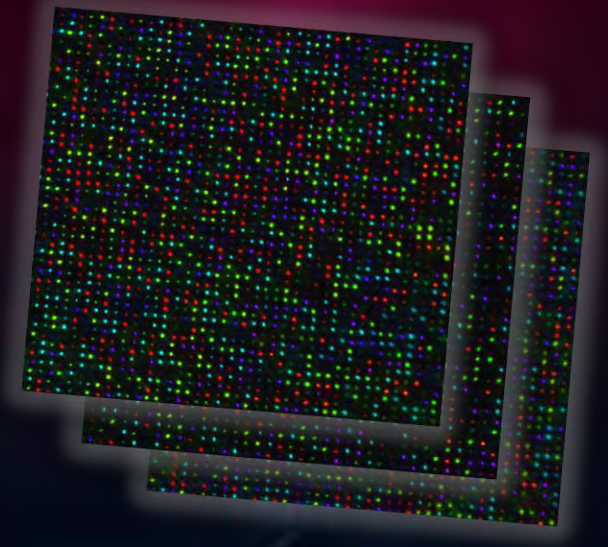
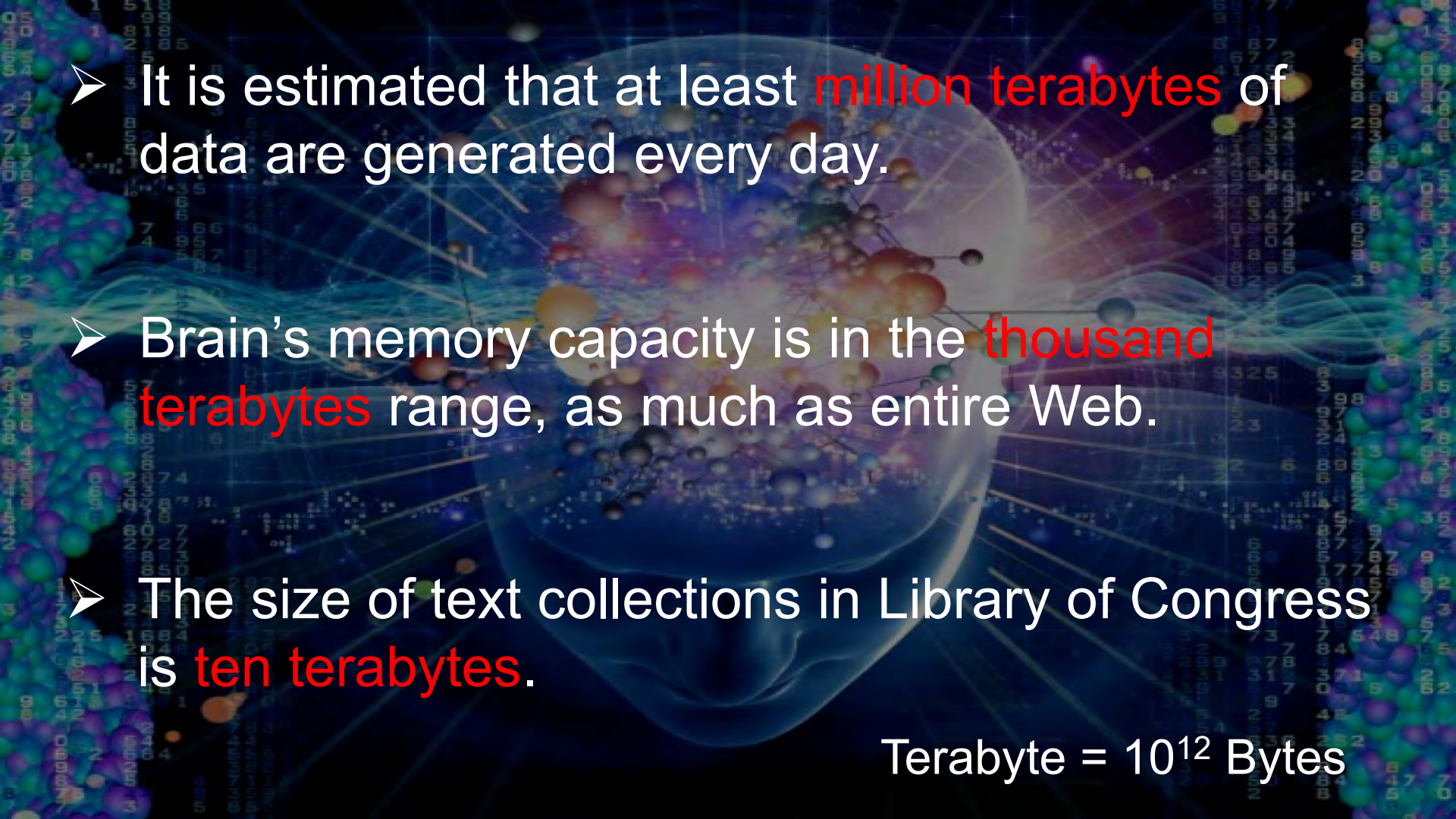
Eternal 5D data storage in glass



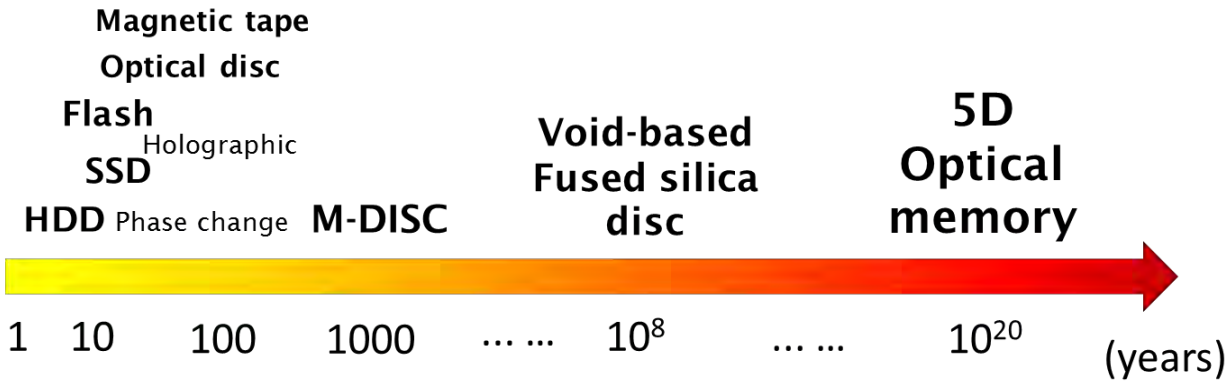
Peter G. Kazansky

Optoelectronics Research Centre, University of Southampton


It is estimated that at least million terabytes of data are generated every day.
Brain's memory capacity is in the thousand terabytes range, as much as entire Web.
The size of text collections in Library of Congress is ten terabytes.
Terabyte = 10^{12} Bytes

