# Flattened Flexible Non-blocking Switching Node with Quantum and Classic Optic Coexistence

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**Abstract:** Quantum key distribution provides an unconditional physical layer for secure communication.Study on switching and large-scale Networking problems in Quantum Communication could promote QKD communication to industrialization and practical. The current quantum switching nodes can only handle the wavelength of a specific bandwidth and have a strong constraint on the path of the transmission. And the spectrum reuse rate is very low. So it can't meet the demands of build large-scale network. This paper will present a WSS-based flattened flexible and non-blocking switching node that could support quantum communication and classic optical communication at the same time with multi-granularity.

**OCIS codes:** 000.0000, 999.9999.

## 1. Introduction

QKD uses non-orthogonal coded single photon states, such as single photon polarization, phase or angular momentum, to provide secure information exchange for two remote users. These all can be transmitted and switched same as classic optic signal in the fiber. So far, the study on point-to-point QKD communication based on fiber-optic links has been quite mature. More and more researchers have turned to large-scale and multi-user QKD communication network systems based on existing optical devices, dnd strive to make QKD communication network and existing optical network one integration. In 2003, Paul Toliver experimented with the optical switching system of the QKD communication based on the 4x4-based 2-D MEMS switch array under the B92 protocol and reached a transmission distance of more than 10 km at the time of the device attenuation of 5.9 dB. But this system can not achieve the singals with the existence of multiple wavelengths in one fiber are transmitted and switched, only can provide signal switching services for the fiber that only contains one signal. In 2010, Shuang Wang et al. Of China University of Science and Technology proposed a wavelength-saving quantum signal switching device composed of a three-port looper and wavelength division multiplexer, and this scheme has lower power loss and higher stability than using active device. However this cheme alse adopted the real-time full connection, increased the complexity of the network, and is difficult to expand. Although the wavelength can be reused, but the reuse rate is relatively low. the schme above two have a certain routing path compared with the using of beam spliter, but neither considered to integrate the quantum network with the existing classical optical network. This paper presents an quantum switching node scheme supporting the coexistence of quantum signals and classical optical signals based on WSS and coupler and providing more flexible spectrum allocation and non-blocking switching for any wavelength with any bandwidth in any input port.

## 2. Difference between quantum communication and classical optical communication

To integrate quantum communication with classical optical communication, we should consider the same point and difference between quantum communication and classical optical communication. The quantum signal can't be amplified, it needs the transmission link loss to be extremely low, while the classic optical signal is not sensitive to the link loss due to the signal power is very large. The quantum signal will show in one branch of the beam splitter at a specific probability when passing through the beam splitter, while the classical optical signal is transmitted to the branch of the beam splitter at a specific ratio of the input optical power. In the process of quantum communication, the delay time between quantum signal and synchronization signal has an important effect on secret key generate rate.the synchronization signal is needed to transport in the same way 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 the classic optical signals of other channels, so it is very important to consider the effects of classical signals on quantum signals when this two kind of signals are transported at the same time in the same fiber or switching node.

## 3. Flattened switching node based on WSS

This article 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 three features simultaneously meet the needs of quantum signal switching and classical optical signal switching, Which can be used to simultaneously transmit quantum signal and classical signal. the switching node scheme is show as figure 1. The

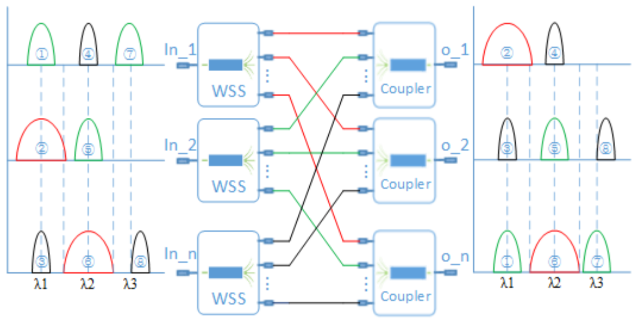


Fig. 1. Switching Node Structure.

switch node only have two kinds of optical devices, WSS and coupler and have the characteristics of flexible grid, multi-granularity, low loss, non-blocking. it has the flexibility to switch a variety of bandwidth signals Simultaneously and it can achieve "Packet Routing" that the signals that have same destination but have different center wavelength and bandwidth could always keep in the same fiber. 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 the degree, it doesn't increase the device cascade, and it's attenuation remains the same, approximately 3.5 dB under current technical conditions. For classic optical signal, this switching node only have one constraint that the signals switched to the same port can't overlap in the spectrum. For example, 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 classic optical signal in the fiber, let the quantum signal stay away from these channels to reduce the interference induced by FWM when allocating the quantum signal channel. In the past studies, some have proposed switching node based on WDM and OXC, and the three-layers multi-granularity switching node based on DWDM, CWDM and OXC. There are some comparisons to these three structures below.

Table 1. A stunning table

| | 使用的器件 | | 器件插入损耗 | 节点总插入损耗 |
|---|---|---|---|---|
| 基于WDM与光开关矩阵的交换节点 | 1*4的DWDM | | 1.8dB | 8.3dB |
| | 16*16的光开关矩阵 | | 6.5dB(Max) | |
| 多粒度的交换节点 | 光纤级 | 4*4光开关 | 2.5dB(Max) | 10.6dB |
| | 波带级 | 1*2CWDM | 0.8dB | |
| | | 4*4光开关 | 2.5dB(Max) | |
| | 波长级 | 1*4DWDM | 1.8dB | |
| | | 8*8光开关 | 3dB(Max) | |
| 基于WSS的带宽可变交换节点 | 1*4的WSS | | 4.2dB(Max) | 4.4dB |
| | 耦合器 | | 0.2dB | |

#### 3.0.1. Math Notation

Equations should use standard LaTeX or AMSLaTeX commands (sample from Krishnan *et al.* [1]).

$$\begin{aligned}
\bar{\varepsilon} &= \frac{\int_0 \infty \varepsilon \exp(-\beta\varepsilon)\,\mathrm{d}\varepsilon}{\int_0 \infty \exp(-\beta\varepsilon)\,\mathrm{d}\varepsilon} \\
&= -\frac{\mathrm{d}}{\mathrm{d}\beta} \log\left[\int_0 \infty \exp(-\beta\varepsilon)\,\mathrm{d}\varepsilon\right] = \frac{1}{\beta} = kT. \qquad (1)
\end{aligned}$$

## 4. Tables and Figures

Figures and illustrations should be incorporated directly into the manuscript, and the size of a figure should be commensurate with the amount and value of the information conveyed by the figure.

Fig. 2. Sample figure with preferred style for labeling parts.

Table 2. Sample Table

| One | Two | Three |
|---|---|---|
| Eins | Zwei | Drei |
| Un | Deux | Trois |
| Jeden | Dvě | Tři |

No more than three figures should generally be included in the paper. Place figures as close as possible to where they are mentioned in the text. No part of a figure should extend beyond text width, and text should not wrap around figures.

## 5. References

References should be cited with the `\cite{}` command. Bracketed citation style, as opposed to superscript, is preferred [1–7]. The `osameet2.sty` style file references `cite.sty`. Comprehensive journal abbreviations are available on the CrossRef web site: http://www.crossref.org/titleList/.

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