FDTD for Parametric Modeling of Nano-Structured Surface Relief Profiles for an Alternate Mode of Optical Data Storage

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Current generation memory devices generally rely on one of two technologies, magnetic or optical storage. Examples would be hard drives for the former, and CD-ROMs for the latter. Both methodologies have provided very high capacity, and research continues in the improvement of both approaches. Classical resolution scales typically limit current optical memories to structures on the order of half a wavelength. Holography has been used to extend memories into the third dimension to capitalize on density. Demonstrations have shown faster access time than a hard disk for holographic random access memory, and 40Mbits/cm^2 capacity has been demonstrated in a working holographic read-only memory system. However, a limit is eventually reached where adding extra holograms will distort existing ones due to interference effects

Sub-wavelength topographical features created by imprint lithography can also be used as data that can be read using atomic force microscopy. Work in this area has demonstrated significantly enhanced storage densities, i.e., on the order of 400Gbits/in^2. One of the limitations with such a method is that each feature is read serially, and the time scale of the reading process introduces non-trivial latency effects.

The focus of our research is to gain the benefits of both methodologies: an excellent density of features obtained through imprint lithography or some other such process, and the ability to read data in parallel. Sub-wavelength surface-relief structures (binary and non-binary) are being investigated for this data storage application. These structures are amenable to low-cost manufacturing processes and facilitate near-field parallel readout with optical power detectors.

A variety of candidate structures have studied using the finite-difference time-domain (FDTD) method: simple relief patterns with low and high index refractive materials, high index materials with low index backfill, and low index materials with high index backfill. The high index profile with low index backfill appears to provide the best discrimination of the data readout vectors. The flexibility of the materials and geometries accessible to modeling with the FDTD approach has proved beneficial to testing these structures. Preliminary parameterizations have yielded storage densities of more than 5 bits per wavelength. A second objective of our studies has been to determine how varying nearby structures randomly (neighboring cells) affects each data vector, i.e., to determine the crosstalk between storage elements. For a given configuration *k* and associated data vector, varying the neighbors creates an ensemble of data vectors associated with that *k*. We then determine whether *every* element in the ensemble *k* will be distinguishable from every other element (in the sense that it is read as *k* or as some other value) in all other ensembles. If it is distinguishable, then this configuration can represent a valid memory state. The number of distinguishable configurations (states) determines our capacity, and hence our memory storage density.

The bulk of the progress made in the past year has revolved around parameterizing and optimizing structures, according to metrics such as the height of features, the gap between cells, and the material constants. The storage density of these structures has approached 10Gbits/cm^2. This result should be compared with the approximately 5Gbits that a CD-ROM now holds. Several of these metrics, the resulting storage density results, and anticipated improvements will be discussed.