STORAGE DEVELOPER CONFERENCE

SDC 23

BY Developers FOR Developers

Bit-to-DNA Writing Machines

a Microfluidic Platform and Future Data Center Operation Overview

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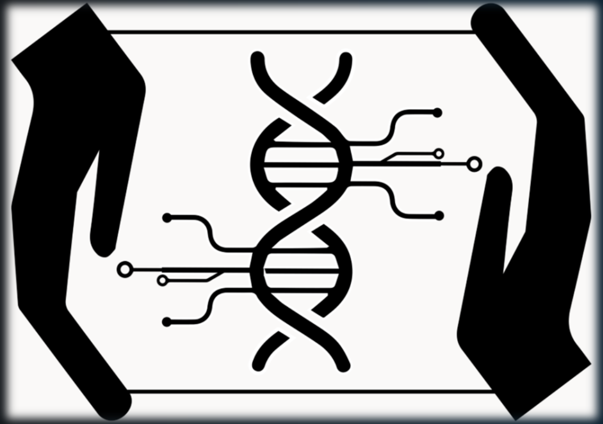
ipt INSTITUTO DE PESQUISAS TECNOLÓGICAS
Lenovo

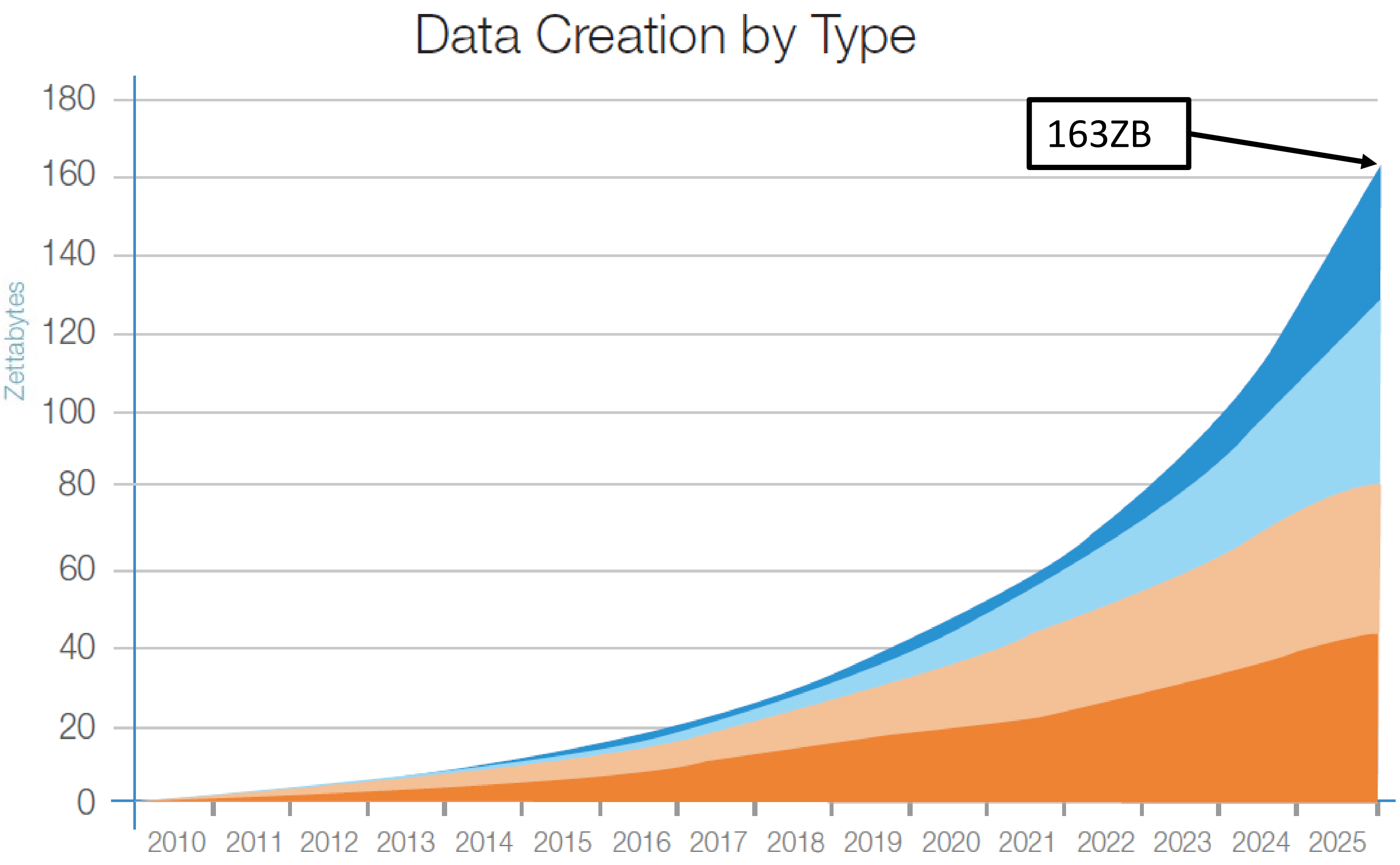
About us

Since 2021, the Prometheus group has been working on converting DNA synthesis from Biotech industry into Data Storage application

We are a multidisciplinary group that develop technology for many aspects of the molecular data pipeline, such as biology, biochemistry, computation and microfabrication



