal. Meanwhile,quantum signal is extremely weak and is very easy to be disturbed by optical signals of other channels, so it is very important to consider the effects of optical signals on quantum signals when they are co-propagated.

3. Flattened switching node based on WSS

We makes full use of the characteristics of WSS: (a)Flexgrid Dynamic Channel Width Control; (b)Flexgrid Dynamic Attenuation Control; (c)Channel plans are configurable 'on-the-fly'. These make WSS meet the needs of co-switching of quantum signal with optical signal. the switching node structure is showed in figure 1. The switch node only have two kinds of optical devices, WSS and coupler. It has the characteristics of flexible grid, multi-granularity, low loss, non-blocking. so it could switch signal with variety of bandwidth Simultaneously and could achieve "Packet

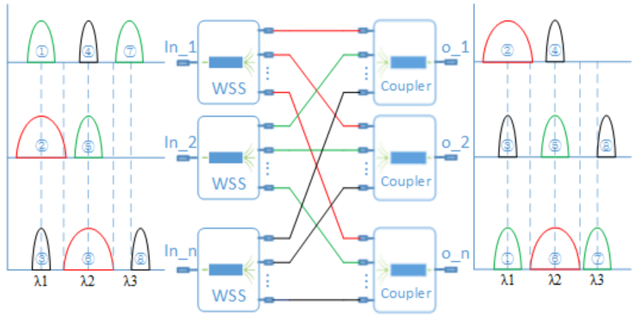

Fig. 1. Switching node structure.

Routing" that the signals who have same destination but different center wavelength and bandwidth could always passing through the same optical fiber path. Based on this switching node, we could also design a wavelength allocation algorithm to reduce the impairment on the quantum channels induced by four-wave mixing (FWM). When expanding node's degree, it doesn't increase the device cascade, Since it's attenuation remains stable, approximately 3.5 dB under current technical conditions. For optical signal, there is only one constraint that the signals couldn't overlap in the spectrum when switched to the same port. In Fig.1, wave 2 and wave 6 have different center wavelength, but their spectrum have a little intersection, so they can't be switched to the same port. For quantum signal, we could compute the channels that FWM sit on according to the current optical signal passing the node, and make quantum signal stay away from these channels to reduce the interference induced by FWM when allocating the quantum signal channel. In the past studies, someone have proposed switching node based on WDM and OXC, and multi-granularity switching node of three-layers based on DWDM, CWDM and OXC. Under the same conditions of 4 * 4 optical switching nodes and assuming each fiber has four channels, we compared these three structures that show that the flattened switching node we proposed has lower loss.

	device of passing through		Insertion loss	Node total insertion loss
switch based on DWDM and OXC	1*4 DWDM		1.8dB	8.3dB
	16*16 OXC		6.5dB(Max)	
swith of multi-granularity	Fiber level	4*4 OXC	2.5dB(Max)	10.6dB
	waveband level	1*2 CWDM	0.8dB	
		4*4 OXC	2.5dB(Max)	
	Wavelength level	1*4DWDM	1.8dB	
		8*8 OXC	3dB(Max)	
switch based on WSS and Coupler	1*4 WSS		4.2dB(Max)	4.4dB
	Coupler		0.2dB	

