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Efficient Channel Coding Scheme for Optical Memory: An Overview

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Abstract— The nowadays huge amount of data generated each year. The main challenge behind current information technology is not able to store efficiently. In this paper analyzed the recent development in optical storage techniques. The essential requirement for any memory system is data reliability. In optical memories data may be corrupted while recorded, retained or readout from the optical memory. For example, the readout system and material noise, optical effects such as reflection, diffusion, and pixel crosstalk due to additive noise in Gaussian amplitude. Mechanical noise sources are also present; such as jitter due to positioning the readout mechanism or optical media. The data reliability is achieved by using error correcting codes and media-specific data modulation. The research is focused to design a hardware for optical memory. The hardware is designed with LDPC algorithm. The high potential of LDPC codes, binary and nonbinary LDPC decoding algorithms for the optical system is implemented in FPGA using VHDL language. LDPC codes are the most powerful error correcting codes. And this encoding scheme is compared with another encoding scheme and get the most hardware efficient encoding scheme.

Keywords— Low-Density Parity Check (LDPC) encoder, decoder, VHDL language, Field Programmable Gate Array (FPGA).

I. INTRODUCTION

There is technological evolution in the recording and storage of information. The main revolution in this field is digitization, which allows music, sounds, pictures, words, and movies to be stored in a binary form. The invention of optical compact discs (CDs), where a laser beam was used to store the binary data, it was one of the major milestones in digital information technology. The magnetic storage devices and CDs have played a crucial role in the digital life of human beings. Economically digital information technology has played a great role. The estimation results show that the information generated by the major sectors is nearly doubled every year. The total amount of data generated globally will reach 35 ZB by 2020, According to a report prepared by International Data Corporation (IDC) in 2011, However, there is a growing gap between the amount of digital data being created and the available storage capacities.

A large amount of data may corrupt while in transmission or reception. So, this information should be stored in a specific manner. The customer should be promised by the security of the data. In this paper considering with an encoding scheme that will promise the data integrity and storage capacity. Here encoding scheme is preferred that is Low-Density Parity-Check coding, which is a class of linear block codes and also an error correcting code. The LDPC codes have decreased the complexity of decoding.

Section II discusses about different encoding/decoding methods. These encoding/decoding schemes are compared in section III. Section IV concluded with a conclusion and future work.

II. ENCODING/DECODING METHODS

Various encoding techniques have been developed in the field of optical memory by researchers to detect efficient channel coding in optical memory.

Leo Selavo, Donald M. Chiarulli and Steven P. Levitan [1] proposes the encoding of optical memory. The optical memories should match the requirements of large, fast and reliable data storage. Here the data is represented as codewords in each page. The codewords are partitioned in rectangular code blocks. The data is read out from memory as pages. A laser beam is used for the decoding system. This encoding technique attains reliability. In this encoding scheme, the whole line encoded block by block and page line by line. Here the page is encoded from the left-topmost. The figure1 shows the code block with a different color the light gray represents the CB is being encoded. The dark gray represents the code block has been encoded, and the white block shows the block with all zeros and they will be subsequently encoded. This encoding scheme will minimize inter-symbol interference (ISI) and other system noise.

11001 00101 01010	01011 11010 11011	10111 10011 11010
10101 10001 11000	????? ????? ?????	00000 00000 00000
00000 00000 00000	00000 00000 00000	00000 00000 00000

Fig 1. Encoding scheme [adapted from ref.1]

Ya-Fen Hsiao and Pin-Ju Tsai [2] introduces a quantum memory and communication protocol and evaluates the performance of quantum memory. which include the fidelity, efficiency, storage time, capacity and bandwidth. The paper achieves a storage efficiency of 92% for an optical memory based on the electromagnetically induced transparency. The author described how the storage efficiency attained using an electromagnetically induced transparency scheme.

A. J. Al-Sammak, K. Al-Ruwaihi, and 1. Al-Kooheji [3] proposes a Manchester coding scheme for optical data communication. It attains a high data rate transmission at the local area network. The Manchester encoder is simple and can be implemented exclusive OR gate using a clock frequency is equal to the data rate. The paper explains the Manchester encoder-decoder circuits.

