Microsoft

Project Silica

2026 Library of Congress *Designing Storage Architectures for Digital Collections*

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Project Silica Research Director

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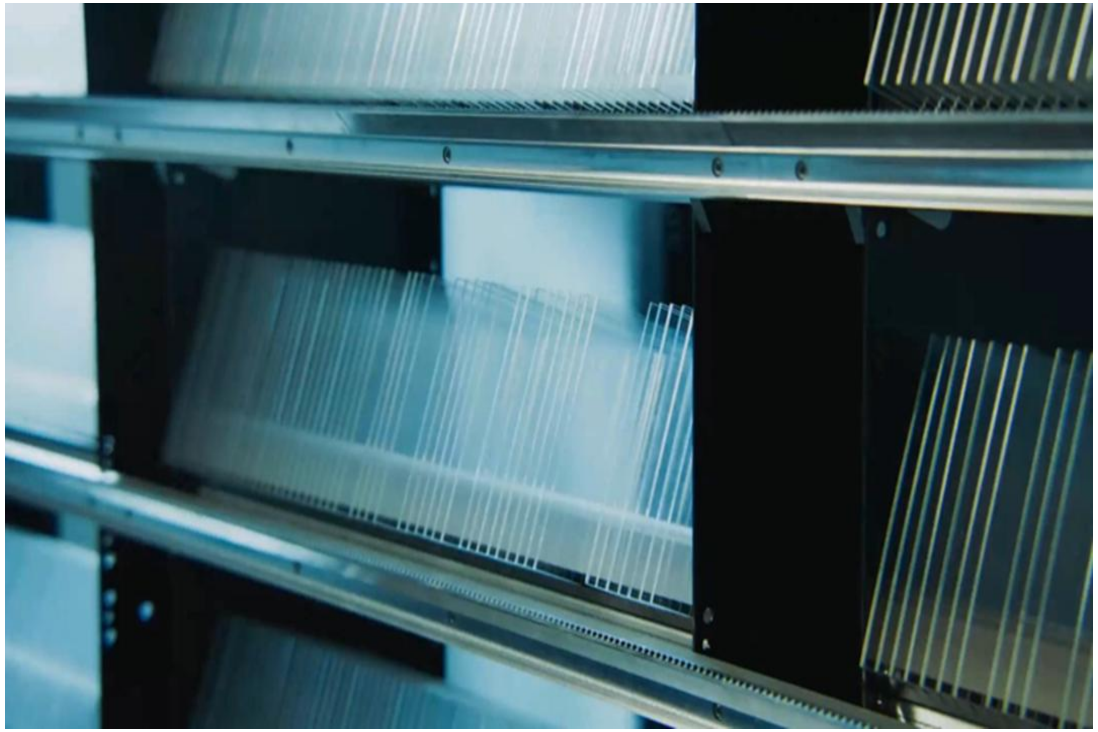
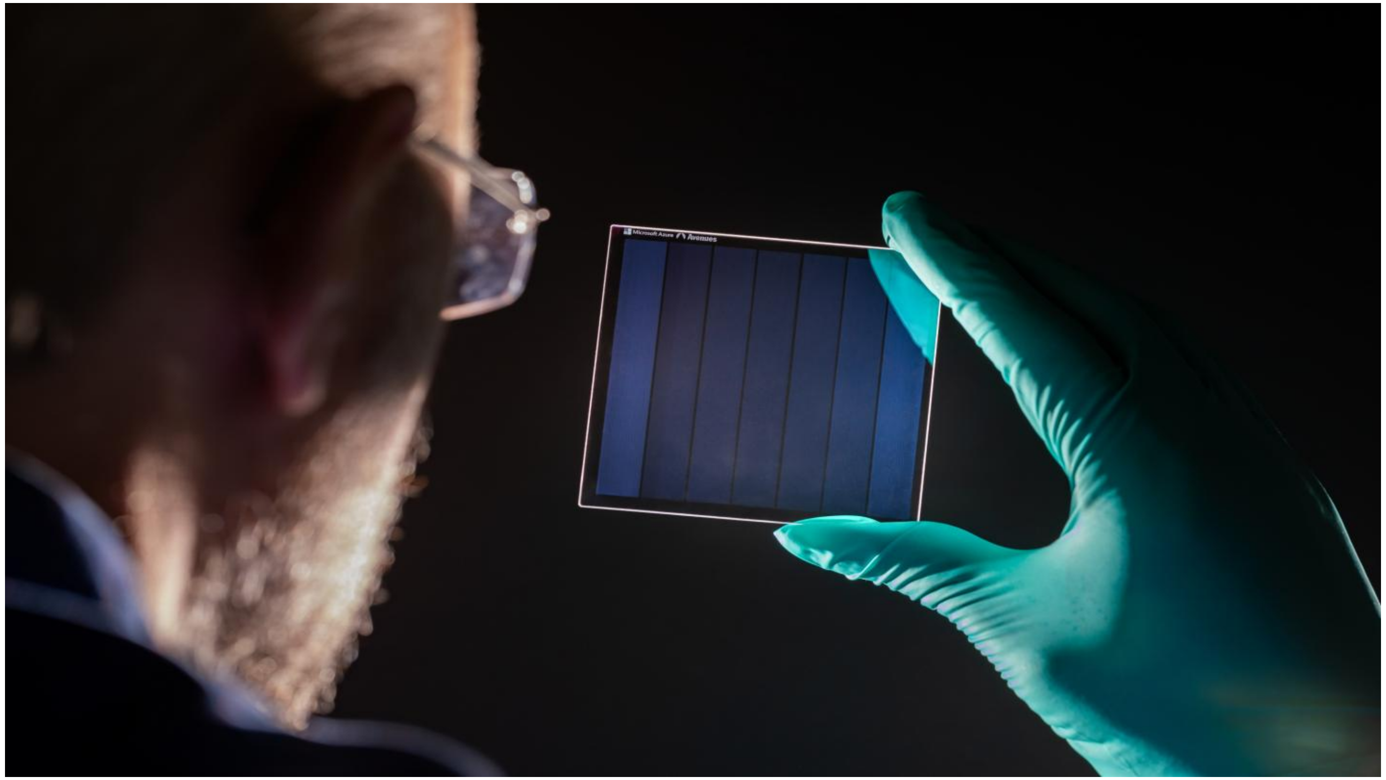
Project Silica