Long-term data preservation

- Nature's choice: DNA (1M years @ -18 ^{o}C)
- Current archiving technology: Magnetic tape (20 years)
- Optical based technologies: CD or DVD (10 years)
  M-Disc (1000 years)
  Quartz glass (100M years)

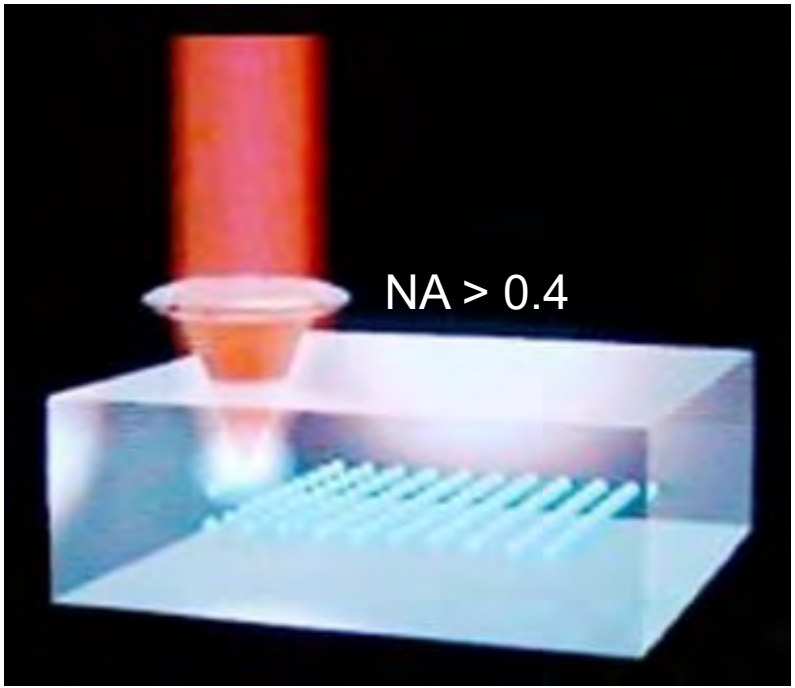


Optical data storage benefits

Courtesy: **Optical Media Roadmap**
"The revival of Optical Storage"
Ken Wood
Hitachi Data Systems

Femtosecond laser direct writing: The principle

- Tight focusing of laser beam (e.g. λ =800 nm, $\Delta\tau$ =100 fs) into transparent material
- High intensity leading to multi-photon absorption
- Structural changes in matter confined to focal volume due to short pulse duration – 3D

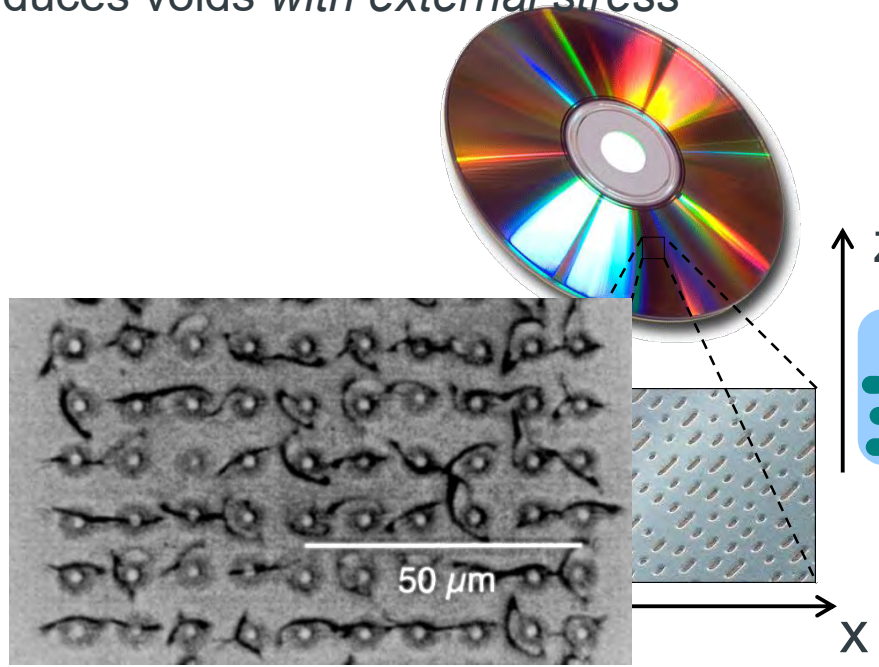


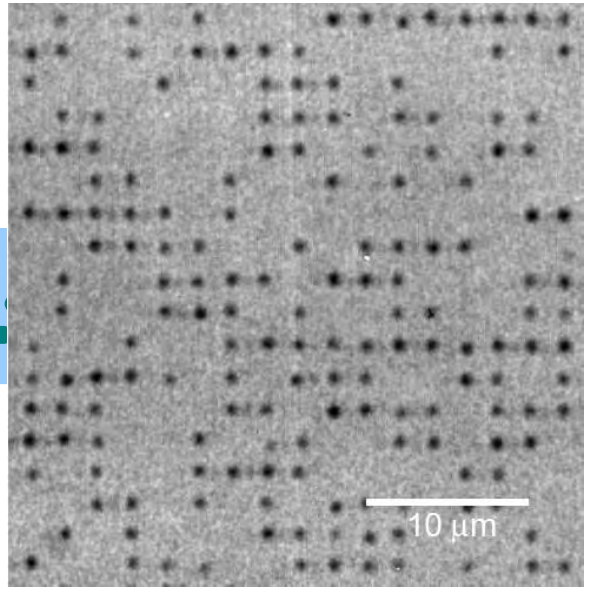
Intensity ~ 5×10^{13} W/cm^2
Electron temperature ~ 10^5 K /10 eV
Pressure ~ 10^6 bar

