5D optical digital preservation in glass

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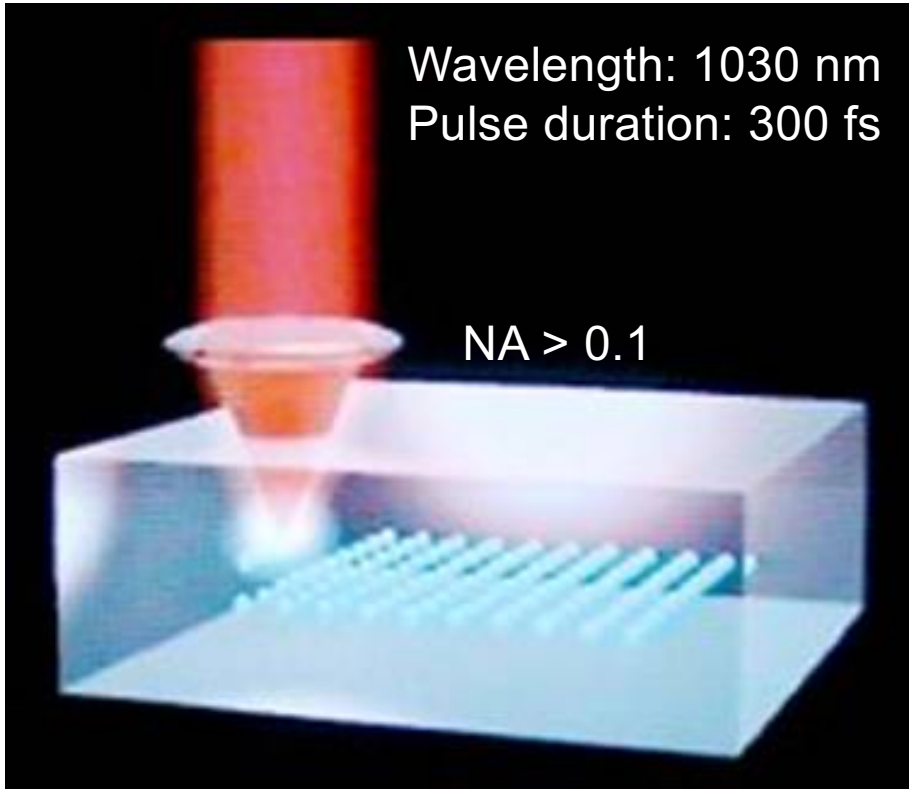
Serendipity Photonics

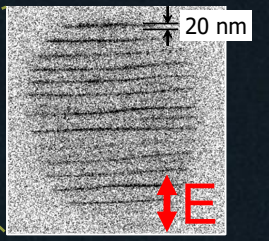
Femtosecond laser direct writing: The principle

- Tight focusing of laser beam into transparent material
- High intensity leading to nonlinear 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

