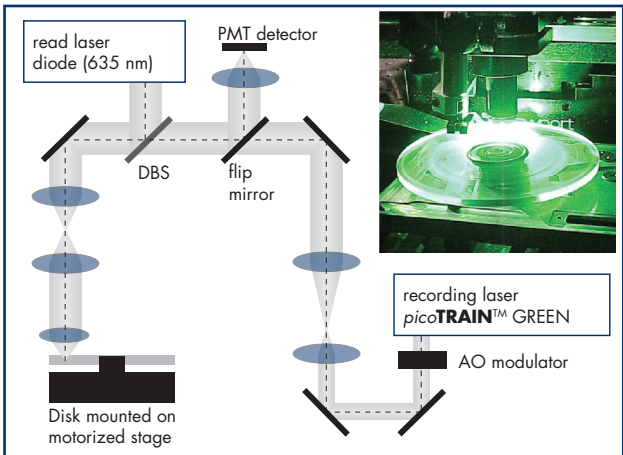
HIGH Q LASER®

# Application Note

## Two-photon writing of a three-dimensional 1 Tbyte DVD-size disk

Today`s optical data storage technologies, such as CD, DVD and Blu-ray, use one-photon absorption processes for writing and reading information. The devices are recorded by pulsing a laser diode to heat areas of a single organic dye layer. The induced heat permanently changes the optical properties of the dye, changing the reflectivity of those areas.
In contrast, the nonlinear two-photon absorption process can be used to store data within the volume of a disk, thus achieving three-dimensional storage by simply changing the focusing position of the writing beam within the medium. In this fashion it is possible to store hundreds of layers within the volume of a 1-mm thick DVD-type disk.
The high peak intensities needed for a dominant two-photon absorption process is provided by a picosecond laser at a wavelength of 532 nm. The high intensity in the laser spot locally changes the medium`s properties and thus write a data bit of information. To read this data, the recorded bits are illuminated with a red laser diode that induces fluorescence from the written bits.

## Experimental setup



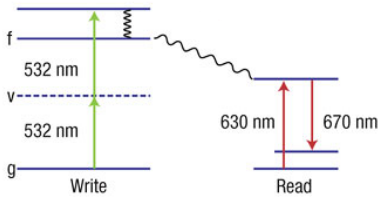

**Schematic diagram of the single-beam two-photon recording and one-photon readout system**

| | |
|---|---|
| Recording laser | *pico***TRAIN**™ GREEN, picosecond oscillator |
| Wavelength | λ = 532 nm |
| Pulse duration | τ = 6.5 ps |

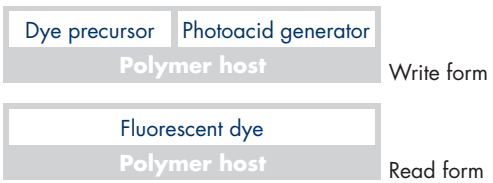
An automated computer program defines the tracking/layer addressing, objective lens movements and motor speed control. The desired data pattern is recorded by controlling an acoustooptic modulator. For reading, the fluorescence, ecxited by a red laser diode, is picked up by the same objective as used for writing and focused onto a detector (photomultiplier tube PMT).

## Theory

### Energy band diagram




### Material composition




**3D Recording**

**Write**
Three-dimensional recording is possible by a non-linear two-photon absorption process. Since two-photon absorption, compared to linear absorption, is an intensity depended mechanism it only occurs in the focal spot of the laser beam. The unwritten form of the material is composed of a colorless dye precursor and PAG molecules uniformly dispersed in a transparent polymer matrix. Two-photon excitation generates colored spots inside the volume where the laser beam was focused.

**Read**
The recorded bits are read by fluorescence that is emitted when they are excited by a 635 nm red laser diode in a single-photon absorption process within the written spot volume. The written bits are thermally stable and the information may be stored for years without noticeable decay.

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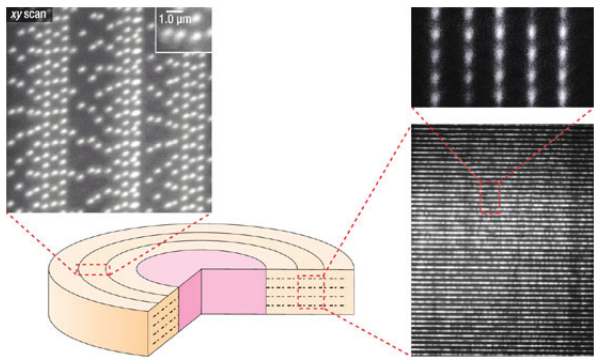
## Layers recorded in a 3D disk




Images on the left show a number of layers stored in a two-photon WORM memory, a 120 mm diameter, 1.5 mm thick disk with parallel surfaces polished to optical quality.

Experimental data show that the stored bits can be read over $10^6$ times and that the write and read forms are thermally stable.

Layer spacing: ~ 4 µm
Bit volume: 0.5 x 0.5 x 2 $\mu m^3$

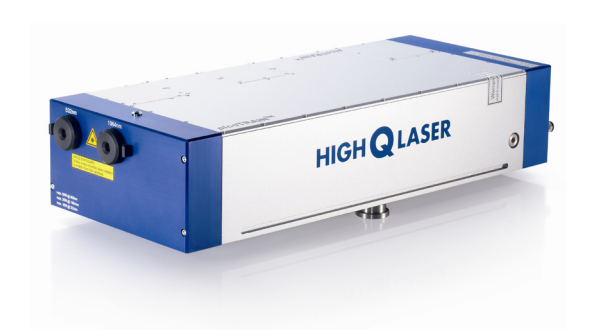
Laser pulse energy: 50 nJ / bit

## 3D disk - 1 Tbyte stored data

On the left, a thick clear, unwritten disk is shown. The blue disk on the right is fully recorded (1 Tbyte) using 7 nJ per bit and a recording rate of 25 Mbit $s^{-1}$.
It is expected that shortly the data capacity will be increased to 100 Mbit $s^{-1}$.

The readout signals were found to have a signal-to-noise ration of 32 dB. The disk contains 200 layers, with each layer having the capacity of a 5-Gbyte DVD.

## Laser used




### *pico***TRAIN**™ GREEN

The *pico***TRAIN**™ GREEN offers light pulses with a duration of 6.5 ps at an average power of up to 4 W @ 532 nm and a repetition rate of 80 MHz in the basic configuration. The *pico***TRAIN**™ platform is based on High Q Lasers Industrial Compatible housings and features a very compact design and small footprint. The housing is machined from a massive piece of aluminium and is forming a heavy Monolithic Aluminium case leading to low vibration coupling.

## Acknowledgements

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Dr. Peter Rentzepis
University of California

Ed Walker
Call/Recall

References
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J. Phys. Chem. A, Vol. 113 (49), pp. 13633–13644 (2009).