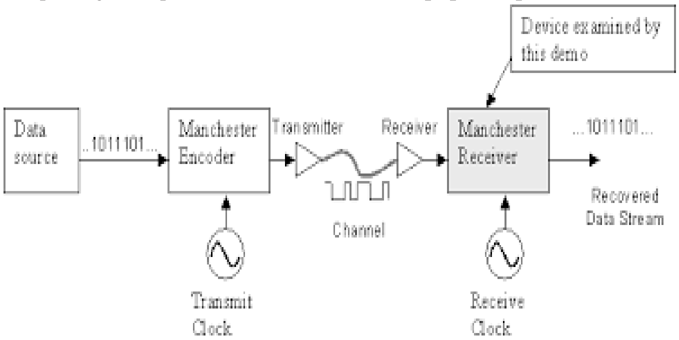

Fig 2. Block diagram of Manchester encoding scheme [adapted from ref 3]

Wei Hu, Diqing Hu, Changsheng Xie and Fan Chen [4] proposes a new scheme for the optical storage system. Coding efficiency and performance of correcting errors which decide the capacity of the optical storage system. It is a new coding scheme of NVD (Next Generation Versatile Disc), which is one of the key technologies of the optical storage system. Reed Solomon codes are used for error correcting codes. NVD which reduce the redundancy and increase the encoding-decoding efficiency. Redundancy rate parity symbols which increase storage capacity. This paper suggests increasing the storage capacity without decreasing error correction performance.

Moritz Merklein and Birgit Stiller [5] proposes a chip-integrated Brillouin based optical memory. Storing and delaying optical signals are facing a new challenge such as operational bandwidth, capacity, and energy efficiency. The speed of light, which provides fast data transmission that will cause reroute, buffer or process data. So, the system needs a chip-integrated optical buffer. In this paper presents a coherent transfer of information from optical signals to acoustic phonons in a planar integrated circuit. The paper also uses on-chip signal processing schemes and non-reciprocal light storage. The principle behind this technique is signal transfer from the optical domain to acoustic phonons via stimulated Brillouin scattering.

Wim Coenen and Ernest Chuang [6] proposes a combi-code for high-density optical recording. Combi-codes are a new coding concept for efficient byte-oriented codes. It is the rewritable optic disc for digital video recording with high numerical aperture and a blue laser.

Ali Zahid, Bo Dai, Yao Chen, and Dong Wang [7] proposes a novel spectral phase encoding for optical communication by using a ±Π/2 phase shift in encoding and decoding. The system offers high security at the time of code extraction from the encoded signals. Paper presents the procedure for optical code extraction from the encoded spectrum. ±Π/2 phase shift spectral phase encoding provides a good coding performance, so the proposed system guarantees both the security and coding performance.

Xu Wang [8] proposes a DPSK optical code hopping scheme for secure optical communications using a single-phase modulator. The proposed system demonstrates a bit-by-bit scrambling technique based one-time domain spectral phase encoding-decoding scheme, which enhances transmission security.

Yu Huang, Xuhua Wang, Kaimin Wang and Dawei Zhang [9] proposes a novel encoding scheme based on time-domain SPE/D. the optical codes are randomly selected from a given code set and organized to a hopping pattern. The code selection process increases the difficulty for eavesdroppers to break the code sequence. With the code selection, the communication system can achieve an identical security level by using fewer system resources.

Jay w. schwartz and Richard C. Barker [10] al presents the bit plane encoding technique, which is used for reducing the redundancy in space probes. In the block diagram binary input are required for this technique.

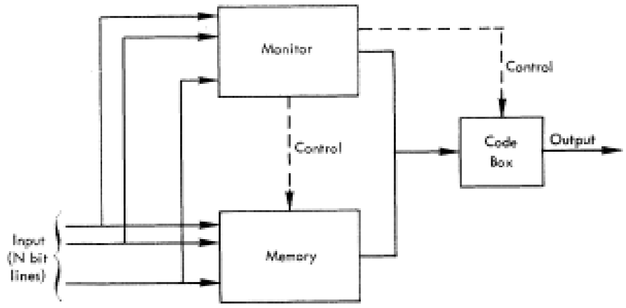

Fig 3. Block diagram of bit plane encoder [adapted from ref 10]

The memory to store data samples, a monitor and a code box is required for encoder implementation. The monitor and code box will perform simple operations on binary sequences. This encoding method is also lossless compression technique

Kees A. Schouhamer link [11] introduces a new optical recording medium with a storage capacity five times higher than the conventional compact Disc. They reported on an alternative to Eight-to-Fourteen Modulation called EFMPlus which has adopted as the recording format in the multimedia Compact Disc. The strategy of EFMPlus is much more refined than the original EFM of Compact Disc. The saving in the rate of EFMPlus offers a serviceable 6% increase in capacity as compared with its predecessor EFM, without in the least compromising the reliability of the servo systems or data recovery.

