Summary: We have studied the transient effects in a Raman amplifier due to input power fluctuations. We observed a signal power transient lasting for 50µs. Such transients will impact the performance of optical telecommunication systems using Raman amplifiers. We have proposed a model that resulted in an accurate description of transient effects in a Raman amplifier. Our model, in general, can be applied to other transient studies in Raman amplifiers.

Acknowledgments: The authors would like to thank Y. Sun for initiating the project, H.-S. Tsai, Y.-J. Cheng, and K. Kantor for their helpful discussions, V. Tchakarov for laboratory assistance, and K. Lum for proofreading.

10 January 2001
Electronics Letters Online No: 20010256
DOI: 10.1049/el:20010256

Chien-Jen Chen and W.S. Wong (*Onetta, Inc., 71 Vista Montana, San Jose, CA 95134, USA*)

E-mail: cjchen@onetta.com

References

1 EMORI, Y., TANAKA, K., and NAMIKI, S.: '100nm bandwidth flat-gain Raman amplifiers pumped and gain-equalised by 12-wavelength-channel WDM laser diode unit', *Electron. Lett.*, 1999, **35**, (16), pp. 1355–1356

2 NISSOV, M., DAVIDSON, C.R., ROTTWITT, K., MENGES, R., CORBETT, P.C., INNIS, D., and BERGANO, N.S.: '100Gb/s (10×10Gb/s) WDM transmission over 7200km using distributed Raman amplification'. Proc. ECOC'97, 1997, Vol. 5, (PDP), pp. 9–12

3 SUN, Y., ZYSKIND, J.L., and SRIVASTAVA, A.K.: 'Average inversion level, modeling, and physics of erbium-doped fiber amplifiers', *J. Lightwave Technol.*, 1997, **3**, (4), pp. 991–1007

4 KRUMMRICH, P.M., GOTTWALD, E., MAYER, A., NEUHAUSER, R.E., and FISCHER, G.: 'Channel power transients in photonic networks caused by stimulated Raman scattering'. OAA'2000, 2000, Paper OTuC6

5 FOLEY, B., DAKSS, M.L., DAVIES, R.W., and MELMAN, P.: 'Gain saturation in fiber Raman amplifiers due to stimulated Brillouin scattering', *J. Lightwave Technol.*, 1989, **7**, (12), pp. 2024–2032

All-digital window discriminator for photon counting pixel detectors

B. Oelmann, M. Abdalla and M. O'Nils

An all-digital window discriminator is presented. It is event-driven and does not rely on any external or internal timing references. In addition, it provides an area-efficient implementation of photon counting pixel detectors. The transistor-level implementation of the circuit is presented with its circuit area and timing performance.

Introduction: One problem that must be handled by window discriminators is related to timing problems that occur in the decision process. This decision is based on the logic output values from independent integral discriminators that may have unknown duration and time walk. A window discriminator by Lauch [1] conditionally generates clock pulses to one single counter. Here, the circuit complexity is high and it relies on an internally generated timing reference that must be adjusted for safe operation. The window discriminator for photon counting pixel detectors, presented by Fischer [2], greatly simplifies this problem by using two counters, one for each integral discriminator. The counter values are read out and the actual window discrimination is made by post-processing in software. High spatial resolution of pixel arrays puts hard constraints on the circuit area. Area-efficient solutions for both analogue and digital circuits are needed. In addition, the mix of analogue and digital circuits on a small area will make the analogue part subjected to digital noise. The deficiencies of Fishers' [2] solution are doubled circuit area for the counters and increased read-out time. The two counters also generate problems with digital noise in the analogue part.

In this Letter, we propose an all-digital window discriminator (ADWD) for photon counting pixels that reacts upon the events generated by the integral discriminators and conditionally generates a clock pulse for input pulses with energy levels within the defined window. This circuit relies only on the sequence of events of the input signals, which makes it insensitive to timing variations. Furthermore, it only requires one counter in each pixel.

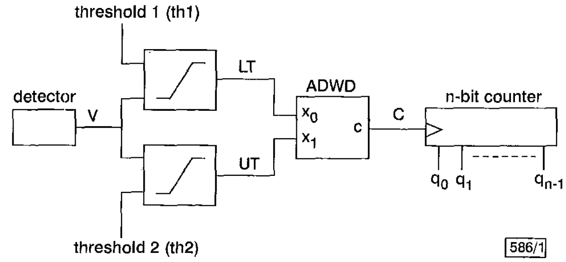

Fig. 1 *Simplified block diagram of photon counting pixel*

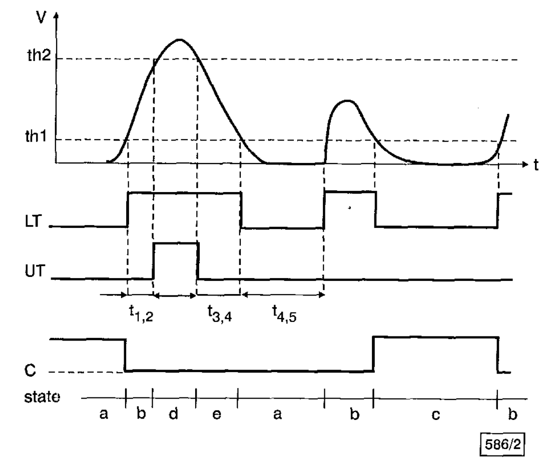

Fig. 2 *Timing diagram of detector voltage pulses, discriminator output signals and generated clock pulses*