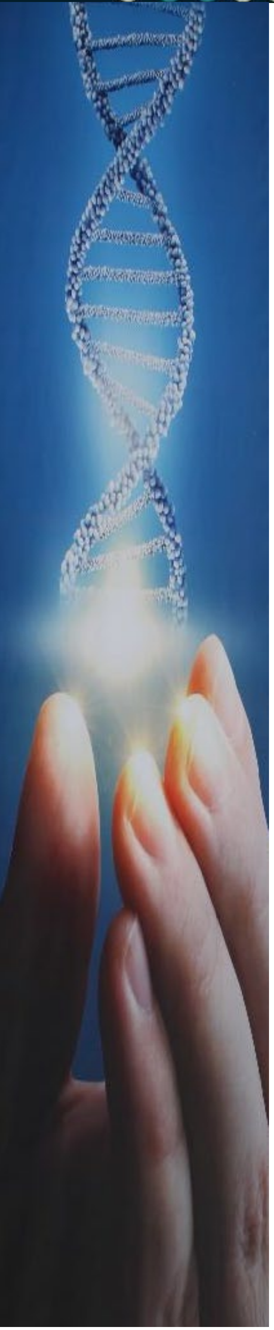
The issue at hand

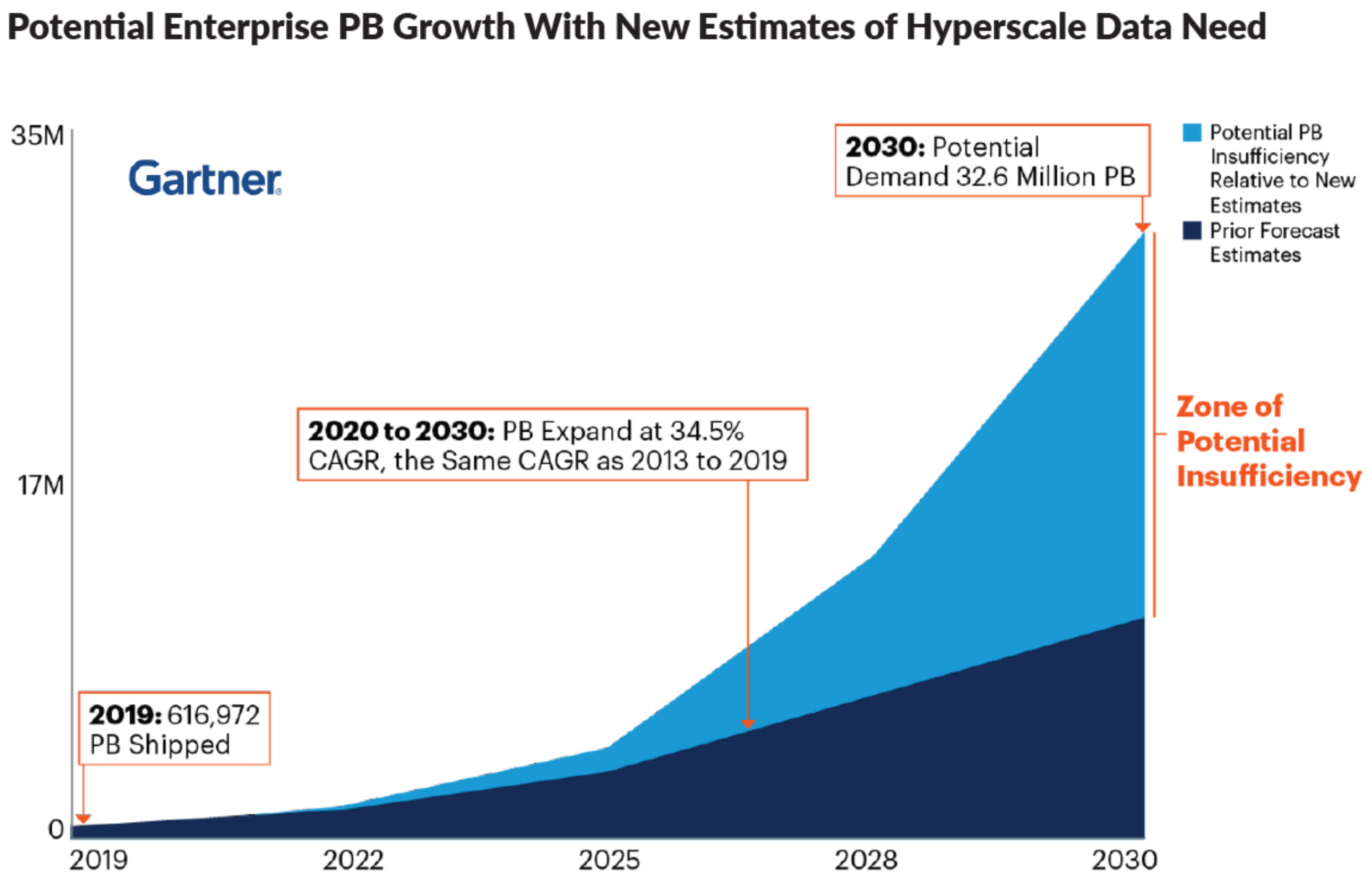


Credits: IDC's Data Age 2025: The Evolution of Data