3D optical storage by femtosecond laser writing

Picosecond (10×10^{-12} s) laser induces voids *with external stress*

Femtosecond (100×10^{-15} s) laser induced *small* voids in quartz glass

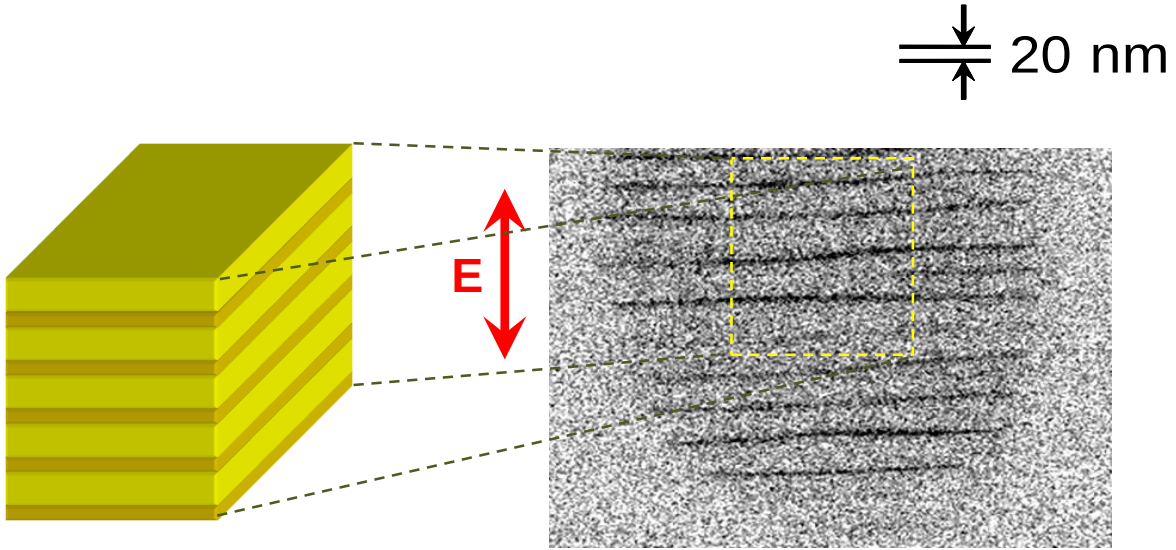




Glezer et al., *Optics Letters* (1996)

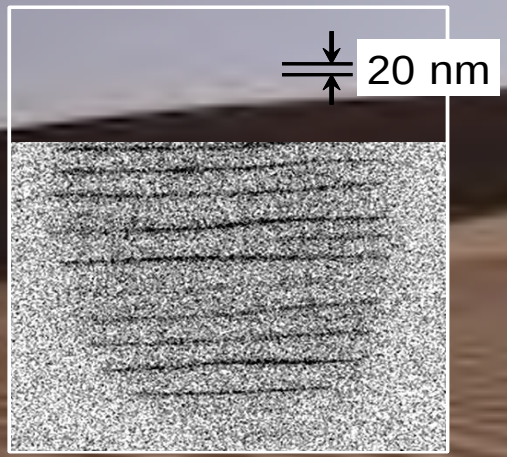
Femtosecond lasers perform vision-correction surgery

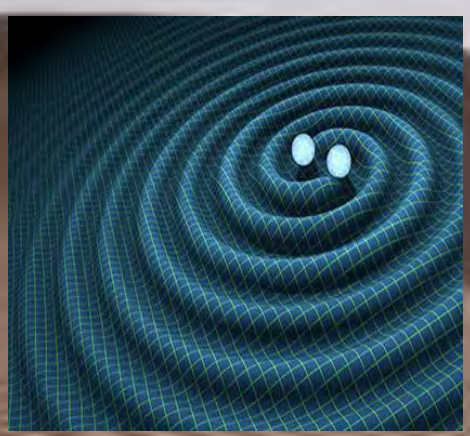
Ultrafast-laser nanostructured (ULN) quartz glass: The finest bulk ripple ever produced by light



P.G. Kazansky et al., *Phys. Rev. Lett.,* **82**, 2199 (1999)
Y. Shimotsuma et al., *Phys. Rev. Lett.* **91,** 247405 (2003)