Ultrafast laser writing with self-assembled nanostuctures in glass

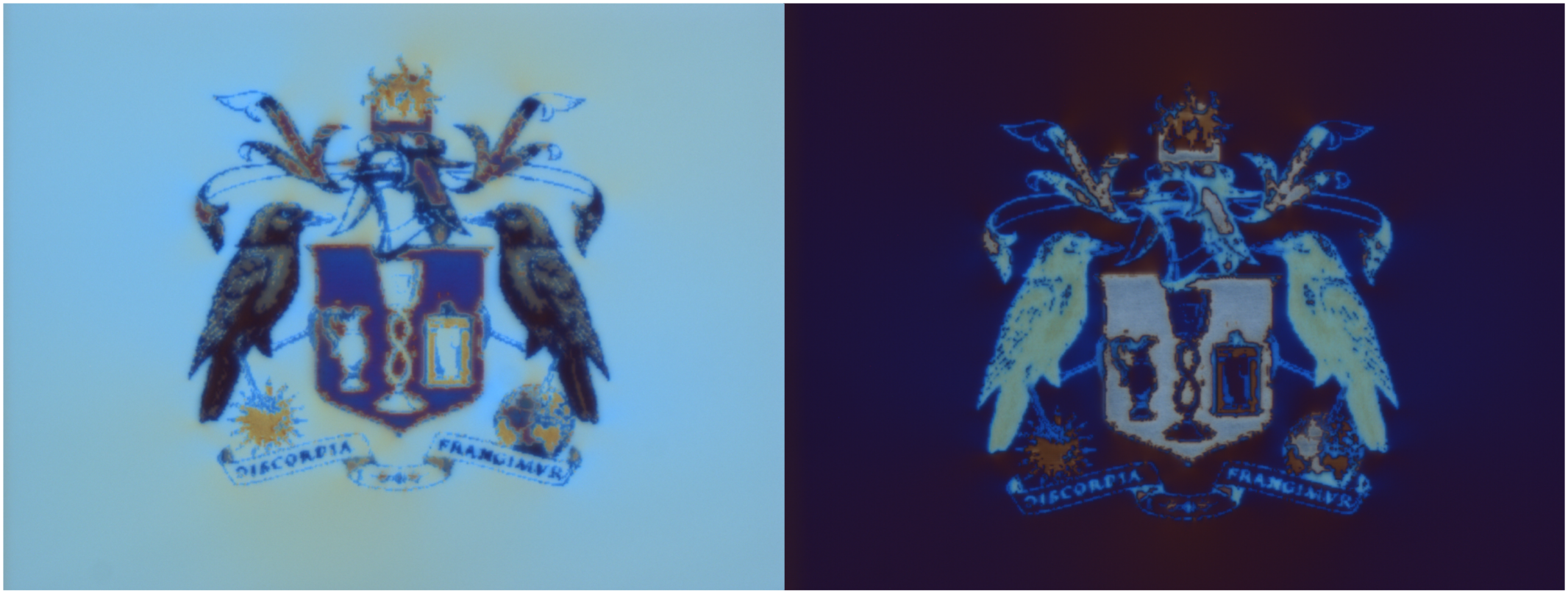


of Extraordinary

The Laboratory

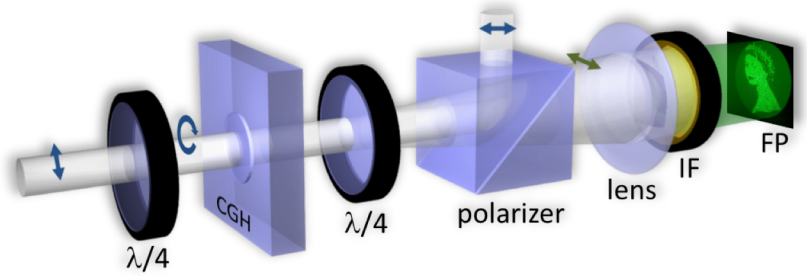
Optical Phenomena

