To determine the modal gain we have performed gain studies by
the variable stripe length method with current injection following
the technique described in [6]. In this method the modal gain spec-
tra are extracted from the amplified spontaneous light emitted
from the sample edge. The measurements are not limited by the
lasing threshold and can be carried out up to high excitation den-
sities. These studies were performed under pulse excitation. The
gain spectra are shown in Fig. 4. The maxima at 1.254 and
1.18 µm correspond to the ground and first excited state tran-
sitions. At current densities of ~900 A/cm² the gain of the ground
state transition saturates. The value of the maximal modal gain of
the ground state transition (12 cm⁻¹) agrees very well with the
result for the broad area devices [2] as well as with the value
derived from Fig. 1.

Fig. 4 Modal gain spectra for different current densities
(i) 98 A/cm²; (ii) 193 A/cm²; (iii) 467 A/cm²; (iv) 975 A/cm²; (v) 1950 A/
cm²; (vi) 2925 A/cm²

Conclusions: We have studied high power single transverse mode
long wavelength lasers based on QDs. The maximum output
power of these devices is typically ~330mW with singlemode opera-
tion observed up to 110mW. The maximal modal gain for the
ground state transition measured by using the variable stripe
length method is 12 cm⁻¹.

Acknowledgments: This work is supported by the Volkswagen
Foundation (grant 173-631), INTAS (grant 96-0467), BMWF-
DRL, NanOp CC, and DAAD and the Program 'Physics of Solid
State Nanostructures' of the Ministry of Science of Russia.

© IEEE 1999
14 October 1999
Electronics Letters Online No: 19991192
DOI: 10.1049/el:19991192

M.V. Maximov, Yu. M.Shernyakov, I.N. Kainander, D.A. Bedarev,
Mikrin, A.F. Tsatsulnikov, V.M. Ustinov, B.V. Volovik, A.E.
Zhukov and Zh.I. Alferov (A.F. Ioffe Physical-Technical Institute,
Poli tekhnicheskaya 26, 194021, St. Petersburg, Russia)
N.N. Ledentsov and D. Binberg (Institut für Festkörperphysik,
Technische Universität Berlin, Hardenbergstrasse 36, D-10623 Berlin,
Germany)

References

diode laser on a GaAs substrate", to be published in IEEE
IEEE/LEOS Summer Topical Meeting, Workshop on
Nanotechnology and Quantum Dots, San Diego, CA, USA, 26-27
July 1999, pp. 27-28 (IEEE Catalog Number: 99TH8455)
5 VOLOVI K, B.V., TSATSULNI KOV, A.F., BEDAREV, D.A., EGO ROV, YU.M., ZHUKOV, A.E., KOVSH, A.R., LEDENTSOV, N.N., MAXIMO V, M.V.,
wavelength emission in structures with quantum dots formed in the
stimulated decomposition of a solid solution at strained islands',
Semiconductors, 1999, 33, (8), pp. 990-995
6 OSTER, A., ERB E GT, G., and WENZEL, M.: "Gain spectra measurement
by a variable stripe method with current injection", Electron. Lett.,
1997, 33, (10), pp. 864-866

Polynomial bidirectional hetero-correlator

Chua-Chin Wang and Cheng-Fa Tsai

A novel pattern recognition method is proposed using a
polynomial bidirectional hetero-correlator. Simulation results
show that the new scheme has a higher storage capacity than
other BAM-like associative memories and fuzzy associative
memories.

Introduction: The bidirectional associative memory-like (BAM-
like) associative memory is a two-layer hetero-associator that
stores a set of bipolar pairs. Owing to the ease with which they are
coded and their high noise immunity, BAMs are well-suited to
use in pattern recognition, intelligent control and optimisation
problems. The original Kosko BAM suffers from low storage
capacity [2]. Thus, much effort has been made to improve the per-
formance of the Kosko BAM [1, 3, 5]. In some of these models
the BAM architecture is improved by using the Hamming stability
learning algorithm (SBAM) [5], the asymmetrical BAM model
(ABAM) [3], or by the introduction of a general model of BAM
(GBAM) to improve the performance [1]. Kosko’s fuzzy associa-
tive memory (FAM) is the very first example to use neural net-
works to articulate fuzzy rules for fuzzy systems. Despite its
simplicity and modularity, its model suffers from extremely low
memory capacity, i.e. one rule per FAM matrix. Besides, it is
limited to small rule-based applications. Chuang and Lee [4] proposed
a multiple-rule storage method for an FAM matrix. They showed that
more than one rule can be encoded by Kosko’s FAM. How-
ever, the actual capacity will depend on the dimension of the
matrix and the rule characteristics, e.g. how many of the rules are
overlapped. The capacity of this model depends on whether the
membership function is semi-overlapped or not. In this Letter, we
present a novel fuzzy data processing method using a polynomial
bidirectional hetero-correlator (PBHC) whose architecture is
established and the implementation of the PBHC model is accord-
ingly more efficient. The proposed model has a higher capacity for
pattern pair storage than that of conventional BAMs and fuzzy
memories.