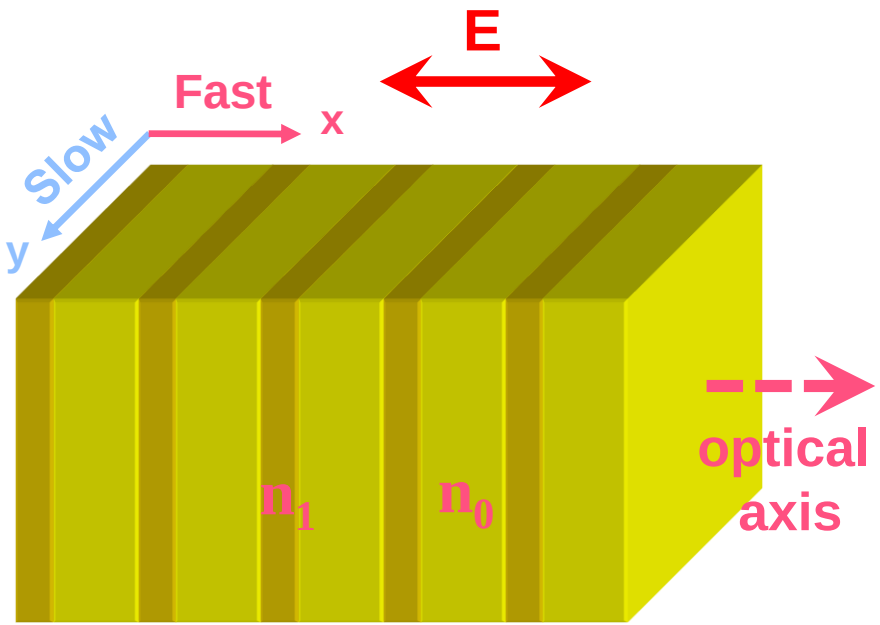
Ripples on Earth and in space





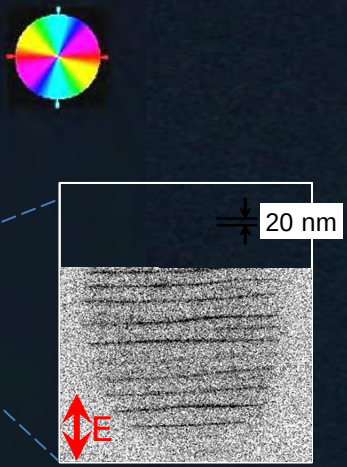
Self-organized form birefringence

Femtosecond laser nanostructured quartz glass: $n_e - n_o = -5 \times 10^{-3}$



Quartz crystal: $n_e - n_o = 9 \times 10^{-3}$

Light logo imprinted by femtosecond laser self-assembled nanostuctures in glass

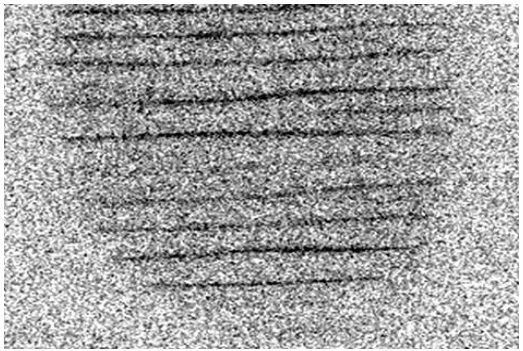


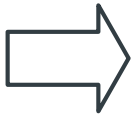
4th and 5th dimensions: Retardance and slow axis angle

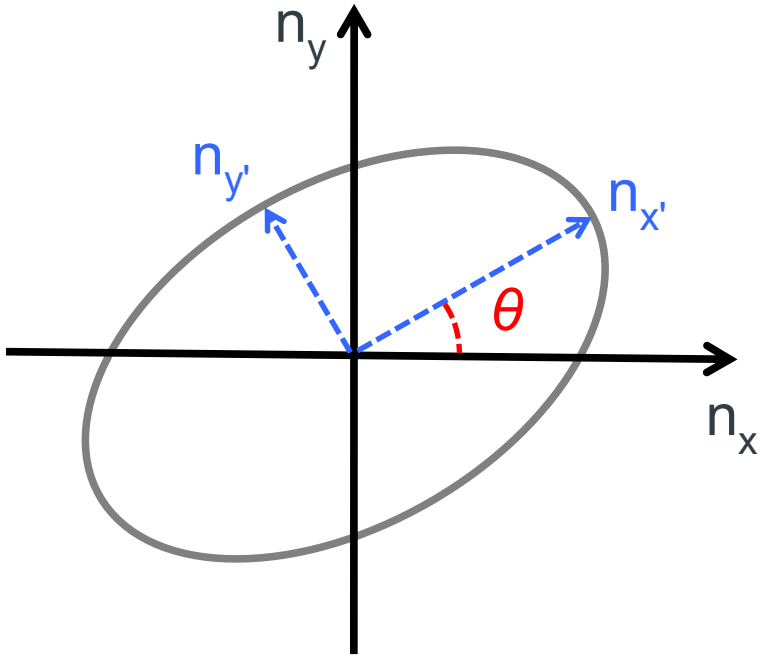
Nanogratings produce birefringence characterized by two parameters:

(4thD) Retardance $R = |n_{x'}-n_{y'}|\times d$

(5thD) Slow axis angle θ







How it works?

- ✓ Position: 3 spatial dimensions
- ✓ Retardance = f(*Intensity, Number of pulses*)
- ✓ Slow axis = f(*Polarization*)

1 Byte (8 bits) per spot:

32 states (5 bits) of slow axis orientation
8 states (3 bits) of retardance

Comparison

	CD	DVD	Blue-ray	5D
Capacity	0.7 GB	4.7 GB	23.5GB	360TB per disc
Longevity	5 years	7 years	7 years	10^20 years
Speed	1.2 Mbit/s (1x)	10.5 Mbit/s (1x)	36 Mbit/s (1x)	20 Mbit/s