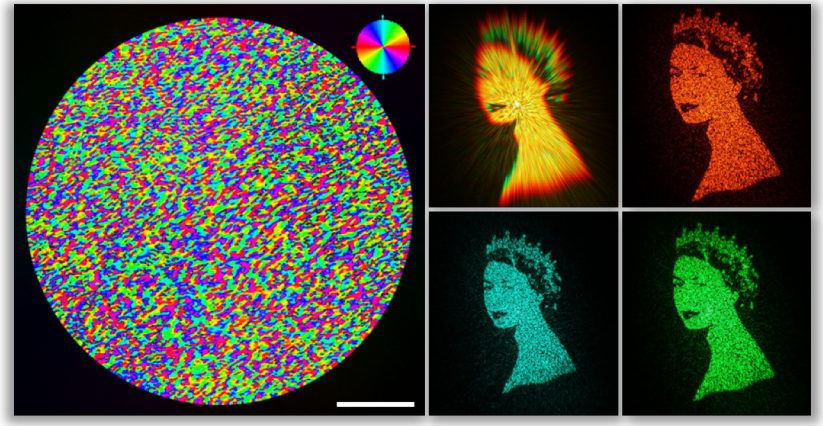
Ravens in Glass Day and Night



Worshipful Glass Sellers of London

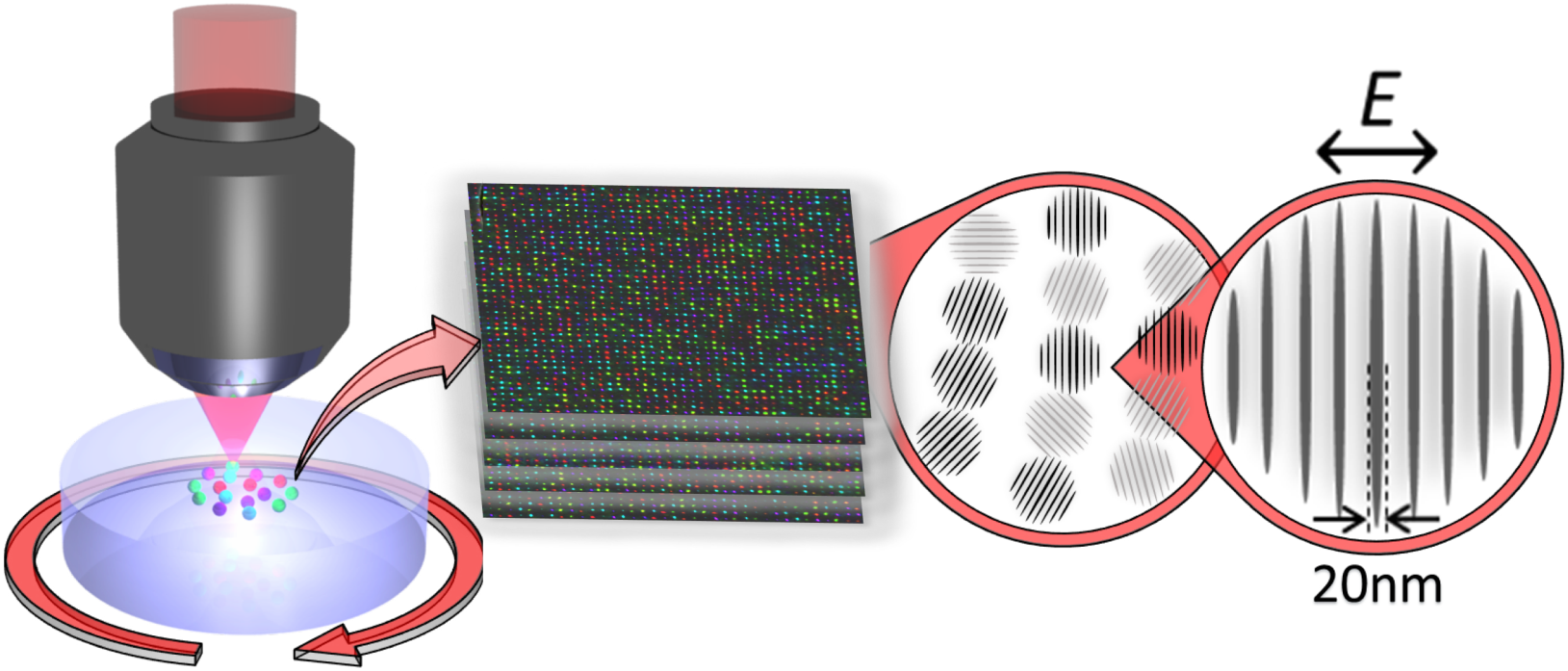
Computer generated holograms in silica glass