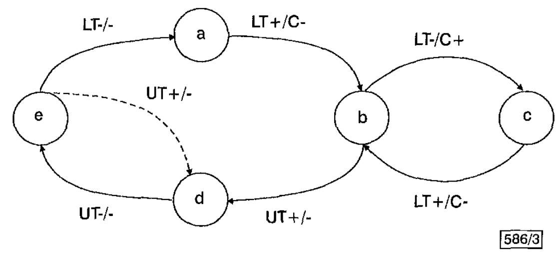

Fig. 3 *Derived STG from sequence of signals given in Fig. 2*

Event detection method: The output of the detector is analogue pulses the amplitudes of which are related to the level of energy deposited by the particles in the detector. From Fig. 1 it can be seen that these pulses are fed to two integral discriminators with different thresholds (*th*1 and *th*2) that define the energy window for the pulses that shall be counted. Based on the digital signals LT (lower threshold) and UT (upper threshold) from the integral discriminators, a clock pulse (C) is conditionally generated and fed to the counter. Dependent on the amplitude of the pulse (V), three different sequences on the signals LT and UT are possible. In Fig. 2 the amplitude of the first pulse exceeds *th*2 and is therefore outside the window and no clock pulse is generated. The peak amplitude of the second pulse is inside the window and a clock pulse is generated. The third sequence, not shown in the diagram, is the result of an incorrect behaviour of a pulse crossing *th*2 more than twice without crossing *th*1. To have a fault-tolerant circuit, this sequence must also be taken into account. The input/output behaviour of ADWD is derived from these three possible sequences of events on LT, UT and C. This behaviour is described in the signal transition graph (STG) given in Fig. 3. The ADWD is implemented as an asynchronous finite-state machine working under the fundamental mode assumption [3] and is synthesised from the STG, shown in Fig. 3, using procedures described in [3].

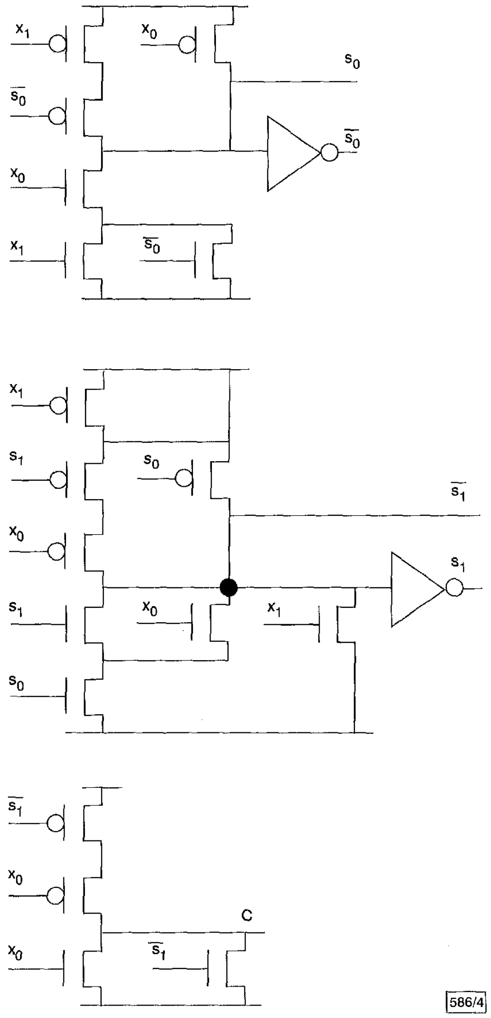

Fig. 4 *Transistor schematic diagram for ADWD*

Circuit implementation: The ADWD has been designed as a full-custom module. The transistor level implementation is given in Fig. 4. It consists of 22 transistors and minimum sized transistors are used for smallest possible circuit area. The circuit area is 650μm² in a 0.6μm CMOS process from Austrian Mikro Systeme.

The minimum size of the discriminator window ($th2 - th1$) is determined by the rise and fall times between the lower and upper window voltage levels and the smallest time separation of the events on LT and UT that the ADWD can resolve. This minimum resolution time, i.e. $\max(t_{1,2(min)}, t_{3,4(min)})$, is 100ps under typical operating conditions at 25°C and 5V power supply voltage. The shortest time between two consecutive pulses that can be detected by the ADWD is 600ps ($t_{4,5}$).