Proposed polynomial bidirectional hetero-associator: We assume that we are given M pattern pairs, which are 

\((x_1, y_1), (x_2, y_2), \ldots, (x_M, y_M)\),

where \(x_i = (x_{i1}, x_{i2}, \ldots, x_{in})\) and \(y_i = (y_{i1}, y_{i2}, \ldots, y_{ip})\). We let \(1 \leq i \leq M, x_{ij} \in [0, 1], 1 \leq j \leq n, y_{ij} \in [0, 1], 1 \leq j \leq p, \) and \(n \) and \(p \) are the component dimensions of \(x_i \) and \(y_i \), and it is assumed to be smaller than or equal to \( p \) without any loss of generality. \(x_{ij} \) and \( y_{ij} \) fuzzy space is \([0, 1], 1 \leq i \leq n, 1 \leq j \leq n\), fuzzy space is \([0, 1], 1 \leq i \leq p, 1 < j < p\). A fuzzy quantum, and \( \alpha \) is a fuzzy quantum gap. For instance, by assuming that \( \alpha = 10, \alpha = [1/10] = 0.1 \) can be obtained. We use the following evolution equations in the recall process of the PBHC:

\(x_{j} = f(x_{i}, y_{i}) = \sum_{j} a_{ij} x_{i} y_{j} + \sum_{j} b_{ij} x_{j} y_{i} + \sum_{j} c_{ij} x_{i} y_{j}
\)
Here, we substitute \( y_{jk} = j/\lambda \) into eqn. 6 and then simplify it as follows:

\[
(M - 1) \cdot \left( \frac{(u - (1/\lambda^2))/u}{\lambda u^2} \right)^{M^2} < \frac{1}{2j} \leq \frac{1}{2}
\]  

(7)

The worst case will occur when \( j = 1 \), and we deem eqn. 7 to be the sufficient condition for the PBHC to accurately recall any desired pattern. Since the value of the polynomial in the absolute value of eqn. 7 is positive, the minimal \( Z \) in the worst case for the PBHC is derived in the following:

\[
Z \geq (1/\lambda^2) \cdot \left( \frac{(u - (1/\lambda^2))/u}{\lambda u^2} \right)^{M^2} < \frac{1}{2j} \leq \frac{1}{2}
\]

(8)

where \( u \leq C_2^M(n + p) \leq C_2^M(2n) \leq M(M - 1)n \).

Eqln. 8 is the lower bound solution of \( Z \), and according to eqn. 7, the minimal capacity can be derived as follows:

\[
M \geq \left( \frac{(n(1/2))/\lambda^2}{\lambda u^2} \right)^{M^2} \leq \frac{1}{2j} \leq \frac{1}{2}
\]

(9)

where \( u = M(M - 1)n \).

Results and conclusions: The BAM-like associative memory consists of two layers of neurons. One layer has \( n \) neurons and the other has \( p \) neurons. \( n \) is assumed to be less than or equal to \( p \) without any loss of robustness. In evaluating a BAM-like associative memory, probably the most important factor is its storage capacity. We consider that some randomly generated desired attractors can each be generally stored as a strong stable state in a BAM-like associative memory by the corresponding evolution equation [1].
60, we can obtain a capacity equal to 40006 and 84059, respectively. Therefore, the PBHC provides an extremely high storage capacity for pattern pairs. The practical capacity of the PBHC in the worst case is estimated, thereby allowing us to predetermine the size of the PBHC.

Acknowledgments: This research was partially supported by National Science Council under grant NSC 89-2219-E-110-001, 89-2215-E-110-014 and 89-2215-E-110-017.

