8:30am - 8:45pm
TUA3

Four-Wave Mixing in Semiconductor Traveling-wave Amplifiers for Efficient, Broadband, Wavelength Conversion up to 65 nm

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Wavelength conversion is recognized as an important function in future fiber networks employing wavelength division multiplexing. We have recently demonstrated broad-band wavelength conversion over spans as large as 27 nm [1, 2]. Our approach uses ultra-fast four-wave mixing dynamics associated with intraband relaxation mechanisms in semiconductor traveling-wave amplifiers (TWA's). In this paper we present new results showing conversion over wavelength spans as large as 65 nm. This surpasses the previous record by over a factor of two. Of equal importance, we also verify experimentally our previous theoretical prediction that wavelength conversion efficiency varies as the cube of TWA single pass gain.

In the course of our previous work [2], we have shown that the theoretical efficiency, η, of this process can be expressed by the simple relation:

$$\eta = 3G + 2P + R(\Delta\lambda)$$

where η is the ratio in dB of the converted signal output power to the signal input power and G is the single pass TWA optical gain. A crucial point is the presence of $3G$ in this expression - *essentially, the wavelength converter uses the available TWA optical gain three times.* We verified this expression using an experimental setup similar to that described in [2]. Tunable, single-frequency, erbium fiber ring lasers were used as pump and signal sources and TWA devices used contained tensile-strained mutli-quantum well active layers described in [3]. Figure 1 shows conversion efficiency data plotted versus single-pass saturated optical gain. The pump power was -5.2 dBm and the signal power was -11.3 dBm. The measured slope of 3.18 confirms the cubic dependence of efficiency on single pass gain.

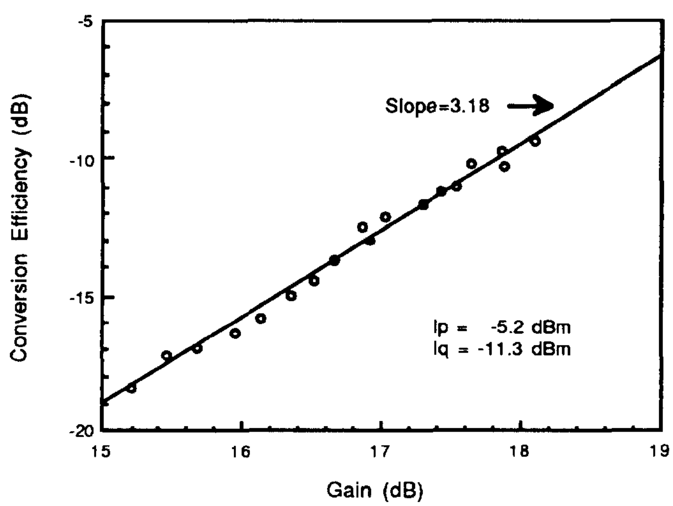

Figure 1: Measured conversion efficiency versus saturated single-pass TWA optical gain, showing cubic dependence of efficiency on gain.

Other parameters appearing in the above equation include the input optical pump-wave power P (expressed in dBm), and a quantity we call the relative efficiency function, $R(\Delta\lambda)$. The relative efficiency function contains information on the intraband dynamics responsible for wide-band four-wave mixing. By using a tandem geometry amplifier (i.e., two low gain amplifiers in series, separated by an optical isolator), it was possible to measure $R(\Delta\lambda)$ for wavelength shifts as large as 65 nm. Data for positive and negative wavelength shifts are presented in figure 2. It is important to note that figure 2 is *not* the actual conversion efficiency, η, which is a vastly larger number, because of its dependence on amplifier gain, G (in dB), and pump power, P (in dBm). Once, however, $R(\Delta\lambda)$ is measured, the requirements on these other quantities for specific conversion efficiencies are known. Based on the above data, figure 3 shows the TWA single-pass gain required for lossless wavelength conversion versus the desired wavelength shift. The four-wave mixing pump power assumed in this calculation is a modest -9 dBm. Because of the cubic gain dependence verified here, it can be seen that 100% efficiency is attainable for wavelength shifts as large as 65 nm with optical gains in the range of 30 dB.