Considering that the proposed discriminator eliminates one counter, the area reduction in the digital part of the 18 bit photon counting pixel is 40%.

30 November 2000
Electronics Letters Online No: 20010265
DOI: 10.1049/el:20010265

B. Oelmann, M. Abdalla and M. O'Nils (*Department of Information Technology, Mid Sweden University, SE-851 70 Sundsvall, Sweden*)

E-mail: Bengt.Oelmann@ite.mh.se

References

1 LAUCH, J., and NACHBAR, H.U.: 'A versatile differential discriminator with stable time information', *Nucl. Instrum. Methods*, 1969, **73**, (3), pp. 292–300

2 FISCHER, P., HELMICH, A., LINDNER, M., WERMES, N., and BLANQUART, L.: 'A photon counting pixel chip with energy windowing', *IEEE Trans. Nucl. Sci.*, 1999, **47**, (3), pp. 881–884

3 UNGER, S.H.: 'Asynchronous switching circuits' (John Wiley & Sons, 1969), ISBN 471 80632 2

Broadband semiconductor saturable absorber mirror at 1.55μm using Burstein-Moss shifted $Ga_{0.47}In_{0.53}As$/InP distributed Bragg reflector

N. Xiang, O. Okhotnikov, A. Vainionpää, M. Guina and M. Pessa

The authors report on the first broadband semiconductor saturable absorber mirror (SESAM) that consists of a Burstein-Moss blue-shifted $Ga_{0.47}In_{0.53}As$/InP distributed Bragg reflector operating at the wavelengths centred around 1.55μm. This device is applied to the passive modelocking of an erbium-doped fibre laser.

Introduction: Semiconductor saturable absorber mirrors (SESAMs) are used to passively modelock fibre lasers and solid-state lasers. The SESAM is made of a thin, narrow-bandgap absorption region sandwiched in between a wide-bandgap cap layer and a spacer layer on top of a high-reflectivity (R) distributed Bragg reflector (DBR). The DBRs at long wavelengths, λ = 1.3 to 1.55μm, are not as good mirrors as GaAs/AlAs-based DBRs at shorter wavelengths (0.8 to 1.0μm). In the 1.55μm region, DBRs of InGaAsP/InP [1 – 3], AlAsSb/InGaAs(P) [4], (Al)GaAsSb/AlAsSb [3, 5], (Al)GaSb/AlSb [6], and InAlGaAs/InAlAs [3, 7] have been made, but each of them has problems either related to difficulties in growing the layers or to a small refractive index contrast (Δn). For example, the Δn of an $In_{0.65}Ga_{0.35}As_{0.73}P_{0.27}$/InP DBR is only 0.27, which means that a large number of pairs of $\lambda/4n$ (n is the refractive index) layers (e.g. 40 pairs) are needed for the SESAM [1].

The ternary alloy $Ga_{0.47}In_{0.53}As$, lattice-matched to InP, would provide a greater Δn ($\simeq$ 0.43) in contrast to InP, but because it is a narrow bandgap semiconductor ($E_g \simeq$ 0.75eV), it absorbs light at 1.55μm. However, we have shown that the absorption problem can be solved [8] by heavily doping $Ga_{0.47}In_{0.53}As$ with silicon. The doping causes the effective optical bandgap to increase just above the absorption limit, due to the Burstein-Moss shift.

In this Letter, we demonstrate the first monolithic SESAM equipped with a Burstein-Moss shifted $Ga_{0.47}In_{0.53}As$/InP 1.55μm DBR. We show a rather simple technological approach to mode-locking an erbium-doped fibre laser for generating self-started sub-picosecond pulses.

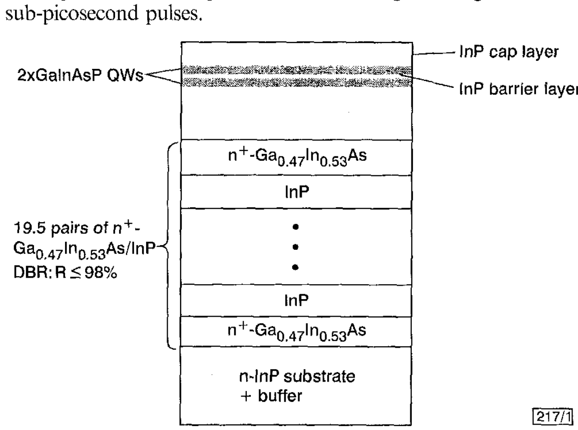

Fig. 1 *Structure of monolithic semiconductor saturable absorber mirror (SESAM)*

Material growth: The SESAM was grown by all-solid-source molecular beam epitaxy (SSMBE) on an S-doped n-type InP (100) substrate. SSMBE is a viable alternative to the more conventional metal-organic chemical vapour deposition (MOCVD) process for growing state-of-the-art phosphide structures for optical telecom-