Current writing speed: 12 Kbits/s

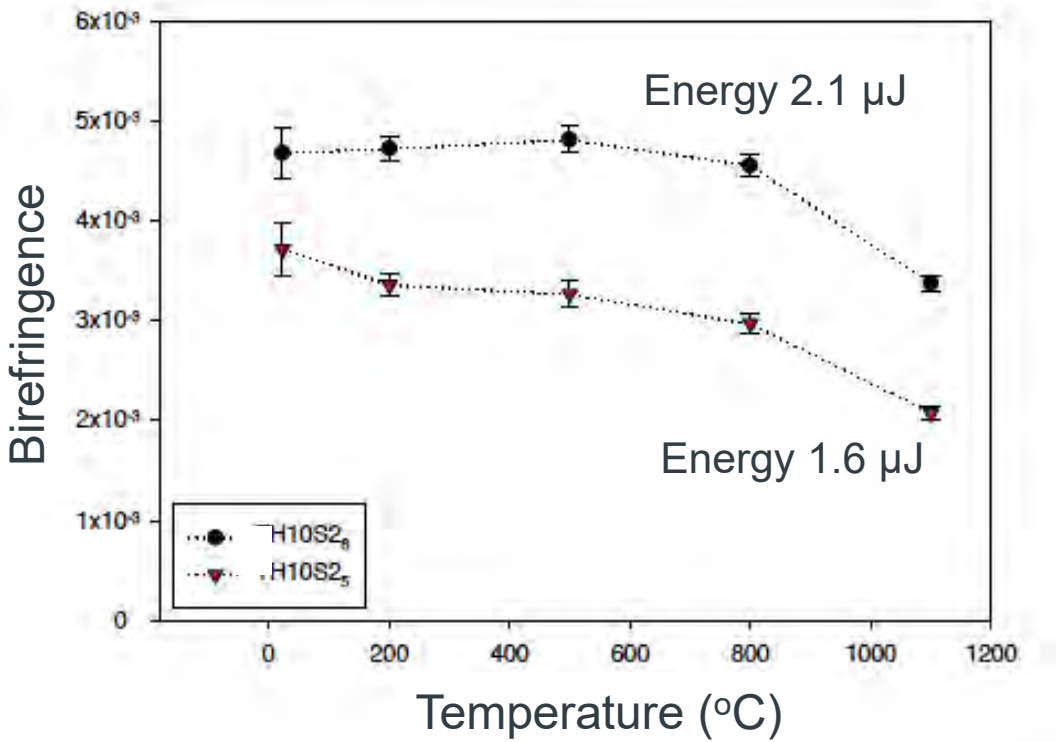
Current capacity: 100 GB/disc

5 bits per dot

Advantages of 5D in quartz glass: High capacity

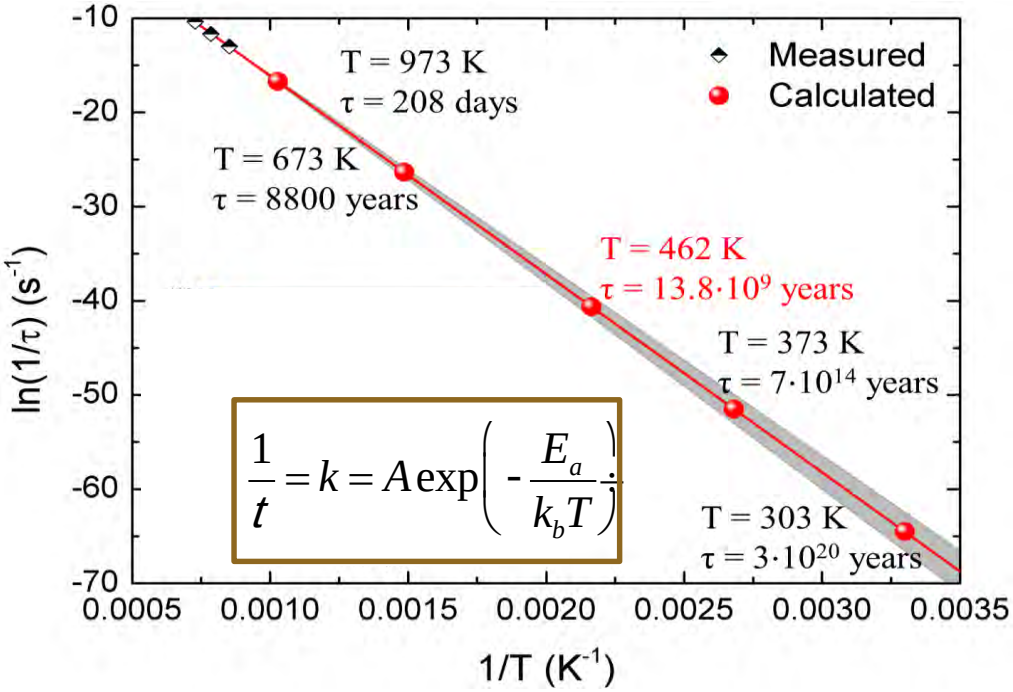
Long life time

Thermal stability



Bricchi and Kazansky, *Appl. Phys. Lett.* (2006)

Thermal stability



$$R(t) = R_0 \times e^{-t/\tau}$$

T = 900° -> τ = 121 h

T = 1000° -> τ = 32 h

T = 1100° -> τ = 9 h

Using the Arrhenius law,
the lifetime can be extrapolated
to the room temperature

T = 30° -> $\tau = 300 \times 10^{18}$ years

Two images in one day

The Telegraph

HOME NEWS WORLD SPORT FINANCE COMMENT BLOGS CULTURE TRAVEL LIFE FAS

Technology News | Technology Companies | Technology Reviews | Video Games | Technolog

HOME » TECHNOLOGY » TECHNOLOGY NEWS

Superman's memory crystals may become reality in computers

Computers may soon be saving their data onto hard drives made of glass following research by British scientists who have developed a way of storing information similar to the "memory crystals" seen in the Superman films.

The glass memory has been compared to the 'memory crystals' used in the Superman films

