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Magnonic Holographic Memory

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***Abstract*-Data storage has been fundamental part of the computing from the beginning. The technology for data storage has been evolving along other side over areas of computing technology. As these other areas of technology have developed the need for bigger and fastest storage has been evident. To meet the need for better storage new technologies are constantly being developed as the old technologies reaches its physical limits and become outdated. Holographic memory has received attention in recent years as a technology that can provide very large storage density and high speed. Information is recorded in holographic medium through interface of two coherent beams of light .We refer to information carrying beams as signal beam and interfering beam as reference beam. The resulting interference pattern causes an index grating (the hologram) to be written in the material. When hologram is to subsequently illuminate within one of the original reference beams, light is diffracted from the grating in such a way that the signal beam is reproduce. Many holograms can be multiplexed within the same volume of the material by angle, fractal, wavelength, and phase code; multiplexing. Holographic memory can read and write data in parallel allowing for much higher data transfer speeds. Unlike conventional storage media such as magnetic hard disks and CD-ROM's which can access only 1 bit at a time, each access of a holographic memory yields an entire data page-more than a megabit at a time. Holographic random access memory design leads to the implementation of compact and inexpensive memory modules that can be used to construct large read-write memories.**

***Keywords-CD-ROM*, data transfer speeds, computing technology, holograms, etc.**

I.INTRODUCTION

Holography is a technique based on the wave nature of light which allows the use of wave interference between the object beam and the coherent background. It is commonly associated with images being made from light, such as on driver's licenses or paper currency. However, this is only a narrow field of holography.Holography has been also recognized as a future data storing technology with unprecedented data storage capacity and ability to write and read a large number of data in a highly parallel manner.The present study rests on the idea that a holographic memory device needn't replace a computer's electronic circuits. Instead, the device could work with the existing system and help with certain tasks such as image recognition.

1.Holography Technique

Holographic data storage refers specifically to the use of holography to store and retrieve digital data. To do this, digital data must be imposed onto an optical waterfront, stored holographically with volumetric density and then extracted from the retrieved optical waterfront with excellent data fidelity. A hologram preserves both the phase and amplitude of an optical waterfront of interest called the object beam by recording the optical interference pattern between it and a second coherent optical beam –the reference beam. The reference beam is designed to be simple to reproduce original data at later stage. (A common reference beam is a plane wave: a light beam that propagates without converging or diverging).These interference fringes are recorded if the two beams have been overlapped within a suitable photosensitive media, such as photopolymer or inorganic crystal or photographic film.

This bright and dark variation of the interference pattern as a change in absorption, refraction index or thickness. When the recording is illuminated by a readout beam similar to the original reference beam, some of the light is diffracted to "reconstruct "a copy of the object beam .If the object beam originally come from a 3D object, then the reconstructed hologram makes the 3D object reappear.Holography is recognized as the future of data storage. The latest study shows that one can apply advanced holographic technique used in optics to magnetic structures, creating a kind of "magnonic holographic memory device.

"Researchers have now created a new type of holographic memory device that can store a large amount of data using spin waves.The results open a new field of research, which may have tremendous impact on

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the development of new logic and memory devices. The device exploits spin wave interference or collective oscillations of spins in magnets.

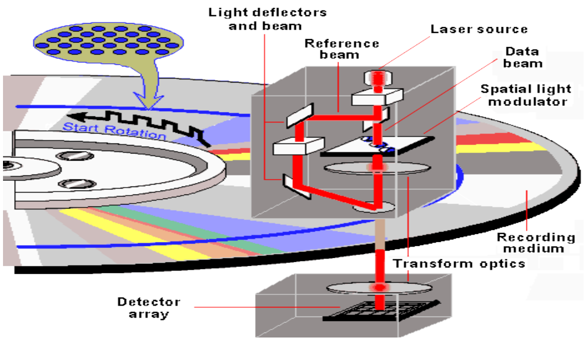

Fig.1 Memory Structure.

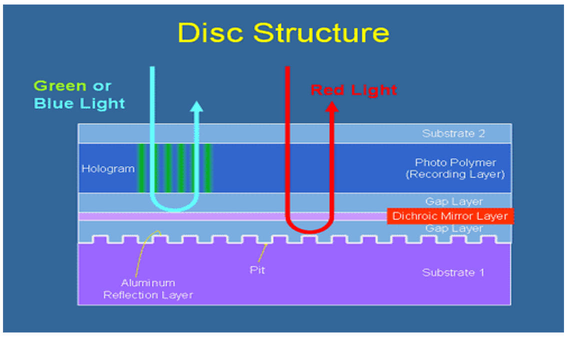

Fig.2 Disc Structure.

