On Wavelength Asymmetry of Extinction-Ratio Improvement by Two-Wave Competition in ULSOAs

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Experiments have shown: the improvement of the extinction ratio (ER) by two-wave competition (TWC) exhibits a strong wavelength asymmetry. It "is a prerequisite for achieving an ER improvement, to set the CW beam to the long wavelength side of the signal" [1]. This asymmetry has qualitatively been atributed to the asymmetry of four-wave mixing (FWM). Here I shall check this hypothesis quantitatively on base of the theory presented in [1].

I consider copropagation of a signal and a CW wave with intensities S_s and $S_{\rm cw}$, respectively, in the saturated SOA. The asymmetry of FWM is generally a result of the interferences between fast intraband contributions, represented by the gain saturation coefficient ε, and contributions from carrier population pulsations (CPP). In the appendix of pamphlet [2], I have already shown how the CPP contributions enter the evolution equation for the intensity ratio. Here, I rewrite these equations with an adapted notation.

$$\frac{\partial}{\partial z}\ln(\frac{S_s}{S_{\rm cw}}) = q_s S_s - q_{\rm cw} S_{\rm cw}, \tag{1}$$

$$q_{s,\rm cw} = g\left(\varepsilon \mp \frac{g'|\alpha_H|\lambda_0^2}{2\pi n_g(\lambda_{\rm cw}-\lambda_s)}\right), \tag{2}$$

where the upper sign belongs to q_s.

The crucial points for the ER are the "zeros" of the signal bit sequence. Thus, I can confine to a case with $S_s \ll S_{\rm cw}$. Thus, we can neglect the signal intensity on the r.h.s. of Eq. (1). Furthermore, saturation conditions require $S_s + S_{\rm cw} \approx S_{\rm cw} = S_{\rm sat}$. Thus, we can approximate the cw intensity by the saturation intensity, yielding

$$\frac{\partial}{\partial z}\ln(\frac{S_s}{S_{\rm sat}}) = -q_{\rm cw} S_{\rm sat}, \tag{3}$$

Obviously, the quantity $q_{\rm cw}$ governs the decay of the signal intensity. The right hand side is constant, hence the solution is

$$S_s(z) \sim \exp(-z/L_s) \tag{4}$$

with the decay length

$$L_s = \frac{L_{\rm TWC}}{1+\Delta_{\rm asym}/(\lambda_{\rm cw}-\lambda_s)}. \tag{5}$$

Here $L_{\rm TWC}$ is the large-detuning limit of the characteristic decay length as given by formula (13) of our paper [1], and

$$\Delta_{\rm asym} = \frac{g'|\alpha_H|\lambda_0^2}{2\pi n_g \varepsilon} \tag{6}$$

is a critical detuning below which the wavelength asymmetry becomes essential. With the parameters of [1], it is $\Delta_{\rm asym} = 3.86$ nm.

The effectiveness of ER improvement increases with the inverse of the signal decay length L_s. Thus, without explicitely calculating the ER, the plot of $L_{\rm TWC}/L_s$ in Fig.1 allowes a theoretical estimate how the ER improvement should depend on the detuning. Indeed, it is quite similar to Fig.8 (a) of [1]. Of course, the agreement is not complete because the approximations hold only in the very last part of the SOA and the parameters are only estimates.

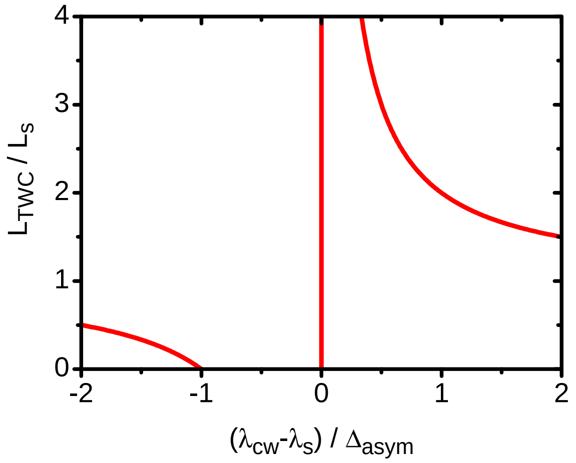

Fig.1: *Plot of the inverse decay length versus wavelength detuning.*

Conclusion

The basic features of the measured wavelength asymmetry of the ER improvement by TWC are well described by the theory developed in [1].

References

[1] Gero Bramann, Hans-Jürgen Wünsche, Ulrike Busolt, Christian Schmidt, Michael Schlak, Bernd Sartorius, and Hans-Peter Nolting, "Two-Wave Competition in Ultra Long Semiconductor Optical Amplifiers", to appear in IEEE Journal Quantum Electronics, October 2005

[2] H.-J. Wünsche, "Notes on Two-Wave Competition by Four-Wave Mixing", http://photonik.physik.hu-berlin.de/ede/pamphlets/twcnote.pdf