- Research project 2017 to 2025
- Digital archival storage in glass
  - Long term archive
  - Scientific archive
  - Preservation archive
- Last presented here in 2023
- Research phase is complete



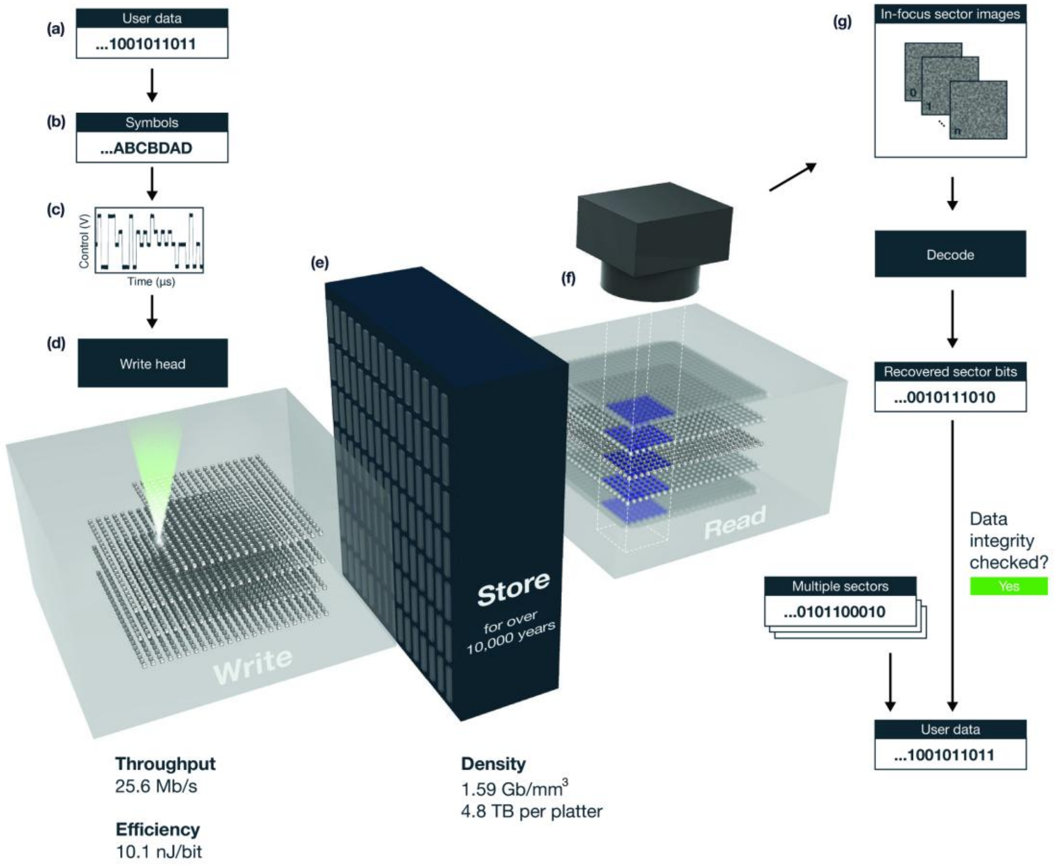
Why glass media is disruptive

- Low cost
- Durable
- Archive relevant properties
  - Immutable
  - Electromagnetic field proof
  - Faster to seek
- Exceptional Lifetime
  - No copying, scrubbing, garbage collecting
- Operational Proportionality
  - Cost (energy, emissions, $) of archive data scales with the **operations** performed



Project Silica – How it works

- Femtosecond laser writing
- Transparent detectable modification
  - 3D storage using voxels
  - Hundreds of layers of data
- Microscope reading
- Digital decode with ML



Project Silica Research Updates

ACM DIGITAL LIBRARY | Association for Computing Machinery

Project Silica: Towards Sustainable Cloud Archival Storage in Glass

Authors: Patrick Anderson, Erika Aranas, Youssef Assaf, Raphael Behrendt, Richard Black, Marco Caballero, Pashmina Cameron, Burcu Canakci, Andromachi Chatzieleftheriou, Rebekah Clarke, + 47 Authors Info & Claims