Currently, storage devices use optical beams.The experiments in the current study were conducted using 2-bit magnonic holographic memory prototype device. A pair of magnets acted as memory elements and was placed on magnetic waveguides.The magnetic field produced by the magnets affect the spin waves moving through the magnetic field. In the experiment, researchers found that spin wave interference led to production of a clear picture and researchers could recognize the states of magnets. The technology is still in its infant stage and will require several years of research before being applied on a commercial scale.

Pattern recognition focuses on finding patterns and regularities in data. The uniqueness of the demonstrated work is that the input patterns are encoded into the phases of the input spin waves.Spin waves are collective oscillations of spins in magnetic materials. Spin wave devices are advantageous over their optical counterparts because they are more scalable due to a shorter wavelength. Also, spin wave devices are compatible with conventional electronic devices and can be integrated within a chip.

The researchers built a prototype eight-terminal device consisting of a magnetic matrix with micro-antennas to excite and detect the spin waves. Experimental data they collected for several magnonic matrixes show unique output signatures correspond to specific phase patterns. The micro antennas allow the researchers to generate and recognize any input phase pattern, a big advantage over existing practices.Then spin waves propagate through the magnetic matrix and interfere. Some of the input phase patterns produce high output voltage, and other combinations results in a low output voltage, where "high" and "low" are defined regarding the reference voltage (i.e. output is high if the output voltage is higher than 1 mill volt, and low if the voltage is less than 1 millivolt.

It takes about 100 nanoseconds for recognition, which is the time required for spin waves to propagate and to create the interference pattern. The most appealing property of this approach is that all of the input ports operate in parallel. It takes the same amount of time to recognize patterns (numbers) from 0 to 999, and from 0 to 10,000,000. Potentially, magnonic holographic devices can be fundamentally more efficient than conventional digital circuits.

The work builds upon findings published last year by the researchers, who showed a 2-bit magnonic holographic memory device can recognize the internal magnetic memory states via spin wave superposition. The main challenge associated with magnonic holographic memory is the scaling of the operational wavelength, which requires the development of sub-micrometer scale elements for spin wave generation and detection.

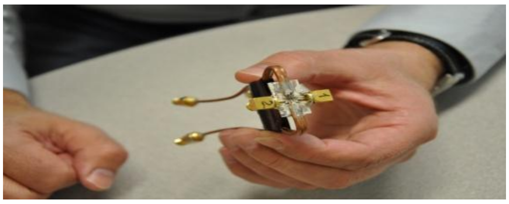

Fig.3 A Prototype of Holographic Memory Device.

II.MATERIAL STRUCTURE AND THE PRINCIPLE OF OPERATION

The concept of Magnonic Holographic Memory (MHM) for data storage and dataprocessing has been recently proposed. MHM evolves the general idea of opticalapproach to applications in the magnetic domain aimed to combine the advantages ofmagnetic data storage with the unique capabilities for read-in and read-out provided byspin waves.

At the same time, the use of spin waves implies certain requirements onthe memory design, which are mainly associated with the need to preserve the energyof the spin wave carrying signals and the mechanisms of spin wave excitation anddetection. The schematics of MHM as described in Ref.are shown in Figure 1(A). Itcomprises two major components: a magnetic matrix and an array of spin wave generating/detecting elements input/output ports.

Table 1Technology Comparison between Conventional & Holographic Storage

Parameters	Significance	Storage	Access	Speed	Advantages
Conventional Data Storage Equipments	There are basically two types of storage media available nowadays: 1.Magnetic(Magnetic tape, hard disk drives) 2.Optical(CD, DVD, Blu Ray)	CD (700 mb), DVD(4.7 GB), BLU Ray(25GB,50GB,1TB)	Red and Blue lasers are used on polycarbonate surface to read and write.	CD(10X), DVD (52X), Blu Ray(54X)	1.Portable 2.Cheap
Holographic Data Storage	In holographic storage we store data on volumetric surface or we can say on a crystal. This is highly dense in nature.	100 Terabytes per crystal	Neon Green laser is used to create holographic image form storage.	1 Gbps	1.Higher speed 2.Max Stroage 3.Long Lasting