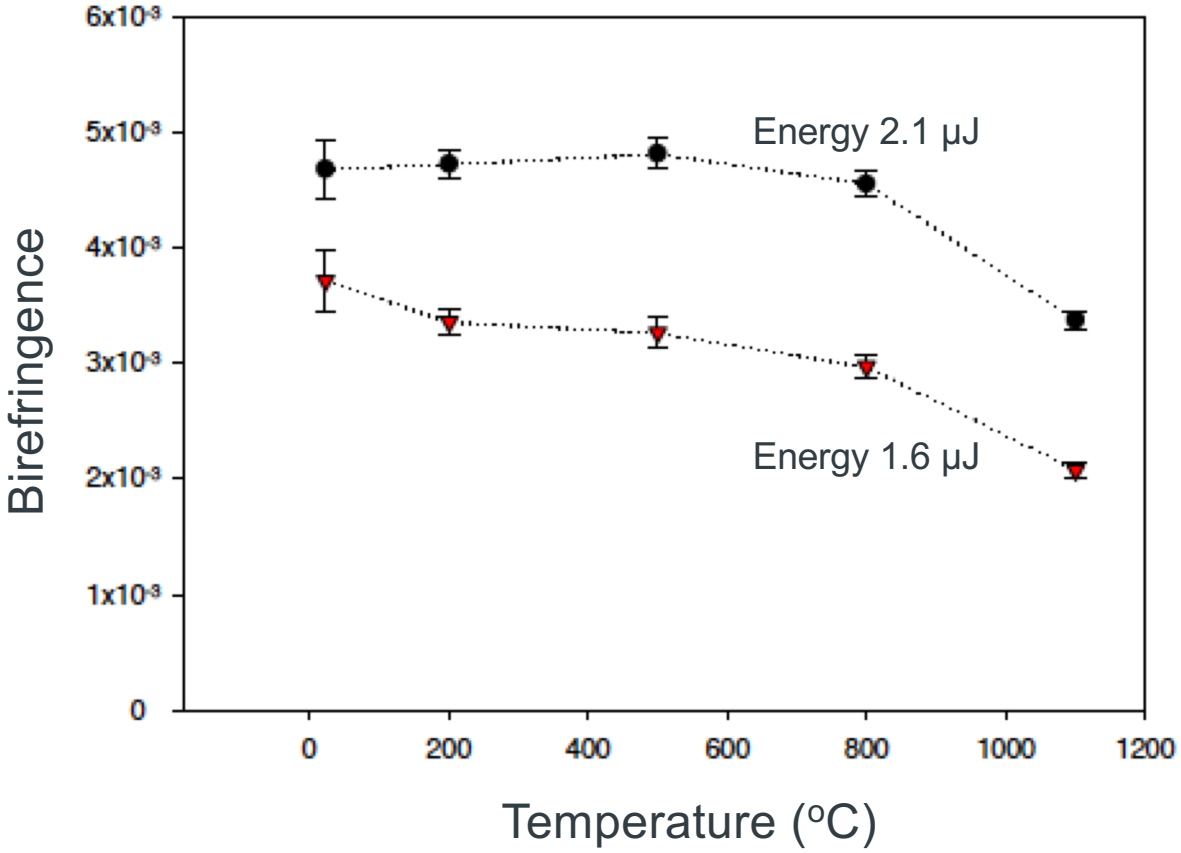


- ✓ ***Continuous phase profiles***
- ✓ ***8-bit CGH***
- ✓ ***Phase gradient up to π rad/μm***

5D data storage
by ultrafast laser nanostructuring in glass



Thermal stability



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


GUINNESS WORLD RECORDS
CERTIFICATE
The most durable digital storage medium
is stable at room temperature for
300 quintillion years,
a material created by researchers from
the University of Southampton's
Optoelectronics Research Centre,
as published on
23 January 2014
OFFICIALLY AMAZING

National Museum of Brasil
Fire 2 September 2018

The principle of 5D writing

- ✓ Position: **3 spatial dimensions**
- ✓ Retardance = f(*Intensity, Number of pulses*): **4th D**
- ✓ Slow axis angle = f(*Polarization*): **5th D**
- ✓ Ultimate resolutions of slow axis angle ~2° and retardance ~2 nm.

1 Byte (8 bits) per spot:

64 states (6 bits) of slow axis orientation
4 states (2 bits) of retardance

Comparison

	CD	DVD	Blue-ray	5D
Capacity	0.7 GB	4.7 GB	23.5GB	360TB per disc
Last Long	5 years	7 years	7 years	10^20 years
Speed	150 kB/s (1x)	1.3 MB/s (1x)	4.5 MB/s (1x)	100 MB/s