ACM Transactions on Storage, Volume 21, Issue 1 • Article No.: 7, Pages 1 - 31 • https://doi.org/10.1145/3708996

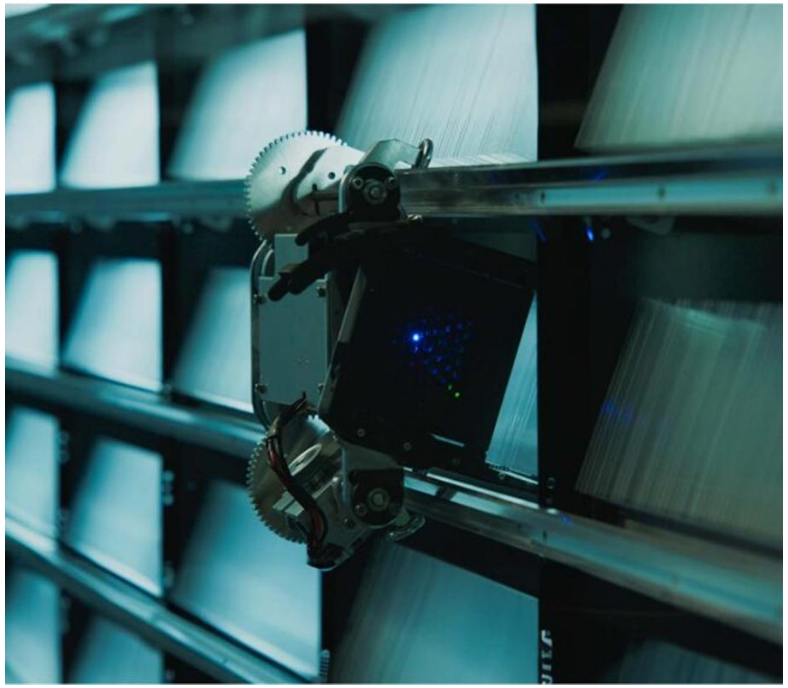
Published: 08 February 2025 Publication History

Abstract AI Summary

Sustainable and cost-effective long-term storage remains an unsolved problem. The most widely used storage technologies today are magnetic (hard disk drives and tape). They use media that degrades over time and has a limited lifetime, which leads to inefficient, wasteful, and costly solutions for long-lived data. This article presents Silica: the first cloud storage system for archival data underpinned by quartz glass, an extremely resilient media that allows data to be left *in situ* indefinitely. The hardware and software of Silica have been co-designed and co-optimized from the media up to the service level with sustainability as a primary objective. The design follows a cloud-first, data-driven methodology underpinned by principles derived from analyzing the archival workload of a large public cloud service. Silica can support a wide range of archival storage workloads and ushers in a new era of sustainable, cost-effective storage.