Fig. 2. Comparison of insertion loss

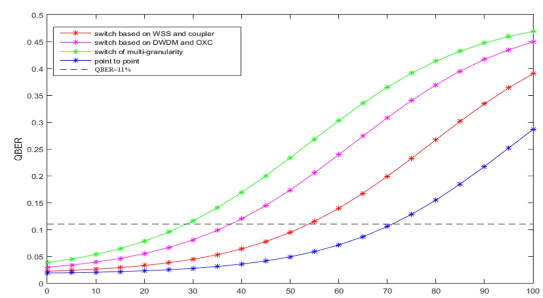

Fig. 3. Transmission distance vs QBER

4. Experiment setup

Our experimental implementation is composed of quantum transmitter/receiver, optical transmitter/receiver and the switching node as Fig.4 show. Alice have abilities of sending the quantum signal, quantum sync signal and optical signal. Bob could receive and parse these three kind of signals. QKD transmitter consists of a pulsed light source (LS), a Faraday-Michelson interferences(FM) containing a phase modulator (PM) and a variable optical attenuator(VOA). QKD receiver has one more signal photon detector(SPD). Since it is difficult to create true single photon pulses, a pulsed 1553.73nm laser diode (1-ns pulse width) with 10MHz repetition rate is followed by variable optical attenuator to approximate single photon generation. In order to detect the quantum signal within the appropriate time, we need a signal to synchronize the time of detection and set it's center wavelength 1529.99nm. There are two 1550nm Optical waves for sending large data as text, image, video etc. When performing quantum communication, there are a lot base selection information needed to be send on the public network. Since the switching node is unidirectional, if we make

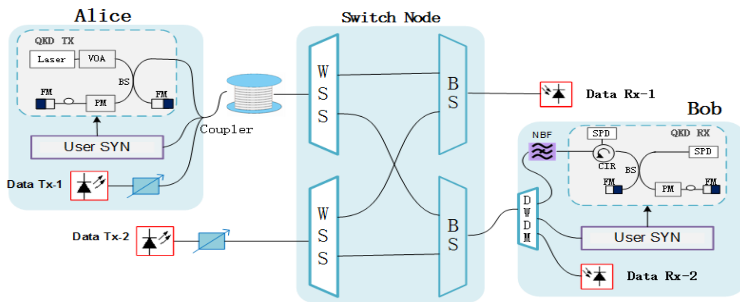

Fig. 4. Experiment setup of coexistence switching node

the public network through the quantum switching node and switched by switching node, we need to build two switch nodes. In account cost consideration, we build another public network without switching that connect Alice and Bob Directly. In this experiment, we set up three sets of contrast experiments. (a) Point-to-point quantum communication experiment; (b) Only quantum communication passes through the switching node; (c) Quantum communication and classical optical communication pass through the switching node at the same time. Fig.5.6 show 24 hours of continuous operation of experiment. The results show that the co-propagation switching could be realized by the switching node we proposed and the QBER and key generation rate is acceptable.

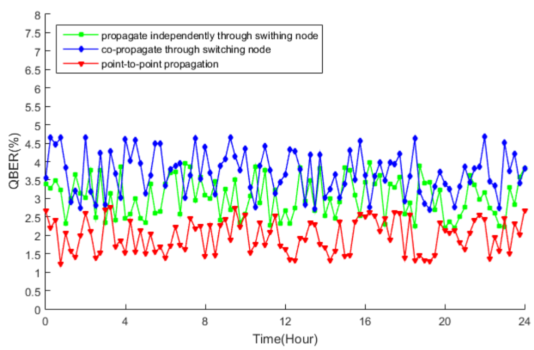

Fig. 5. QBER performance for 24 hours

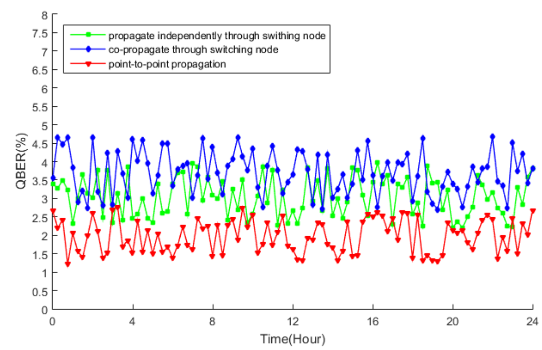

Fig. 6. Key generation rates performance for 24 hours

5. Conclusions

We propose a flattened switching node with flexible co-propagation of quantum and classical opticals signal. This architecture support flexiable spectrum allocation and the experiment demostrate that this node could support the co-propagation swithcing of quantum signal with optical signal.

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