Print this article

Share 2K

Facebook 1K

Twitter 311

Email

LinkedIn 0

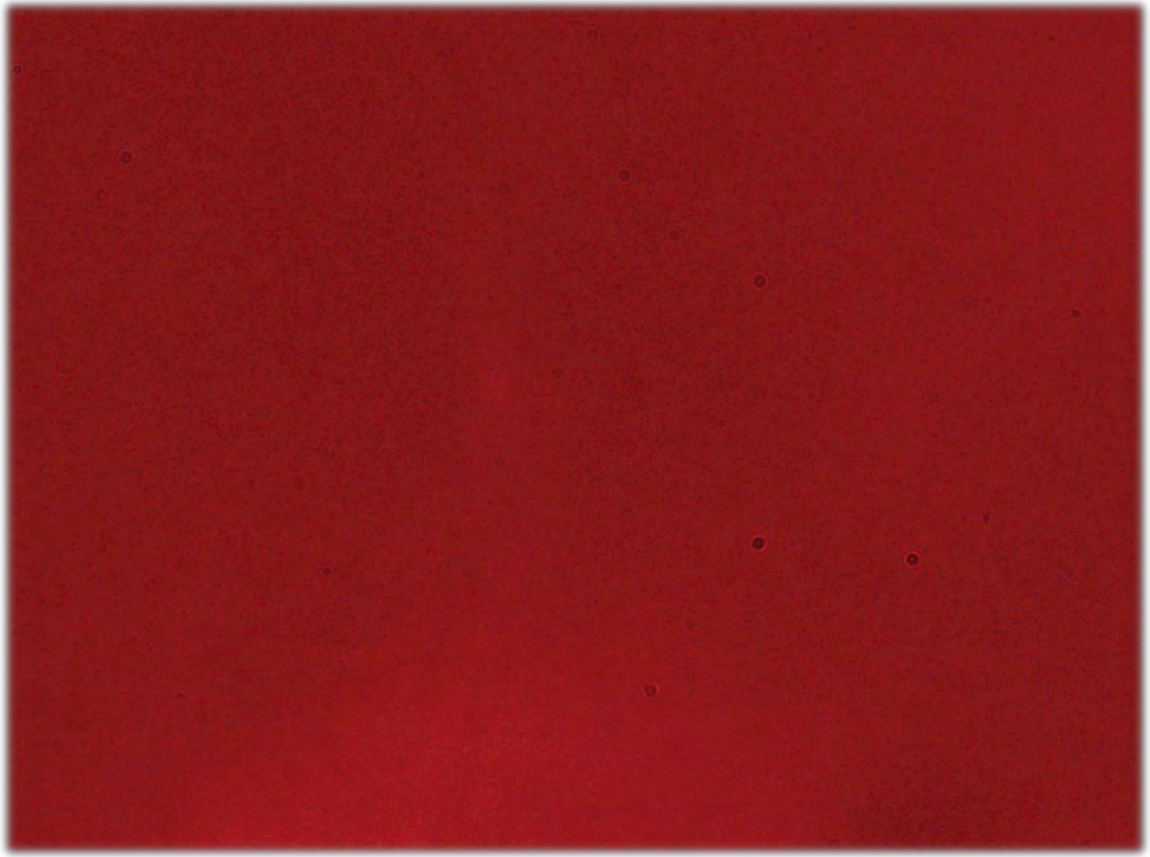
+1 0

Technology News

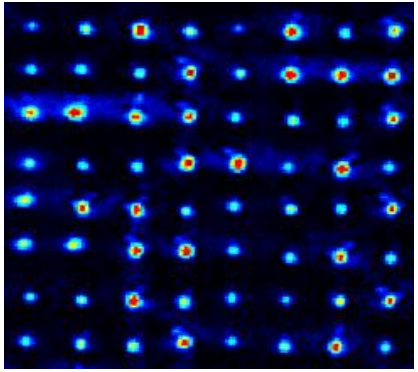
News » UK News »
Science »
Science News »
Technology »