Min Gu and Xiang Ping Li [12] paper present the evolution of optical data storage systems. In 2-D optical data storage system information is recorded only in one layer inside the medium, 99.99 percent of the volume of the disc has not been used. In multi-dimensional optical data storage uses a spatial region of a recording medium.

Dinesh C. Suresh and Jun Yang [13] et al presents two novel data bus encoding schemes to reduce power consumption in the data bus. The first encoding scheme called variable length value encoder (VALVE). VALVE is capable of detecting and encoding the variable length of repeated bit patterns in the data. The second encoding scheme called tunable bus encoder (TUBE) encoder repetition in contiguous as well as non-contiguous bit positions of data values.

Kaichun Yao, Libo Zhang [14] et al explain about dual encoding technique. This encoding scheme consists of primary encoder, a secondary encoder, and a decoder equipped with an attention mechanism. The primary encoder will calculate the semantic vector for each word in the input sequence.in secondary encoder first calculates the importance weight for each word in the input sequence and then recalculates the corresponding semantic vectors and the decoder with attention mechanism decodes by stages and generates a partial fixed length output sequence at each stage.

D.L. Tao, C.R.P. Hartmann, and Yunghsing S. (Sam) Han [15] et al present an algorithm-based fault tolerance (ABFT), which enhance low-cost error protection for array processors and multiprocessor systems. In ABFT consider with the minimum distance 3(4) is mapped into an array processor to compute fault-tolerant matrix operations, all single faults can be tolerated. The paper discusses partial checksum: new encoding/decoding schemes, which described by check matrix H*=[hij]. The total overhead reduced by replacing the multiple/division operations with additions/subtractions. The paper also discusses the two different encoding decoding methods are lengthened hamming codes and a single error correcting / double error detecting code. Finally, the paper concludes with an error detecting/correcting codes in GF (3) with the minimum hamming distance 3(4) can construct efficient ABFT to tolerate all single faults.

Zhang Yongjun [16] et al presents a characteristic systematic form of Reed-Solomon (RS) codes in QR code. In the research the the computational complexity of RS error correcting decoding is reduced and the decoding speed of QR code is improved by applying RiBM algorithm, Chien search algorithm and Forney algorithm to RS algorithm.

Bahram Javidi, Guanashen Zhang and Jian Li [17] proposes a double random phase encoding. The author describes an encrypted optical memory. The paper shows that an experimental analysis of double random phase encoding on an encrypted optical memory. In the experiment, two images are considered, which is encrypted and readout by a unique code or a universal code. For encryption, the optical image is encrypted by using a random phase function in the space domain. The original optical image is obtained by using random phase function. Here the experiment used to demonstrate how an image can be encrypted and decrypted.

Kousik Mukherjee [18] proposes a read-only memory (ROM) based on a semiconductor amplifier. A non-linear polarization rotation is used, which uses a 2-4-line decoder based on frequency encoded addressing technique. Semiconductor amplifier ROM has sufficiently high switching speed with the property of efficient ON/OFF ratio. The decoder is based on two basic principles. Frequency routing by an add-drop multiplexer (ADM) and polarization rotation in non-linear SOA of the probe beam. The paper explains simpler hardware compared to other encoding technique.

Victor Y. Krachkovsky [19] proposes a Reed Solomon (RS) code for multiple error correction. Reed Solomon code is used as a two- dimensional format. Error correction is carried out by the multi-sequence shift-register synthesis algorithm. The paper discusses optimal burst correction capability due to certain decoding failure. At last, a low-complexity systematic encoding and syndrome computation algorithms for the RS codes are explained. The paper also discusses the decoding of different coding scheme-based RS codes.

Yunnan Wui [20] proposes a write-once memory for the storage medium. The proposed modulation scheme is the position modulation code. It is the number of “write-once” bit positions (wits), where each wit initially is in a “0” state and changed to a “1” state irreversibly. Flash memory and optical disks are examples. This coding scheme award a low complexity for rewriting write-once memories. The system achieves a code rate higher than optimal rate.

