Improved Data Density Using Dynamic Encoding in a 2-Photon Memory

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Abstract

An empirical study of dynamic modulation encoding for 2-photon optical memory was conducted. Dynamic modulation encoding was applied to the optical model using data extracted from optical memory prototype system at Call-Recall Inc. For this memory system the results of the experiments show the potential bit density and capacity improvement of up to 457Gbit/inch^2.

Introduction

The goal of this study was to evaluate dynamic modulation encoding [1] on a two-photon memory system developed at Call Recall Inc, California, USA. The memory system stores information in data pages, where every bit is represented as a florescent light source 0.7um – 2um in diameter, with 5um pitch between the bits [2]. In our study we applied dynamic encoding to achieve higher data density and improved data reliability. The tradeoffs between code density, detection threshold and pitch between the bits were evaluated.

Variety of factors such as inter symbol interference and jitter affect the density of data storage in optical memories. Data encoding techniques for page oriented mass storage devices are typically conservative in order to overcome these destructive effects and lead to low code rate and low code densities, often below 50% [3]. The typical techniques use static encoding, which assumes the worst-case scenario for every code block location. We have proposed more aggressive dynamic encoding technique, which chooses a custom code for each code block location depending on surrounding data on the data page [1]. In this study the practical implications of applying dynamic encoding to 2-photon memory have been analyzed.

The dynamic encoding assumes data readout detection by a threshold, i.e. every bit read at light intensity below the threshold is considered to have value '0', and every above is '1'. The threshold value is a parameter to the dynamic encoding, and by fine-tuning its value different code densities are achieved. Another parameter of the dynamic encoding is the point spread function (PSF), which describes light distribution from a bit source. Usually this distribution pattern is wide enough to create inter-symbol interference (ISI) with the neighboring bits. Dynamic encoding pre-evaluates ISI and arranges bit patterns for the codewords so that ISI is minimized.

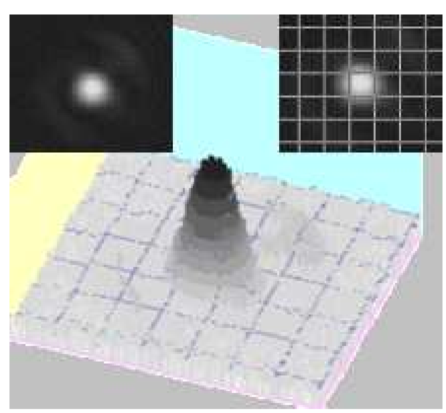

Figure 1: PSF 2D and 3D plots

The point-spread function used in this research was extracted from the images provided by Call Recall Inc. Each image represented a bitmap of light intensities (Figure 1) received at different locations on a photodetector plane. In order to evaluate dynamic encoding the image was superimposed with a grid that defined a pitch between bit locations on the memory page. Then the light intensity values were integrated for each grid cell, and normalized over the whole grid. The result was a PSF matrix, which represents ISI intensity values for neighboring bit locations.

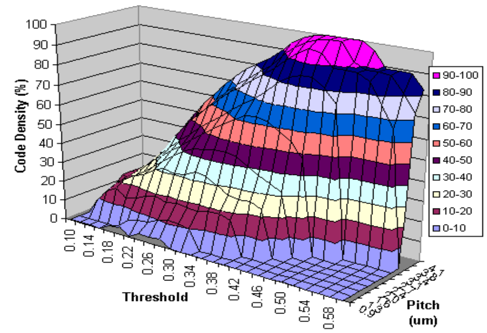

Figure 2: Code density plot

Several PSF matrices were created for different grid pitch values with respect to different raw data density. Then encoding simulations were run for every PSF matrix and a range of thresholds to determine code density provided by the encoding. The results are the surface plot in Figure 2. The peak area indicates the values of the threshold and pitch at which the bits are sufficiently spaced apart so that ISI becomes negligible. However, once the real data density values, defined as kilobytes per square millimeter are computed and plotted (Figure 3), it becomes apparent that the "sweet" spot with the highest data density is located at a different pitch, where ISI is created, but neutralized by the dynamic encoding.

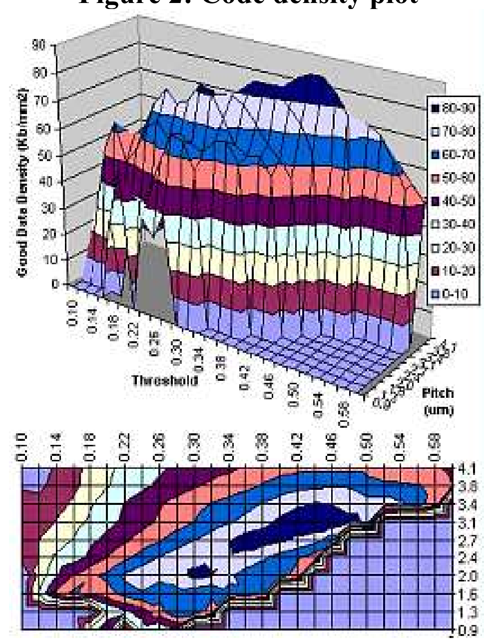

Figure 3: Data density plot

The dynamic encoding simulation results show that for a 2um^2 bit size at 3um pitch the 2-photon memory system can achieve data density of 89 Kbit/mm^2. Reducing the bit size to 1um^2 increases the data density to 356 Kbit/mm^2 (224 Gbit/inch^2). For the smallest bit size 0.7um^2 as reported by Call Recall [1], at 1um pitch dynamic encoding enables data densities as high as 726Kbit/mm^2 (457Gbit/inch^2). Decreasing the pitch even further would be impractical due to destructive ISI.

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References:

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