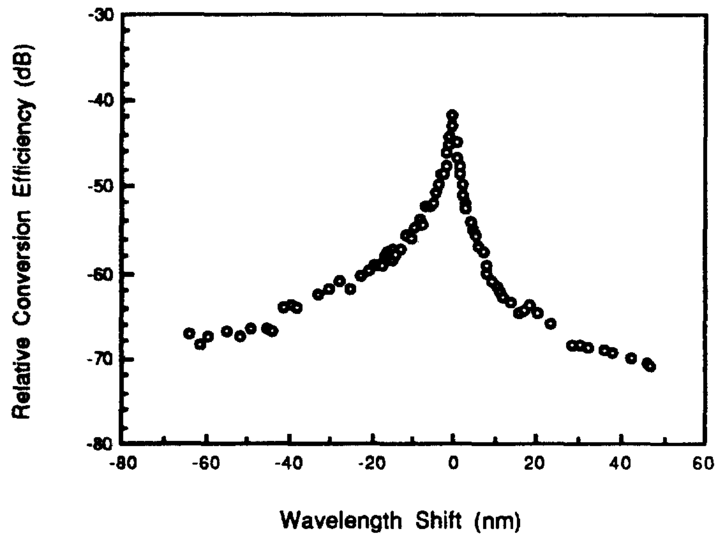

Figure 2: Measured relative conversion efficiency function, $R(\Delta\lambda)$, versus wavelength shift. Note: $R(\Delta\lambda)$ is not the actual conversion efficiency (see equation in paper).

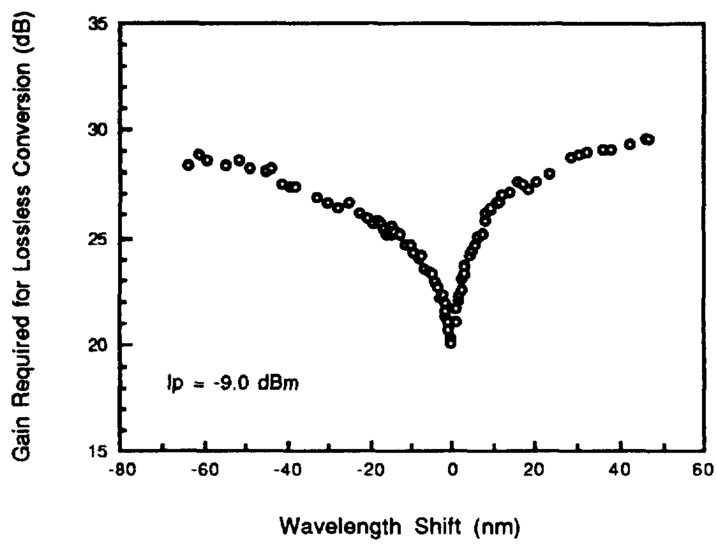

Figure 3: Single pass TWA optical gain required for lossless wavelength conversion.

Due to the limited single pass optical gain of the tandem converter tested here (18.9 dB), lower efficiencies were observed. Figure 4 shows the measured efficiency versus wavelength down-shift for a pump power of -7.0 dBm. Despite the reduced gain, significant wavelength shifts with high efficiency are possible (e.g., -12 dB for 10 nm of shift). These values are already sufficient for certain system applications.

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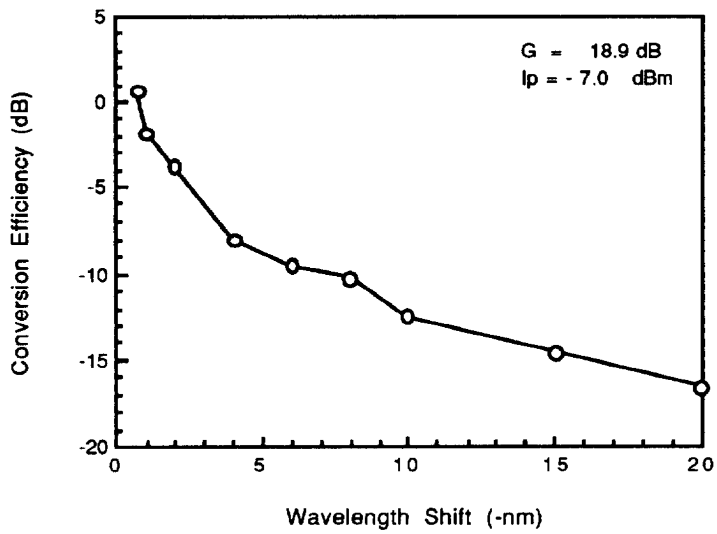

Figure 4: Measured wavelength conversion efficiency versus wavelength downshift for a pump power of -7.0 dBm.

References

[1] J. Zhou, N. Park, J. W. Dawson, K. J. Vahala, M. A. Newkirk, and B. I. Miller, *LEOS'93*, paper OS3.2.

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[3] M. A. Newkirk, B. I. Miller, U. Koren, M. G. Young, M. Chen, R. M. Jopson, and C. A. Burrus, *IEEE Photon. Tech. Lett.*, **4**, 406 (1993).