Haichuan Zhang and Edwin P. [21] Walker presents a technology that can be used for random accessed mass optical data storage. The uses a two-photon recordable plastic disk medium store multiple data layers inside one disk. The technology is capable of achieving 200GB data capacity with a 120mm diameter, 10mm thick disk, and a data transfer rate Gigabits/Sec by using parallel readout. The two-photon recording is based on two-photon absorption, by which one molecule is excited into a higher state by absorbing the combined energy of two photons. The two photons can be at different wavelengths or at the same wavelength. An excited molecule will combine with another type of dye molecule to become a new stable written form. This written form will emit a broadband fluorescence when excited with a readout laser beam at a suitable wavelength. For a two-photon absorption, Single or dual optical beams are used to provide the photons

Jun-Feng Song [22] presents a Silicon photonics integrated circuits (Si-PIC) with well-established active and passive building elements are progressing towards large-scale commercialization in optical communications and high-speed optical interconnects applications. The non-volatile memory should have energy efficient data storage, but current Si-PICs do not have memory capabilities. Here, he proposes an electrically programmable, multi-level non-volatile photonics memory cell (PMC) fabricated by standard complementary-metal-oxide-semiconductor (CMOS) compatible processes. The memory states are read in optical using PMC to the micro-ring resonator (MRR). Switching energy smaller than 20 PJ was achieved. Additionally, an MRR memory array was employed to demonstrate a four-bit memory read capacity. Theoretically, this can be achieved up to ~400 times using a 100 nm free spectral range broadband light source. The main concept of this design is to eliminate the von Neumann bottleneck. The energy-efficient optical storage can complement on-chip optical interconnects for neural networking, memory input/output interfaces, and other computationally intensive applications.

Eiichi Kuramochi [23] says about Photonic integration has long been pursued, but remains immature compared with electronics. Nanophotonic is expected to change this situation. He describes the large-scale and dense integration of optical memories in a photonic crystal chip. For that, he introduces a wavelength-addressable serial integration scheme using a simple cavity optimization rule. The wavelength-division-multiplexing capability, which is the most important advantage of photonics over electronics, and achieves an extremely large wavelength-channel density. Here a demonstration of the large-scale photonic integration of nanophotonic devices coupled to waveguides in a single chip, and also the first dense wavelength-division-multiplexing nanophotonic devices other than filters. This work introduces the way for optical random-access memories and for a large-scale wavelength-division-multiplexing photonic network-on-chip.

Dimitri A. Parthenopoulos and Peter M. Rentzepis [24] proposes a novel three-dimensional (3-D) optical memory device is presented that allows fast random access of the information and extremely high bit densities. Here, he introduces the photochromic material embedded in a polymer matrix based on two-photon writing, reading, and erasing of the information. Two-photon writing and reading of information shown by Absorption and emission of data. The data presented here show the feasibility of a 3-D optical memory device based on two-photon processes. An obvious advantage of this new memory, in addition to the 3-D nature of the device, is the random access and parallel addressing of the information. Any bit plane can be accessed by focusing the beams on the appropriate plane. The speed limits for the memory are (i) the molecular transfer rate for writing and (ii) the fluorescence lifetime for reading. This does not take into account limitations imposed by the processor and other associated components. This new method allows also parallel bit addressing, resulting in high random-access rates. For parallel addressing, the dynamic focusing lenses may be replaced by holographic grating or other devices providing parallel write-read-erase capability. Cross-talk and scattering of the beams, which are common in holographic memories, do not present a problem in this case because the volume accessed by the overlapping beams is well defined and is, in principle, diffraction limited

III. COMPARISON OF ENCODING/DECODING TECHNIQUE

REFE-RENCE NUMBER	ENCODING/DECODING SCHEMES	FEATURES
Ref [1]	Data encoding on page-oriented memory	Data reliability, minimizes cross talk, introduce noise margin
Ref [2]	Electromagnetically induced transparency scheme.	Storage efficiency 92.0%, retrieval efficiency above 50%
Ref [3]	Manchester coding scheme	High data rate transmission, decoder is insensitive in the clock rate within the range
Ref [4]	Error control scheme of Next-generation Versatile Disc	Reduce data redundancy, encoding efficiency up to 4% more than that of DVD
Ref [5]	Brillouin based memory, encoding in phase & amplitude	Achieve bandwidth efficiency and capacity
Ref [6]	Combi code	Coding complexity reduced
Ref [7], [8], [9]	Spectral phase encoding, DPSK optical code hopping scheme	Secure optical communication
Ref [10]	Bit plane encoding technique	Lossless compression, redundancy reduced
Ref [11]	Eight-to-Fourteen modulation (EFM)	Storage capacity five times more than the compact Disc.
Ref [12]	2-D optical data storage	achieve the storage capacity
Ref [13]	TUBE, VALVE encoding scheme	Reduce power consumption, delay

Ref [14],[17]	Dual encoding	Security enhancement.
Ref [15]	ABFT	Low cost error correction
Ref [16],[19]	Reed-Solomon code	Complexity of RS code reduced, speed improved, error correction
Ref [18]	Frequency encoded addressing technique	Achieve hardware efficiency
Ref [20]	Position modulation code	Low complexity, high code rate

IV. CONCLUSION & FUTURE SCOPE

The research is focused to design a hardware design, which will enhance storage capacity and data security. After viewing the related work realized an LDPC encoder-decoder scheme is the best way to enhance the capacity of optical memory. By using LDPC encoder I design an optical memory with high data security and high-speed grade.

