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研究課題名（英文）Pump-Phase-Noise-Free Wavelength Conversion and Multicast for High-Order QAM Signals

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研究成果の概要（和文）：将来のトランスペアレントな光ネットワークでは、波長資源のマネージメントにおける柔軟性やノンブロッキング容量を高めるものとして、波長変換やマルチキャスト（WCM）が重要な役割を果たす。一方、位相ノイズに敏感な高次の変調フォーマットに対しては特に、位相ノイズに対する耐性を有するWCMスキームは重要である。我々は、ポンプ光に由来する位相ノイズをキャンセルするために、WCMにおけるコヒーレントポンピングを提案した。高次の変調フォーマットに対してポンプ光位相ノイズフリーの波長変換やマルチキャスト、データ交換を実験的に示した。これらの成果は、当該分野において極めて著名な国際会議や論文誌において公表した。

研究成果の概要（英文）：In the future transparent optical networks, wavelength conversion or multicast (WCM) plays an important role to enhance the flexibility of wavelength management and the non-blocking capacity. On the other hand, to meet the increasing bandwidth demands, high-order formats have been proposed and widely deployed in optical networks. Therefore, it is crucial to exploit WCM schemes with tolerance against phase noise, especially for phase-noise-sensitive high-order formats. We proposed coherent pumping in WCM to cancel the phase noise from pumps, which is suitable for high-order formats. We have successfully verified the feasibility of our scheme and experimentally demonstrated pump-phase-noise-free wavelength conversion, multicast and data exchange for high-order formats using coherent pumps. The results have been published in top-tier conference and journals in the field.

研究分野：　Optical Communications

キーワード：　Four-wave mixing　Signal processing　Wavelength multicast　Wavelength conversion　Phase noise　Laser linewidth

１．研究開始当初の背景

In the transparent optical networks, optical wavelength conversion or multicast (WCM) is playing an important role for enhancing the flexibility of wavelength management and the non-blocking capacity. To meet the increasing demand on the spectral efficiency and capacity, high-order single-carrier or multi-carrier formats such as quadrature amplitude modulation (QAM) have been proposed and widely deployed in optical transmission systems. For such high-order modulation formats, in order to implement the WCM functionalities, it is crucial to pay more attention to the phase noise in the subsystems, since high-order formats become more sensitive to the phase noise.

２．研究の目的

The research purpose of this project is to exploit low-cost and superior-performance WCM schemes, which are free of phase noise from pumps and suitable for phase-noise-sensitive high-order modulation formats. Specifically, in this project, we focuses on the experimental implementation of pump-phase-noise-free WCM subsystem for phase-noise-sensitive high-order modulation formats.

３．研究の方法

To carry out the project, the research were mainly conducted by numerical simulation and experimental demonstrations. The details are summarized as below.

(1) Numerical simulations:

To verify the proposed scheme, numerical simulation was firstly performed by using commercial simulator to evaluate the system performance of the proposed WCM scheme based on coherent pumping.

(2) Experimental demonstrations:

In the experimental demonstrations, several important experiments have been performed based on the proposed schemes. It is summarized as below.

①. Pump-phase-noise-free WCM for high-order single-carrier signals, e.g. QAM signals. The WCM functionalities has been performed by using both nonlinear fiber and periodically poled lithium niobate (PPLN) waveguide, respectively.

②. Pump-phase-noise-free WCM for high-order modulated multi-carrier signals, e.g. optical orthogonal frequency division multiplexing (OFDM) signal. In this part, the experiment was mainly conducted using nonlinear fiber.

③. Optical subcarrier processing based on the coherent pumping scheme to realize the subcarrier data aggregation and multicast. It was performed using nonlinear fiber.

４．研究成果

In this project, different from the previously reported WCM schemes, we propose WCM schemes which are free from the phase noise from pumps in WCM. It is suitable for the high-order modulated signal-carrier and multi-carrier signals, such as high-order QAM and OFDM signals. Owing to the phase noise tolerance from pumps, it is potentially low-cost and showing superior in performances compared with the previous schemes. In order to demonstrate the superior performance of the proposed coherent pumping scheme, we have achieved several experiment results and have the results published in top-tier international conferences and journals in the field. The details are summarized as below.

(1) Pump-phase-noise-free WCM for QAMs

To demonstrate the phase noise cancelling effect in the WCM process, the experiments were performed based on cascaded second-order nonlinearities in PPLN waveguide. Several phase-noise-free functionalities have been experimentally demonstrated, including wavelength conversion, wavelength data exchange, and wavelength multicast. In all of these demonstrations, our proposed coherent pumping scheme shows phase-noise-free performance especially for the high-order QAM signals, such as 64QAMs. The results have been published in top-tier conferences such as *OFC* and *ECOC*, and top journals like *Optics Express*.

(2) Pump-phase-noise-free WCM for OFDMs

Phase noise is a crucial issue to be concerned not only for single-carrier signals like QAM, but also for the multi-carrier signals such as OFDM. Therefore, we also conducted experiments to verify the phase noise tolerance of our proposed schemes for OFDM signals. The experiment results show that through our proposed schemes, even for high-order-modulated subcarriers, such as 16QAM, no phase noise penalty was observed after the WCM owing to its phase noise tolerance. The corresponding results have been published in *Optics Express* and *OFC* as well.

(3) Subcarrier processing based on coherent pumped WCM

The coherence in the pumps of WCM enables the phase-noise-free WCM for high-order single-carrier and multi-carrier signals. Meanwhile, it provides the coherence between the signal and the replicas after the WCM. By taking a good use of this feature, we extended our proposed scheme for the subcarrier processing for Nyquist subcarrier modulation formats (Nyquist-SCM). We have experimentally demonstrated the subcarrier data aggregation and multicast through the proposed coherent pumping WCM. The results have been published in *Optics*

Express and *ECOC*.

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