Spin waves are excited by theelements on one or several sides of the matrix propagate through the matrix anddetected on the other side of the structure. For simplicity, the matrix is depicted as at two-dimensional grid of magnetic wires. These wires serve as a media for spin wave propagation – spin wave buses. The elementary mesh of the grid is a cross-junction between the two orthogonal magnetic wires as shown in Figure 4(A). There is a nano magnet on the two p of each junction. Each of the senano magnets is a memory element holding information encoded in the magnetization state. The nano-magnet can be designed to have two or several thermally stable states for magnetization, where the number of states defines the number of logic bits stored in each junction. The spins of the nano-magnet are coupled to the spins of the junction magnetic wires via the exchange and/or dipole-dipole coupling affecting the phase of the propagation of spin waves. The phase change received by the spin wave depends on the strength and the direction of the magnetic field produced by the nano-magnet. At the same time, the spins of nano-magnet are affected by the local magnetization change caused by the propagating spin waves. We consider two modes of operations: read-in and read-out. In the read-in mode, the magnetic state of the junction can be switched if the amplitude of the transmitted spin wave exceeds some threshold value. In the read-out mode, the amplitudes of the propagating spin waves are too small to overcome the energy barrier between the states. So, the magnetization of the junction remains constant in the read out mode.

MHM has multiple input/output ports located at the edges of the waveguides. These elements are aimed the convert the input electric signals into spin waves, and vice versa, convert the output spin waves into the electric signals. There are several possible ways of building such elements by using micro-antennas spin torque oscillators ,and multi-ferrous elements For example, a micro-antenna is the most widely used tool forspin wave excitation and detection in ferromagnetic films. An electric current passedthrough the antenna placed in the vicinity of magnetic film generates a magnetic field around the current-carrying wires, which excites spin waves in the magnetic materialAnd vice versa, a propagating spin wave changes the magnetic flux from the magnetic waveguide and generates the inductive voltage in the antenna contour.

The incident spin wave front is produced by the number of spin wave generating elements (e.g. by the elements on the left side of the matrix as illustrated in Figure 1(B)). All the elements are biased by the same RF generator exciting spin waves of the same frequency f and amplitude A, while the phase of the generated waves are controlled by the DC voltages applied individually to each element. Thus, the elements constitute a phased array allowing us to artificially change the angle of illumination by providing a phase shift between the input waves. Propagating though the junction, spin wave accumulates an additional phase shift Δ□ ,which depends on the strength and the direction of the local magnetic field provided by the nano-magnet *H*

$$\Delta\phi = \int_0^r k(\vec{H}_m)dr$$

,where the particular form of the wave number *k(H)* dependence vary for magnetic materials, film dimensions, and the mutual direction of wave propagation and the external magnetic field For example, spin waves propagating perpendicular to the external magnetic field (magneto static surface spin wave – MSSW) and spin waves propagating parallel to the direction of the external field (backward volume magneto static spin wave – BVMSW) may obtain significantly different phase shifts for the same field strength. The phase shift Δϕ produced by the external magnetic field variation □*H* in the ferromagnetic film can be expressed as follows

1.Figure Captions

Figure4(A) The schematics of Magnonic Holographic Memory consisting of a 4×4magnetic matrix and an array of spin wave generating/detecting elements For simplicity,the matrix is depicted as a two-dimensional grid of magnetic wires with just 4 elementson each side. These wires serve as a media for spin wave propagation. The nano-magnet on the top of the junction is a memory element, where information is encoded into the magnetization state. The spins of the nano-magnet are coupled to the spins of the magnetic wires via the exchange coupling. (B) Illustration of the principle of operation. Spin waves are excited by the elements on one or several sides of the matrix (e.g. left side), propagate through the matrix and detected on the other side (e.g. right side) of the structure. All input waves are of the same amplitude and frequency. The initial phases of the input waves are controlled by the generating elements. The output waves are the results of the spin wave interference within the matrix. The amplitude of the output wave depends on the initial and the magnetic states of the junctions.

Figure 4 (A) The schematics of the experimental setup. The test under study is a double-cross YIG structure with six micro-antennas fabricated on the edges. The input and the output micro-antennas are connected to the Hewlett-Packard 8720A Vector Network Analyzer (VNA). The VNA generates input RF signal in the range from 5.3GHzto 5.6GHz and measures the S parameters showing the amplitude and the phases of the transmitted and reflected signals. (B) The photo of the YIG double-cross structure. The length of the structure is 3mm, and the arm width is 360µm. (C) Transmitted signal(S) spectra for the structure without micro-magnets. Two input signals are generated by the micro-antennas 2 and 3. The curves of different color show the output inductive voltage obtained for different phase difference among the two interfering spin waves.(D) The slice of the data taken at the fixed frequency of 5.42GHz (black curve). The red curve shows the theoretical values obtained by the classical equation for the two

