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A Multiwavelength WDM Source Generated by Four-Wave-Mixing in a Dispersion-Shifted-Fiber

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Abstract:

A multiwavelength source is generated by four-wave-mixing in nonlinear dispersion-shifted-fiber with an accurate frequency separation of 100 GHz defined precisely by two seeding wavelengths. The multiwavelength source can find wide applications in dense WDM systems or spectrum-sliced WDM access networks.

Keywords: WDM, four-wave-mixing, spectrum-sliced.

I. Introduction

Wavelength-division multiplexing (WDM) is an attractive technology for providing increased capacity in lightwave transmission systems and optical networks. However, the introduction of WDM system may require the operator to update their management systems. As number of wavelength increases, the inventory of transmitters becomes extremely complicated. It is even very complicate to just store and keep track on all different WDM transmitters. For example, there are 32 types of transmitters with different wavelength for a 32 channel WDM system. A very attractive solution is to use a multiwavelength source that can generate many or all of the system wavelengths to minimize the complexity. As the number of wavelength generated by multiwavelength source reduces, the number of inventory items reduces proportionally.

Multiwavelength sources can also improve the performance of spectrum-sliced WDM access networks [1]-[6]. Conventionally, a spectrum-sliced WDM system uses a broadband lightwave source like LED or optical amplifier amplified spontaneous emission (ASE) as shown in Fig. 1. Multiple filters are used to slice the continuous spectrum into different channels. Each channel is then modulated by an external modulator. It is shown that the performance of spectrum-sliced WDM system can be greatly improved by using

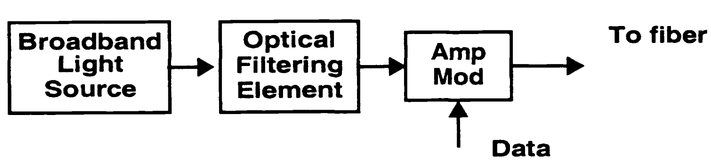

Fig. 1. Schematic diagram of a spectrum-sliced WDM system using a broadband light source, optical filtering element, and optical amplitude modulator.

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more coherent light source, for example, the amplified Fabry-Perot laser source [1] or chirp multiwavelength source [7]-[9].

In this paper, we propose to generate a multiwavelength source using four-wave-mixing in a dispersion-shifted fiber with two seeding wavelengths to accurately define the wavelength separation. There are other techniques [7]-[11] to generate multiwavelength source. However, the frequency separation of a mode-locked laser [7]-[10] is limited by the mode-locking frequency which is usually depending on the geometry of the laser cavity. The scheme of [11] and our scheme utilize the same mechanism of a nonlinear fiber to generate multiwavelength source, but that of [11] defines the wavelength separation by an external modulator. Providing the wavelength separation by two seeding continues-wave wavelengths, our scheme can generate multiwavelength source in almost any separation without limited by the external modulator bandwidth. The wavelength separation can be controlled accurately by using two seeding wavelengths having precise optical frequencies.

II. Experiment

The experimental configuration of the multiwavelength source is illustrated in Fig. 2. Two equal power continuous-wave semiconductor lasers with wavelength of λ_1 and λ_2 are combined using a fiber coupler. The wavelengths of the laser are λ_1 = 1553.7 nm and λ_2 = 1555.5 nm for a separation 0.8 nm or 100 GHz, which is the ITU draft standard frequency separation. The polarization of one of the laser is controlled by a polarization controller (p.c.) to match to polarization of two lasers for better four-wave-mixing efficiency. The combined signal passes through a high-power EDFA with +16 dBm of output power. A 25 km of dispersion-shifted fiber is located after the EDFA to generate multiple wavelengths by four-wave-mixing. In the optical fiber, wavelengths at $2\lambda_1 - \lambda_2$ and $2\lambda_2 - \lambda_1$ are generated first by four-wave-fixing in the dispersion-shifted fiber. As the optical power passing through the nonlinear optical fiber, optical power at other wavelengths of $3\lambda_1 - 2\lambda_2$, $3\lambda_2 - 2\lambda_1$,.... begin to appear due to the mixing of $2\lambda_1 - \lambda_2$, $2\lambda_2 - \lambda_1$ with λ_1 and λ_2. Note that the two seeding wavelengths must be located approximately close to the zero-dispersion wavelength of the dispersion-shifted fiber for a good efficiency. However, the zero-dispersion wavelength of the fiber is usually not uniform in the optical fiber. An exact match is usually impossible but approximately match is still possible.

