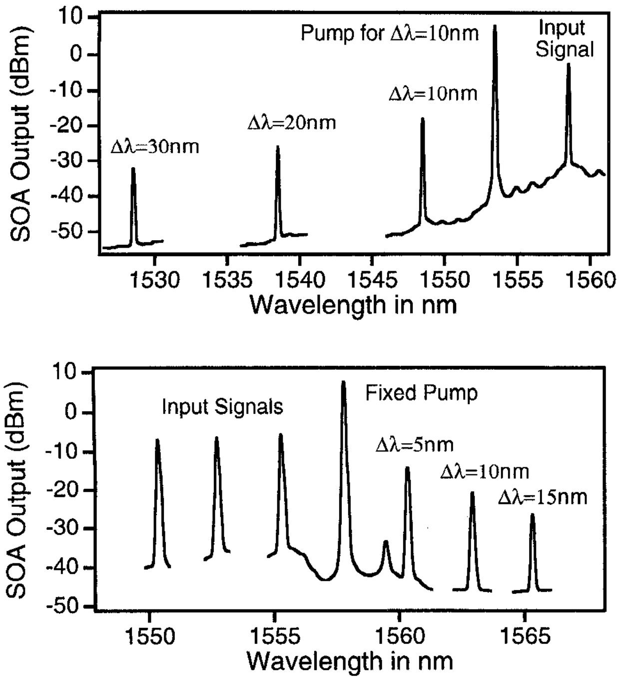
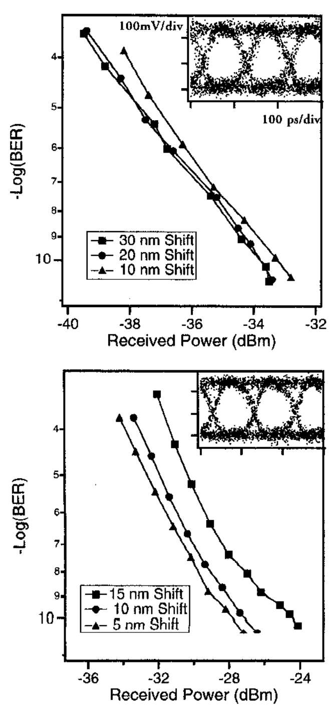


WB7 Fig. 2. Spectra measured at the output of the SOA (0.1-nm resolution bandwidth). The upper shows the down-converted signals for the 30-, 20-, and 10-nm shifts (from left to right). For the smallest shift, we also show the pump and the input signal. The pump wavelength was tuned to lower wavelengths at constant power to achieve the larger shifts. The lower figure shows the up-converted signals for the 5-, 10-, and 15-nm shifts (from right to left). In this case, we changed the input signal wavelength and the pump remained the same for all three shifts. The small peak near 1559.5 nm is a distributed feedback sidemode.



WB7 Fig. 3. BER vs. received signal power for the shifts in Fig. 2. The received signal power was measured at the 10% tap after the attenuator with 0.2-nm resolution bandwidth. The eye diagram in the inset corresponds to the largest shift in each case, with no attenuation.

Figure 3 shows the bit error rates (BER) versus converted signal power measured at the output of the 10% bi-directional coupler in Fig. 1. There is almost no additional penalty when going from 10 to 30 nm shifts in the down-conversion, while for the up-conversion there is a 3 dB penalty going from 5 to 15 nm of up-shift. These record conversions are primarily attributed to the long length of the SOA. Further improvements are expected going to even longer devices. The lower up-conversion performance stems from the well-known detuning asymmetry in the FWM nonlinearity,[1] as well as from the SOA and receiver EDFA gain spectrum.

In conclusion, we have demonstrated a record 30 nm of wavelength down-shifts and 15 nm of up-shift for 10-Gbit/s optical signals. The improvements result from the use of long (1.5 mm) SOAs. Further improvements in performance are anticipated with yet longer devices.

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1. D.F. Geraghty, R.B. Lee, K.J. Vahala, M. Verdiell, M. Ziari, A. Mathur, IEEE Photon. Technol. Lett. **9**, 452–454 (1997).
2. F. Girardin, J. Eckner, G. Guekos, R. Dall'Ara, A. Mecozzi, A. D'Ottavi, F. Martelli, S. Scotti, P. Spano, IEEE Photon. Technol. Lett. **9**, 746–748 (1997).