RASCAL: A Scalable, High-redundancy Robot for Automated Storage and Retrieval Systems

Richard Black, Marco Caballero[†], Andromachi Chatzieleftheriou, Tim Deegan, Philip Heard, Freddie Hong, Russell Joyce, Sergey Legtchenko, Antony Rowstron, Adam Smith, David Sweeney, Hugh Williams



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Laser writing in glass for dense, fast and efficient archival data storage

Microsoft Research Project Silica Team

Nature **650**, 606–612 (2026) | Cite this article

Abstract

Long-term preservation of digital information is vital for safeguarding the knowledge of humanity for future generations. Existing archival storage solutions, such as magnetic tapes and hard disk drives, suffer from limited media lifespans that render them unsuitable for long-term data retention[1,2,3]. Optical storage approaches, particularly laser writing in robust media such as glass, have emerged as promising alternatives with the potential for increased longevity. Previous work[4,5,6,7,8,9,10,11,12,13,14,15,16] has predominantly optimized individual aspects such as data density but has not demonstrated an end-to-end system, including writing, storing and retrieving information. Here we report an optical archival storage technology based on femtosecond laser direct writing in glass that addresses the practical demands of archival storage, which we call Silica. We achieve a data density of 1.59 Gbit mm^{-3} in 301 layers for a capacity of 4.8 TB in a 120 mm square, 2 mm thick piece of glass. The demonstrated write regimes enable a write throughput of 25.6 Mbit s^{-1} per beam, limited by the laser repetition rate, with an energy efficiency of 10.1 nJ per bit. Moreover, we extend the storage ability to borosilicate glass, offering a lower-cost medium and reduced writing and reading complexity. Accelerated ageing tests on written voxels in borosilicate suggest data lifetimes exceeding 10,000 years.

System Design Lessons

Need at least 1 TB in capacity per media

- More is better, but less is unworkable

Readers only need ~45MB/sec

- Beyond this gives very little benefit
- Provided you designed for resilience at cloud scale

Writing is about MB/sec per dollar of capital

- Individual throughput per piece of media is irrelevant

Physics Contributions

New “Phase voxels” in borosilicate

- Writers and Readers are both simpler and lower cost
- Capacity reduces from 4.8TB to 2TB (Glass cost per TB is still lower)

Single pulse writing

- For both phase voxels and polarized (birefringent) voxels
- Enables higher speed writing

Emissions based equipment calibration and dynamic control

Close multi-spot simultaneous parallel writing

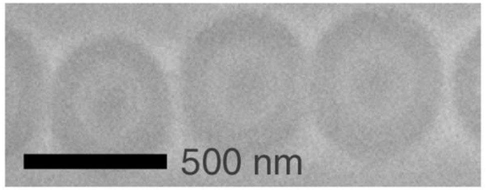
- Model enabling many spots validated experimentally at bench scale.

New voxels and media still suggest > 10,000 years data lifetime

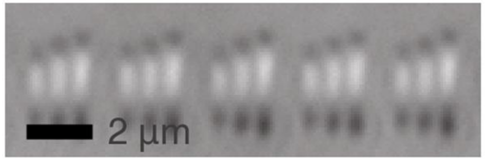
- Combined Optical / Arrhenius method now peer reviewed.

Physics Contributions

SEM from the top



PCM from the side



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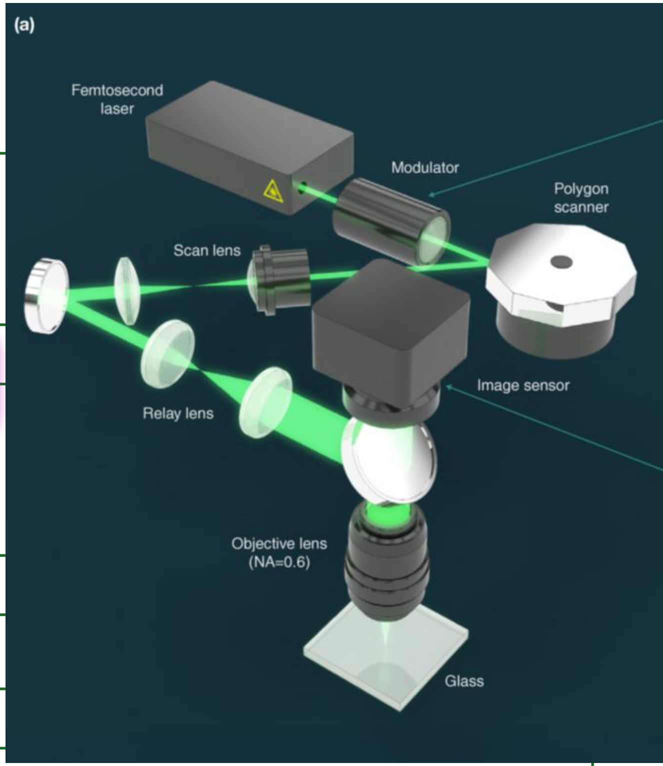