Fig. 3 shows the output optical spectrum of the nonlinear fiber. There are four optical wavelengths with a power difference of 2 dB and ten wavelengths with a power difference of 12 dB. The spectrum of each wavelength in Fig. 3 is very pure and representing a very coherent source. Because the zero-dispersion wavelength of the fiber is not uniformly distributed along the optical fiber and the two seeing wavelengths are not necessary to locate at two sides of the zero dispersion wavelength, the optical power is not symmet-

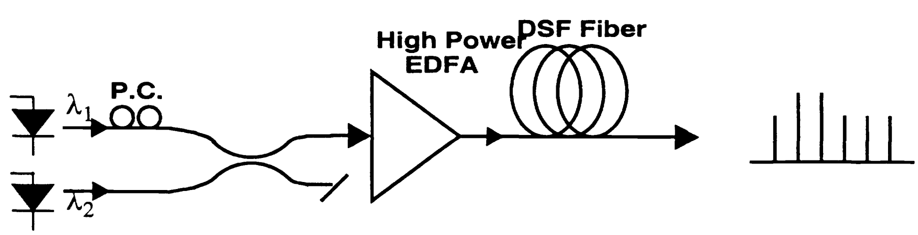

Fig. 2. Schematic diagram of the experimental setup.

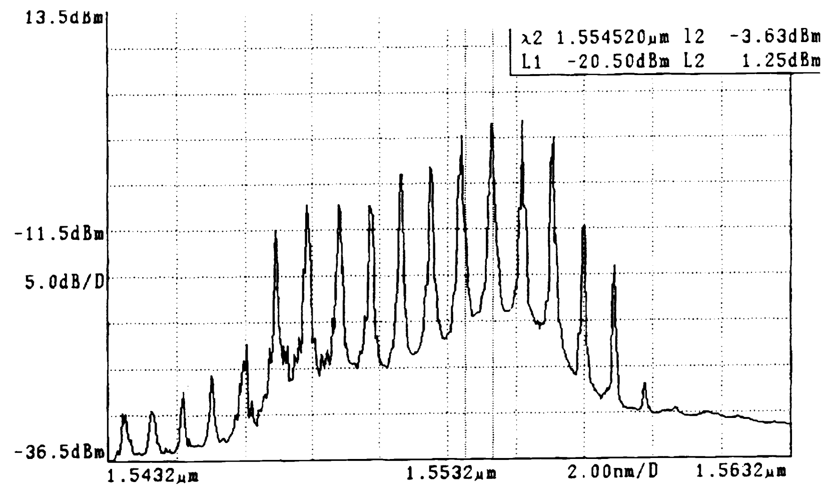

Fig. 3. Output optical power spectrum for the multiwavelength source generated by four-wave-mixing in the nonlinear optical fiber.

rical with respect to λ_1 and λ_2. Depending on the total capacity of the system, the number of wavelengths in Fig. 3 may provide a great reduction in the number of inventory items for WDM transmitters.

The number of wavelengths is determined by the wavelength separation, fiber zero-dispersion wavelength, and the nonlinear fiber launching power. Further experiments find that more than 20 wavelengths can be generated if the wavelength separation of the two seeding wavelengths is reduced to 50 GHz (0.4 nm). Four-wave-mixing provides improved efficiency if the two seeding wavelengths are located approximately close to the zero-dispersion wavelength of the fiber. The number of wavelength also increase substantially if the output power of the EDFA increases to increase the launching power to the nonlinear fiber.

III. Summary

A multiwavelength source with a precise frequency separation of 100 GHz is generated by four-wave-mixing in a nonlinear dispersion-shifted fiber. The wavelength separation can be controlled accurately by two seeding wavelengths. While ten wavelengths are generated in our experiment, more wavelengths can be generated if the wavelength separation reduces or the launching power to the nonlinear fiber increases. The multiwavelength source can be used in dense WDM systems or spectrum-sliced WDM access networks.

IV. References

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