© IEE 1999
Electronics Letters Online No: 19991344
DOI: 10.1049/el:19991344
Chu-Chin Wang and Cheng-Fa Tsai (Department of Electrical Engineering, National Sun Yat-Sen University, Kaohsiung, 80424, Taiwan, Republic of China)
E-mail: cwwang@ee.nsysu.edu.tw

References

320 Gbit/s (8 x 40 Gbit/s) WDM transmission over 367 km with 120 km repeater spacing using carrier-suppressed return-to-zero format


The authors demonstrate +11dBm-per-channel 320Gbit/s (8 x 40 Gbit/s) WDM transmission over a 367 km zero-dispersion-flattened transmission line with 120 km repeater spacing using a nonlinearity-tolerant carrier-suppressed return-to-zero format.

Introduction: When targetting WDM systems with total capacities in excess of terabits per second, there are several advantages in increasing the electrical-time-division-multiplexed (ETDM) channel rate to 40Gbit/s [1]. It is possible to reduce the number of multiplexed channels to less than 25, which simplifies network management and saves on wavelength resources. The channel power of such WDM systems should be linearly increased at the line rate increases in order to return the same signal-to-noise ratio. A numerical simulation has shown that the return-to-zero (RZ) format offers a larger power margin in dispersion-managed transmission lines using singlemode fibre (SMF) at a line rate of 40Gbit/s [2], and there are several experimental reports of using a dispersion-managed line [3 – 5]. No experimental report has, however, detailed 40Gbit/s RZ channel WDM transmission performance at repeater-output powers > +10dBm/channels, levels at which several fibre nonlinear effects, such as self-phase modulation (SPM) and cross-phase modulation (XPM), become significant in determining the system performance.

In this Letter, we show that our proposed optical-carrier-suppressed RZ (CS-RZ) format has a larger power margin than the conventional RZ signal format in an SMF-based, dispersion-managed transmission line (zero-dispersion-flattened (ZDF) transmission line [4]). We demonstrate 320Gbit/s (8 x 40Gbit/s) WDM transmission with 120 km repeater spacing for the first time over a 367 km ZDF transmission line. This is possible because the CS-RZ format achieves record 40Gbit/s channel power of +11dBm (total power: +20dBm/channels).

Experimental setup: The experimental setup is shown in Fig. 1. In the transmitter, the eight optical carriers were simultaneously modulated with the 40Gbit/s non-return-to-zero (NRZ) format (2^7 – 1 pseudorandom binary sequence) using an InP-HEMT multiplexer IC [6] and a push-pull-tube LiNbO_3 Mach-Zehnder (LN-MZ) modulator (MZ 1) [7]. The signal wavelengths ranged from 1546.1 nm (channel 1) to 1557.3 nm (channel 8) with 200GHz spacing. The 40Gbit/s NRZ optical signals were boosted and converted into 40Gbit/s CS-RZ signals in a newly proposed MZ-modulator pulse generator. In the optical pulse generator, the LN-MZ modulator (MZ 2) [7] was biased at the transmission null.

Fig. 1 Experimental setup

Two pairs of 20GHz clock signals were fed to each electrode of the modulator (MZ 2). The phase-encoding characteristics of the modulator yielded a 40GHz chirless CS-RZ signal from a 20GHz electrical input. The full width at half maximum (FWHM) measured by a streak camera was 12ps. To generate a conventional RZ signal with an FWHM of 12ps, the output of the MZ 2 modulator (driven by 40GHz signals) was used with the normal bias condition: the mid-point between the transmission null and peak. The carrier component of the CS-RZ signal spectrum was suppressed and the spectral bandwidth of the CS-RZ signal was smaller than that of the conventional RZ signal, as shown in Fig. 2. In the receiver, the 320Gbit/s signal was WDM-demultiplexed using a tunable bandpass filter with 0.9nm bandwidth, and was optically demultiplexed into 40Gbit/s signals to check the bit error rate (BER) [5]. The 367 km ZDF transmission line consisted of three repeater spans joined by two EDFA in-line repeaters. Each span consisted of SMF and reverse-dispersion fibre (RDF) [8]. The losses of the three sections were 29.06dB (1: 0.23dB/km), 28.04dB (2: 0.24dB/km) and 26.52dB (3: 0.22dB/km). The total dispersion of the 367km ZDF line ranged from –3ps/nm to +16ps/nm over the 8-channel signal wavelengths, and a dispersion-flattened characteristic was obtained for a 10nm wavelength range.

Fig. 2 40Gbit/s modulation spectra (\(\lambda\), optical carrier frequency)

a Proposed CS-RZ format
b Conventional RZ format

40Gbit/s CS-RZ single-channel transmission: The CS-RZ and conventional RZ formats were compared in terms of single-channel transmission performance, both numerically simulated and meas-