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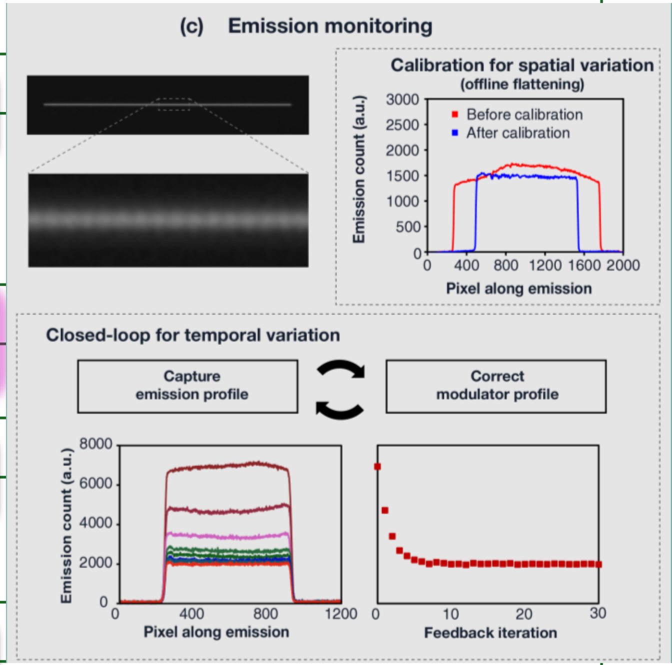

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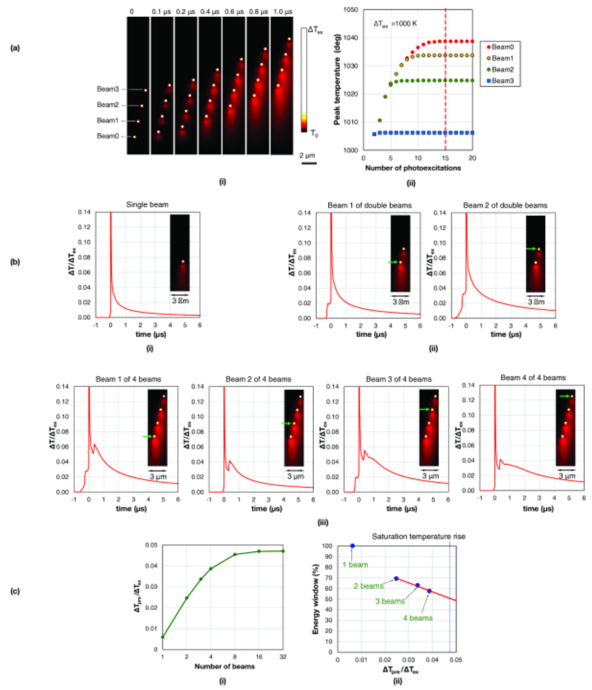

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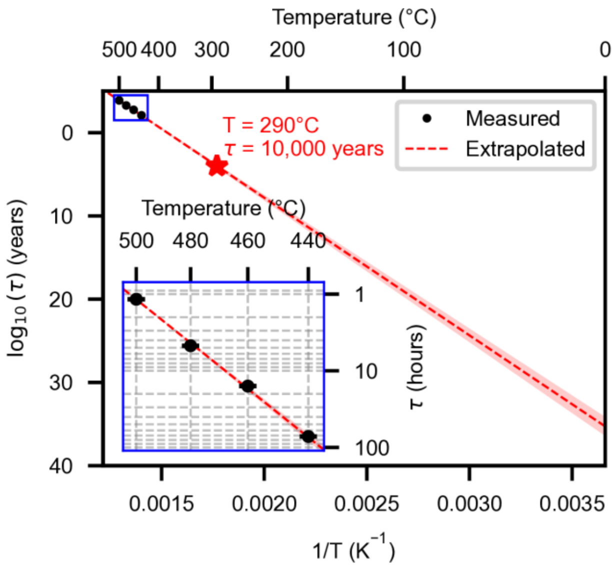

Project Silica Status

- Research project completed in 2025
- Viable path towards commercialization gated only by the laser

- We're happy to have this work featured in *Nature* so others may build on it.

Microsoft