of slow axis

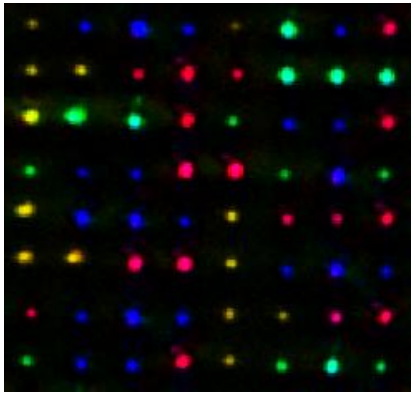
Data writing



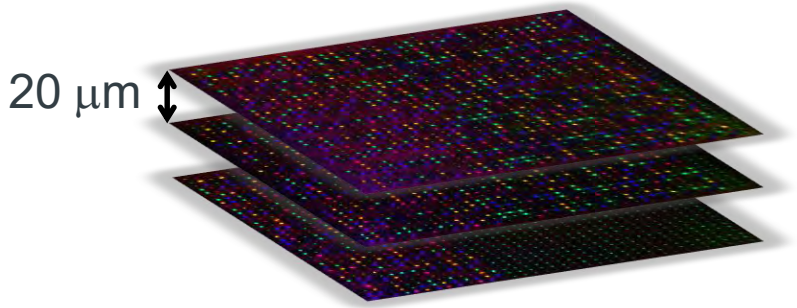
Retardance

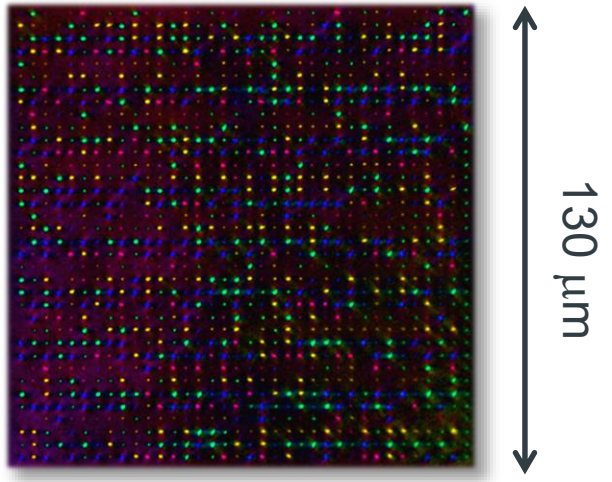


Slow axis orientation



Readout



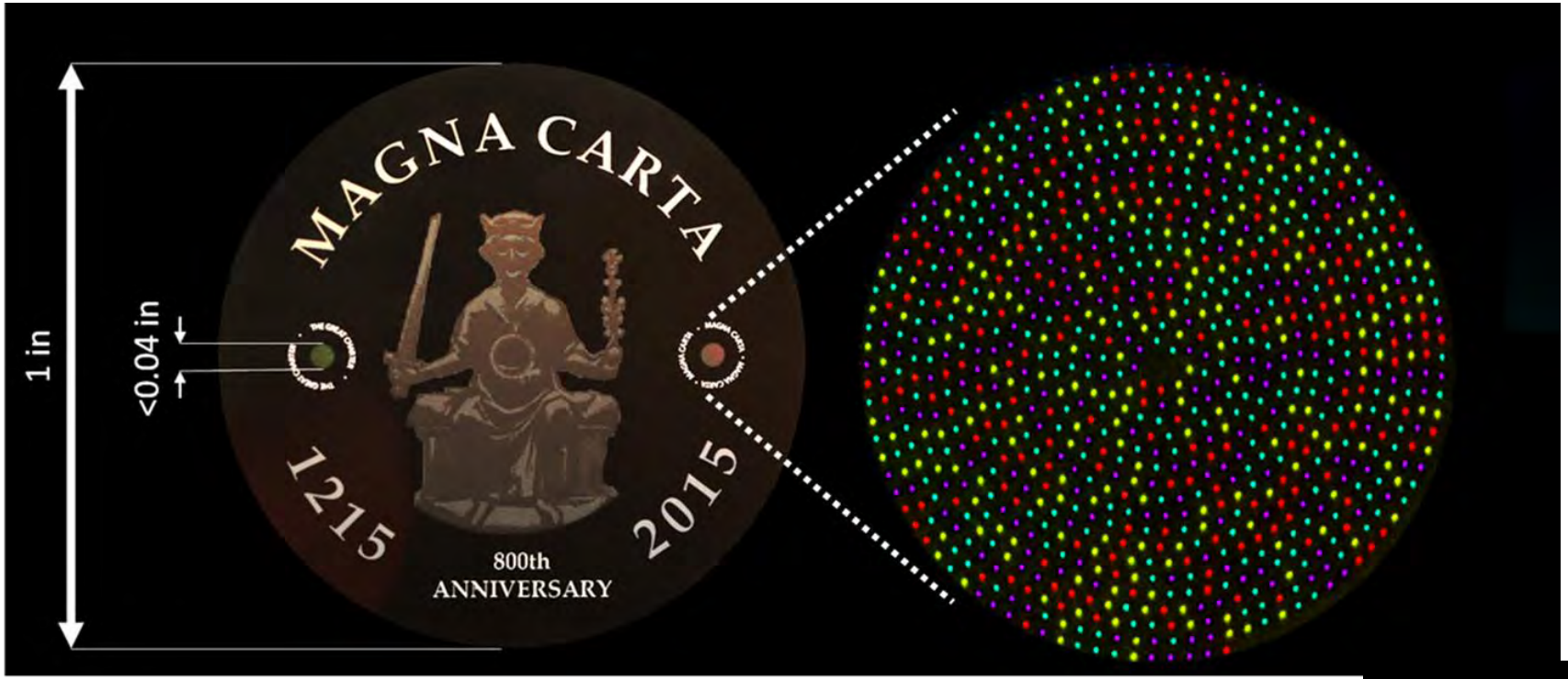


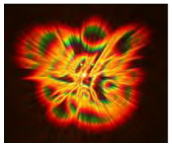
Data retrieved

The idea of the optical memory based on femtosecond laser writing in the bulk of transparent material was first proposed in 1996 [1]. More recently ultrafast laser writing of self-assembled nanogratings in class **s**a**3** proposed for the polarization m**5**ltiplex**E**d optical memory, where the information encoding would be realized by means of two birefringenc**m** parameters, i.e. the sl**g**w axis orientation (4th dimension) and s**42**ength of retardance (5th dimension), **)f** addition to three spatial coordinates [2,**³**]. The slow axi**{** orientation **á**nd the retardance can be controlled by polarization and intensity of the`inciden**ô** beam respectively [4]. The unprecedented parameters including 360 TB/disc data capacity, thermal stabilit **5**p to 1000˚ C and practically unlimited lifetime [5]. However the implementation of digi**4**al d**!4**a storage, whi**b**h is a cruc**a**al step t**k**wards the real world applications, has not **"**een demonst**2**ated by ultraf**!**st laser **s**riting. Here we success**n**ully recorded and`retriev**g**d a`di**o**i**u**al copy**•** f the text **æ**ile in 5D using polarization controlled se**m**f-assembled`ultrafa**ó**t laser nano**{p**ructuring in silica glass.

42 bits errors
out of 11664 bits
(1458 bytes):
Error rate 0.36%

Magna Carta coded in 5D





Courtesy: Ausra Cerkauskaite and Rokas Drevinskas

United Nations Educational, Scientific and Cultural Organization

INTERNATIONAL YEAR OF LIGHT 2015

UNIVERSITY OF Southampton

TO COMMEMORATE THE FIRST EDITION OF NEWTON'S *OPTICKS*

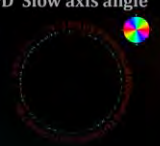
5D OPTICAL MEMORY

Coded text

18 layers
Ø 1.4mm
in Ø25.4mm
fused silica
glass
$\Delta z = 15\mu m$
$200GB/cm^3$

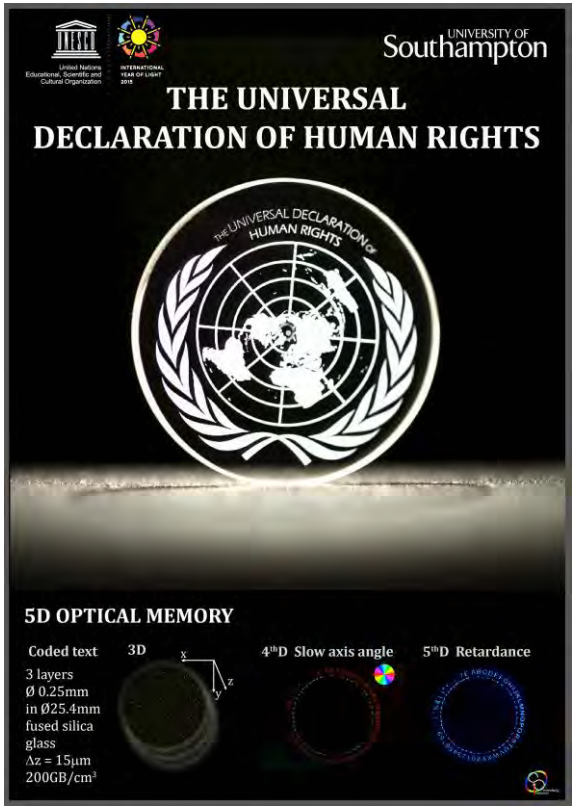
3D

4thD Slow axis angle



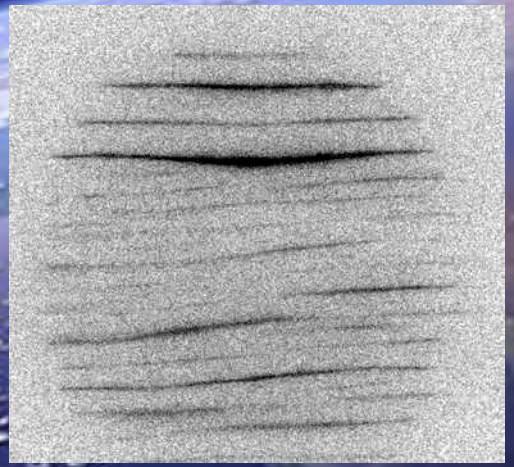
5thD Retardance

The eternal copy of UDHR presented to UNESCO at the Year of Light closing ceremony in Mexico



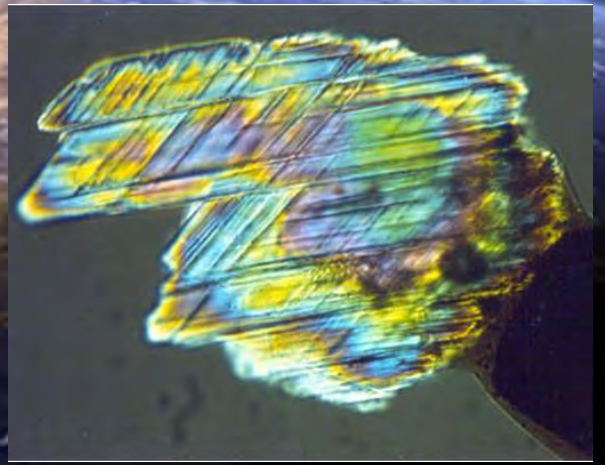
Asteroid of 10 km in diameter collided with Earth 65 million years ago causing mass extinction