In future the system research for algorithms with less complexity and power consumption. And also search for what are techniques need for speed up the encoding and decoding.

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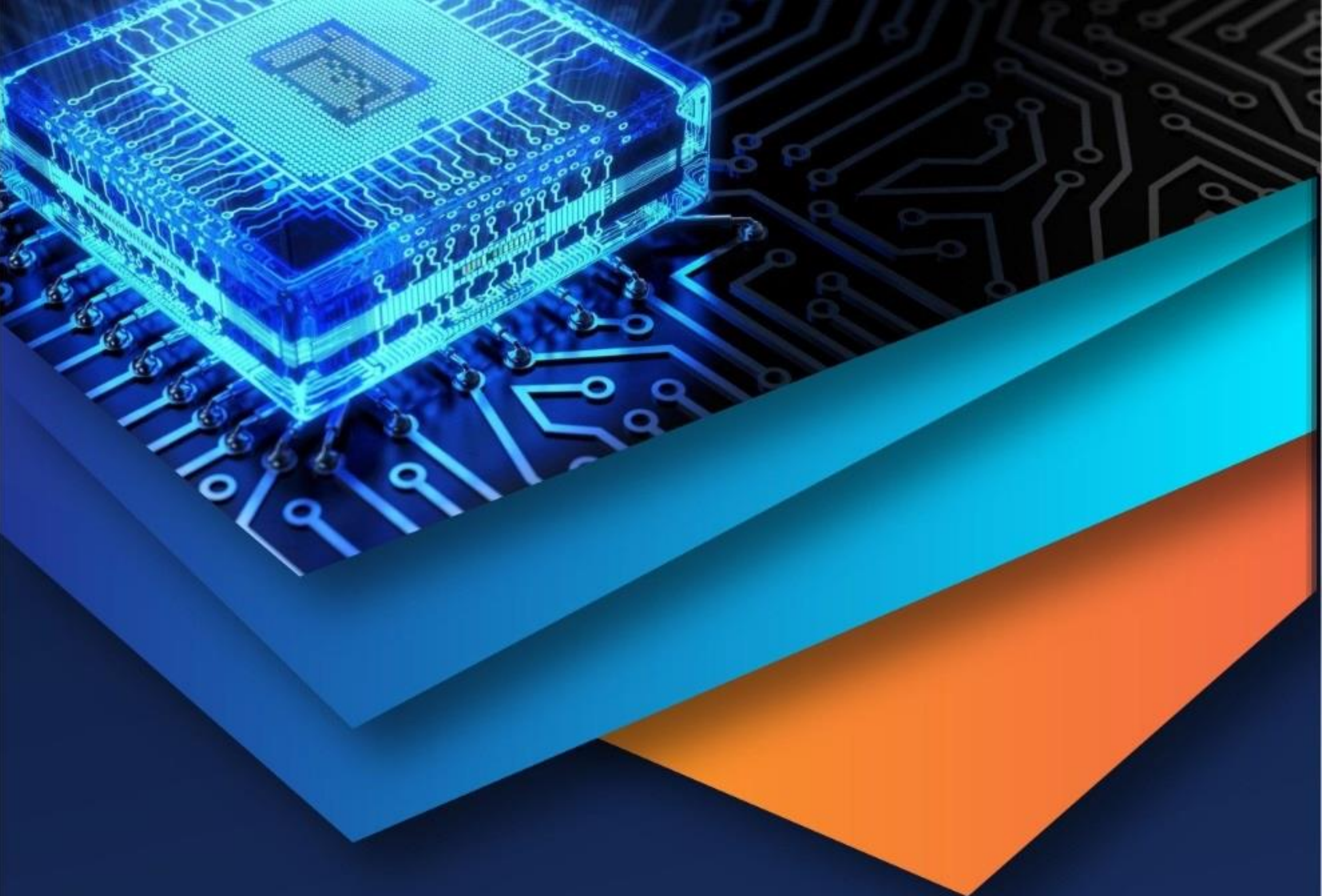

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