Current writing speed: **30 KB/s**

Current capacity: **11 GB per layer**

200 layers

2 TB/disc

Order of magnitude improvement

Advantages of 5D in silica glass: High capacity

Long lifetime

Worldcon 76


MOON to MARS and BEYOND
Iconic Images of
Contemporary Space Exploration

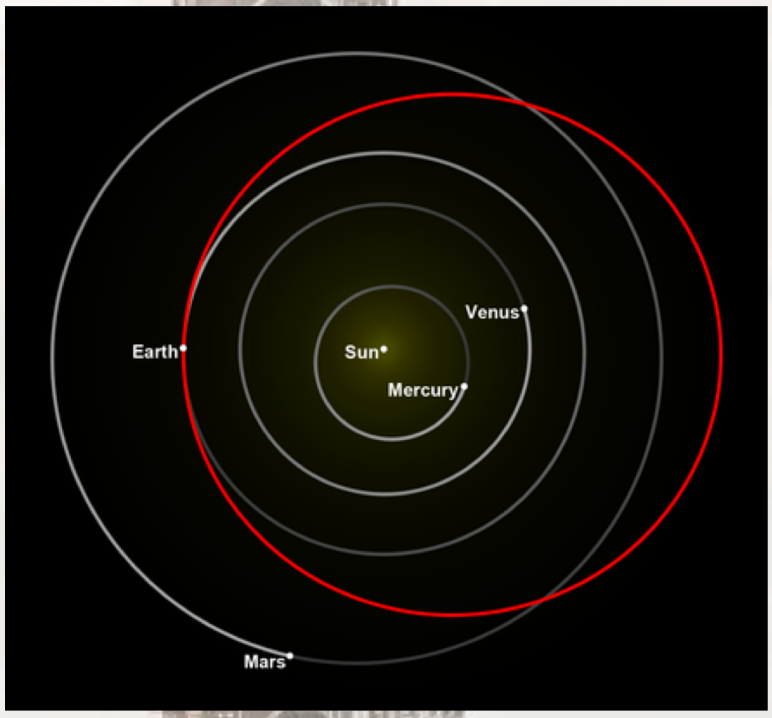

Moon
Mars
and
Beyond

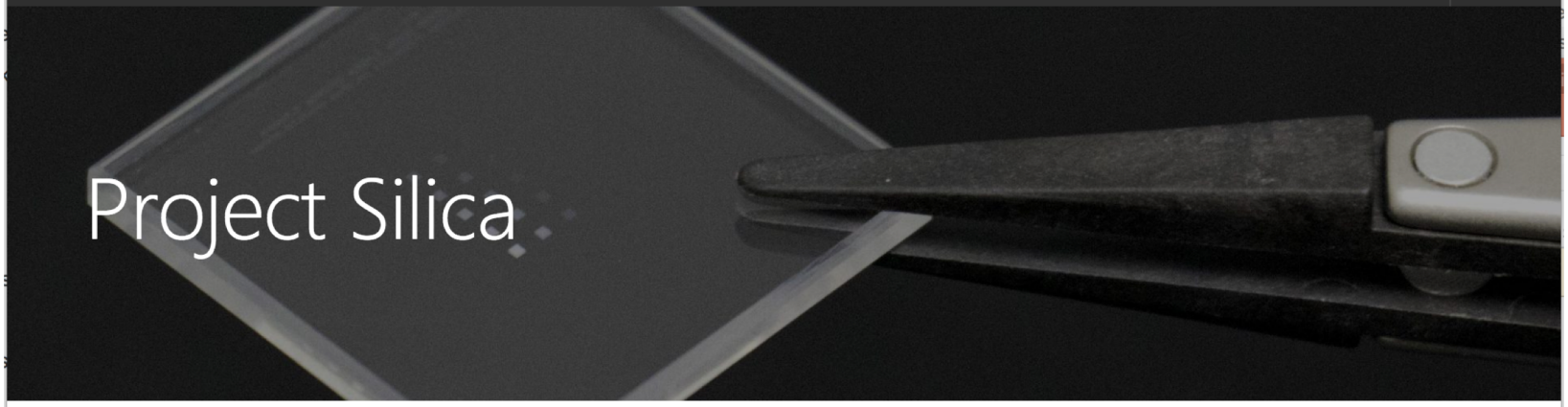
Eternal copies of Hawking's Brief History of Time and UDHR exhibited at "The Future Starts Here" in Victoria and Albert Museum in London

Eternal copies of Isaac Asimov's "Foundation"

The first human document which will orbit the sun for millions of years

Space X Falcon Heavy Demo Flight: 6th February 2018





Project Silica

The demand for long-term data storage is reaching unprecedented levels. By 2020, it's expected that zettabytes of data will be stored in the cloud. Operating at such scales requires a fundamental re-thinking of how we build large-scale storage systems, as well as the underlying storage technologies that underpin them.

Project Silica is developing the first-ever storage technology designed and built from the ground up for the cloud. We are leveraging recent discoveries in ultrafast laser optics to store data in quartz glass by using femtosecond lasers, and building a completely new storage system designed from scratch around this technology. This opens up an incredibly exciting opportunity to challenge and completely re-think traditional storage system design, and to co-design the future hardware and software infrastructure for the cloud.

This project is a collaboration with the University of Southampton Optoelectonics Research Centre, and was featured in a Microsoft Ignite 2017 keynote on future storage technologies.

Conclusions

- Digital preservation with practically unlimited lifetime is possible by ultrafast laser nanostructuring in glass.

- Research towards increase of write and read speed is in progress: Improvement of an order of magnitude is achieved.