WB8 **10:15am**

Wavelength conversion by four-wave mixing in a folded-path, self-pumped semiconductor optical amplifier

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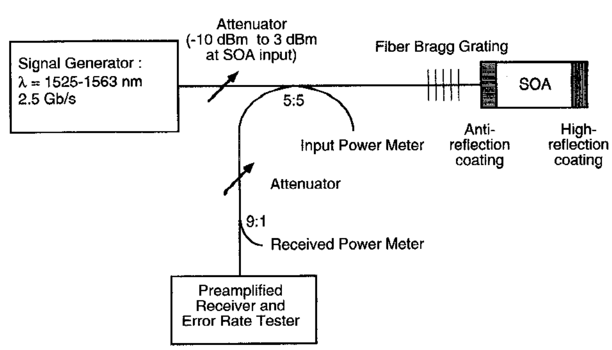
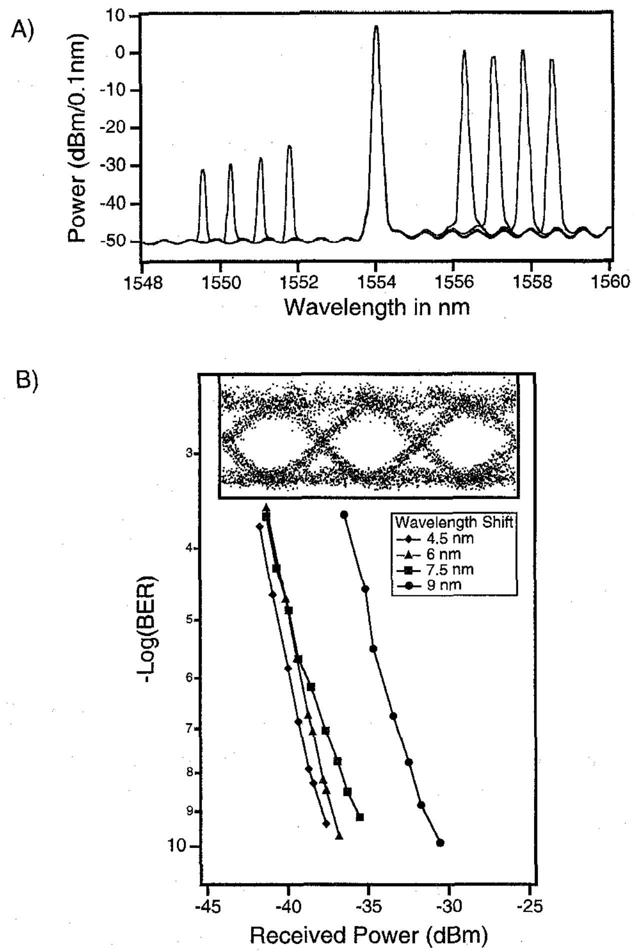
Atul Mathur,* Kerry J. Vahala, *Department of Applied Physics, Mail Stop 128-95, California Institute of Technology, Pasadena, California 91125*

Wavelength conversion is recognized as a key function for the implementation of complex wavelength-division multiplexing (WDM) communication systems. Of the approaches demonstrated so far, only four-wave mixing (FWM) in semiconductor optical amplifiers (SOAs) is fully transparent to modulation format and bit rate while providing arbitrary wavelength mapping. Recent demonstrations[1,2] have shown that the performance of FWM converters can be made technologically competitive. Here we present a novel wavelength conversion scheme that offers additional advantages while significantly reducing the complexity of the device.

The converter consists of an external-cavity semiconductor laser, with a high-reflection coating on one facet, and a fiber Bragg grating pigtailed to the other facet (anti-reflection coated). The pump wave is



WB8 Fig. 1. Schematics of the experimental setup.