Ultrafast-laser nanostructured (ULN) fused quartz



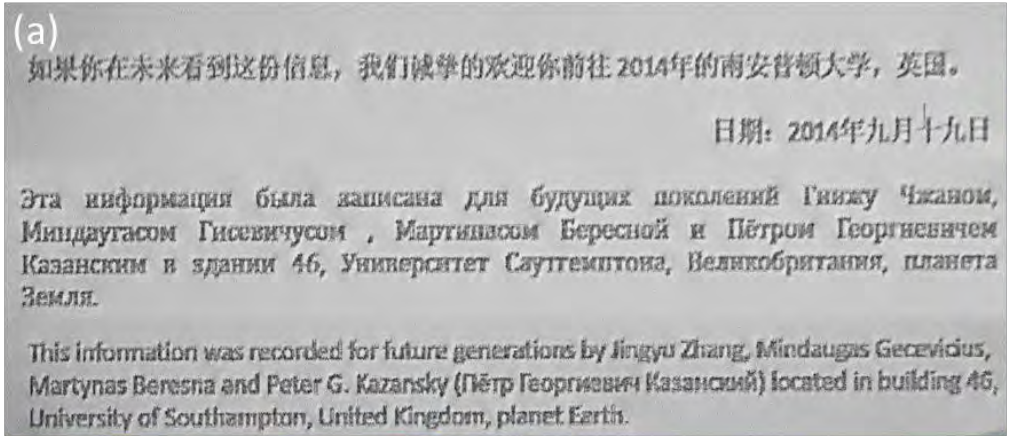
Chicxulub

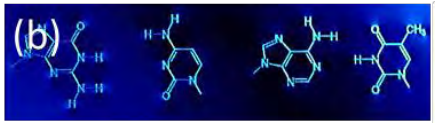
Shocked quartz at impact site

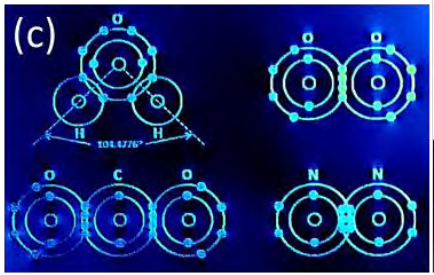


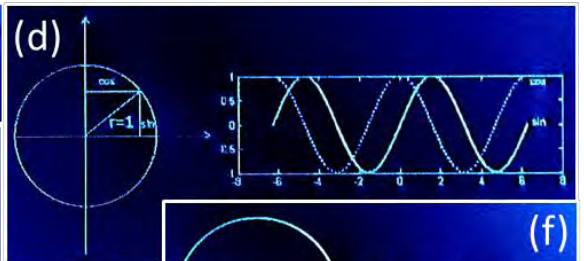
Coincidently, the lamella structures of ULN fused quartz and shocked quartz are similar

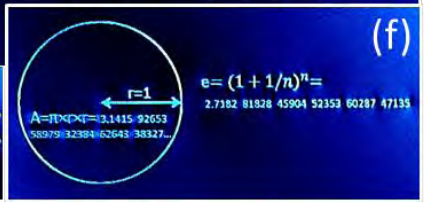
Southampton time capsule in quartz glass

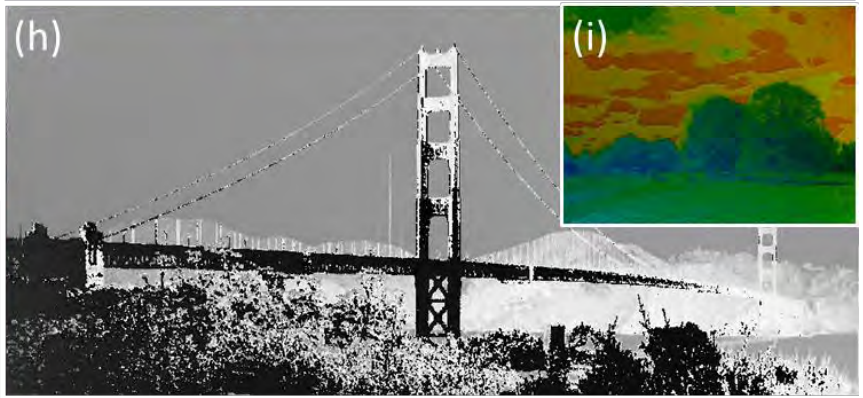




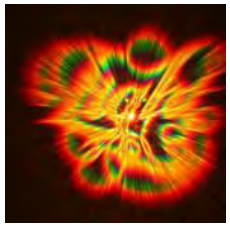


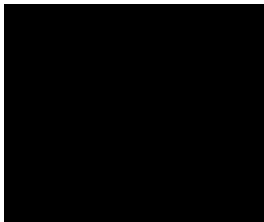






Geometrical phase hologram in glass

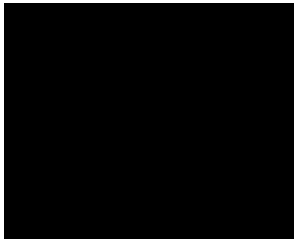




Conclusions

- Optical data storage with practically unlimited lifetime in ultrafast laser nanostructured quartz glass is demonstrated.

- For the first time, storage technology might allow human knowledge to outlive us.

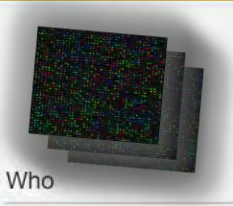


OFFICIALLY AMAZING™

EXPLORE RECORDS | SET A RECORD

Most durable digital storage medium

It has been hailed as a particular significant invention as no other storage medium can so safely ensure that data will be accessible by future generations.



Share

Who

JINGYU ZHANG, MARTYNAS BERESNA, PETER G KAZANSKY, MINDAUGAS GECEVICIUS

What

300 QUINTILLION YEAR(S)

Where

UNITED KINGDOM
SOUTHAMPTON

When

23 JANUARY 2014