1. Interfering waves.

Figure 3.A set of three holograms obtained for the three configurations of the top micro magnets as illustrated by the schematics on the top:

- Two micro-magnets aligned in the same direction perpendicular to the long axis;
- The magnets are directed in the ortho goal directions;
- Both magnets are directed along the long axis. The red markers show the experimentally measured data (inductive voltage in mill volts) obtained at different phases of the four generated spin waves. The cyan surface is a computer reconstructed 3-D plot. The excitation frequency is 5.4GHz, the bias magnetic field is 1000 Oe, all experiments are done at room temperature

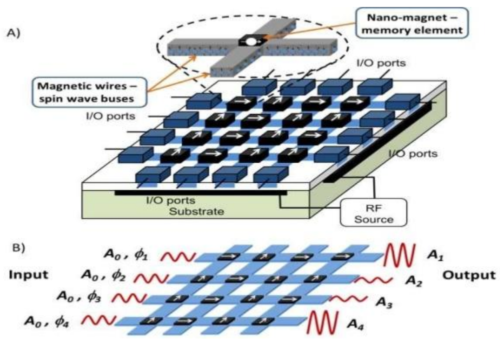

Fig.4(A) Schematics of MHM.

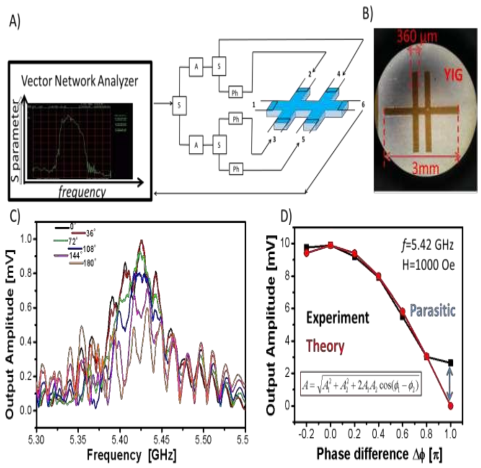

Fig.4 (B) Schematics of experimental setup.

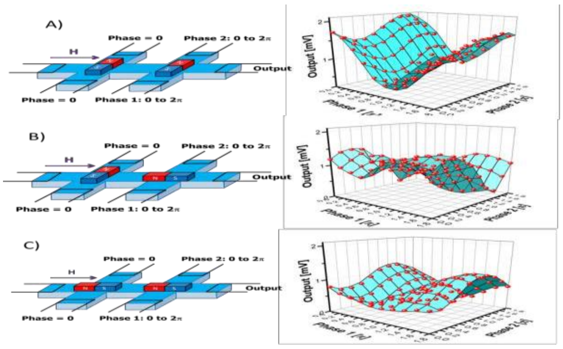

Fig.4(C) Transmitted Signal (S) Spectra.

2. Few Disadvantages

Methods for transparent and diffusively reflecting objects have besides their advantages, also disadvantages that are not negligible:

- The equipment for holographic interferometer is rather complex, expensive (cheaper than in classical interferometers) and limited by laboratory conditions.
- Dimensions of the investigated object are limited by the size of the objective viewing field.
- Larger deformations lead to formation of a non-distinguishable interference structure.
- The method of holographic interferometer is possible to apply mainly in laboratories – to ensure the stability of the holographic equipment (with the exception of the holographic interferometer in the impulse mode).
- The experimental equipment for the object investigation must satisfy the specifications of a holographic interferometer respecting its dimensions and construction.

III.CONCLUSION

The Future of Holographic Data Storage is very promising. Each time you watch a fast-paced DVD movie or pull down a piece of information from the Internet or even access the ATM at the corner of your street, you are actually tapping into large repositories of digital information. The hard disk, the mainstay of personal and corporate storage, has faithfully obeyed the exponential law. This has happened largely due to increases in aerial density, that is, how many bits are crammed into a square inch. This paper provides a description of Holographic data storage system (HDSS), a three dimensional data storage system which has a fundamental advantage over conventional read/write.

Finally, holographic media is meant to be blessed with a lifespan of over 50 years, compared to 2-5 years for magnetic storage. Of course, whether holographic readers will still *exist* in 50 years is another question entirely. Eventually, if the hardware becomes affordable for consumers, holographic storage could supplant DVDs and become the dominant medium for games and movies. Portable movie players and phones that download multimedia from the Web would take off. Holographic storage could even compete with the magnetic hard drive as the computer's fundamental storage unit. And on a larger scale, corporate and government data centers could replace their huge, raucous storerooms of server racks and magnetic-tape reels with the quiet hum of holographic disc drives.

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