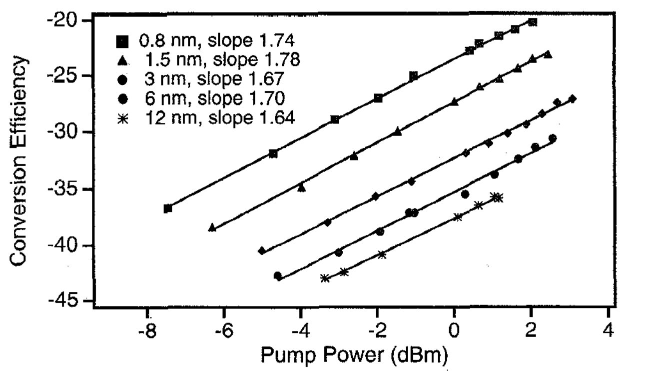


WB8 Fig. 2. (A) Superimposed output spectra (0.1-nm resolution bandwidth) of the wavelength converter for several wavelength shifts. (B) BER vs. received power traces for the same shifts (the eye diagram in the inset is for the 4.5-nm shift).

provided by the lasing mode at the Bragg frequency (self-pumping). The input signal (with frequency outside the Bragg reflection bandwidth) is modulated with a 2.5-Gbit/s pseudo-random binary sequence of nonreturn to zero amplitude-shift keying data and is injected into the cavity through the Bragg grating via a bi-directional coupler; the converted signal is collected from the other input arm. The system used to characterize the converter is shown in Fig. 1. In Fig. 2 we plot the output spectra of the device for different wavelength downshifts ranging from 4.5–9 nm [Fig. 2(A)] and the corresponding bit error rate (BER) vs. received power traces [Fig. 2(B), the eye diagram corresponds to the 4.5-nm shift].

Reflection off the cavity mirror of both the input and converted signals doubles the interaction length, thereby increasing conversion efficiency and signal-to-noise ratio (the measured efficiency is comparable to that observed in a single-pass SOA having a similar structure but twice as long.[1] In addition, this configuration has reduced complexity, because it does not require an external pump source or a high-power erbium-doped fiber amplifier (EDFA) at the converter input (error-free conversion was observed for input signal powers as low as −9 dBm).

A further advantage over conventional externally pumped FWM converters is the fact that the optical gain (and hence the FWM nonlinearity) is clamped at its threshold value by the lasing action. Consequently, the conversion efficiency does not degrade with pump power through gain saturation (as is observed in standard FWM converters.[3] Rather, a steady increase in both efficiency and signal-to-noise with increasing pump power is expected. This is verified in Fig. 3, where we plot conversion efficiency vs. pump power for several wavelength shifts (the observed small deviation from the expected quadratic dependence is currently under investigation).



WB8 Fig. 3. FWM conversion efficiency vs. pump power (at the output port of the bidirectional coupler) for several wavelength shifts.

Finally, it should be mentioned that, while the present device features a fixed pump wavelength, it could be made tunable by using a tunable distributed Bragg reflector structure instead of a Bragg grating. Similarly, by increasing the mirror reflectivity, one would obtain higher signal-to-noise ratio and automatically suppress the pump from the converter output.

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2. F. Martelli, A. Mecozzi, A. D'Ottavi, S. Scotti, P. Spano, R. Dall'Ara, J. Eckner, G. Guekos, Appl. Phys. Lett. **70**, 306–308 (1997).
3. A. D'Ottavi, A. Mecozzi, S. Scotti, F. Cara Romeo, F. Martelli, P. Spano, R. Dall'Ara, J. Eckner, G. Guekos, Appl. Phys. Lett. **67**, 2753–2755 (1995).

WC

8:30–10:30am
Room B

High-Speed TDM

Karen Liu, *Tellabs Operations Inc., Presider*

WC1 **8:30am**

Eight-to-one demultiplexing of 100-Gbit/s TDM data using $LiNbO_3$ Sagnac interferometer modulators

Michael L. Dennis, William K. Burns, Thomas F. Carruthers, Irl N. Duling, III, *U.S. Naval Research Laboratory, Code 5671, Washington, D.C. 20375*

Due to the speed limitations of electronic circuitry, future time-division multiplexed (TDM) optical communications networks operating at data rates of the order of 100 Gbit/s will require optical demultiplexing techniques. Toward this end, a variety of all-optical demultiplexing schemes, based on third-order nonlinearities in fiber or on resonant nonlinearities in semiconductors, have been proposed