to Life Critical, study

- 30% being critical or hypercritical data
- 60% being Cold Data

The issue at hand

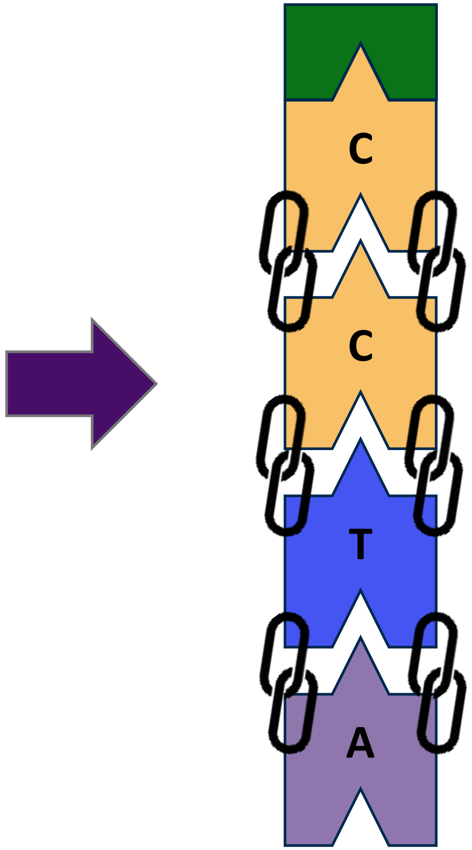


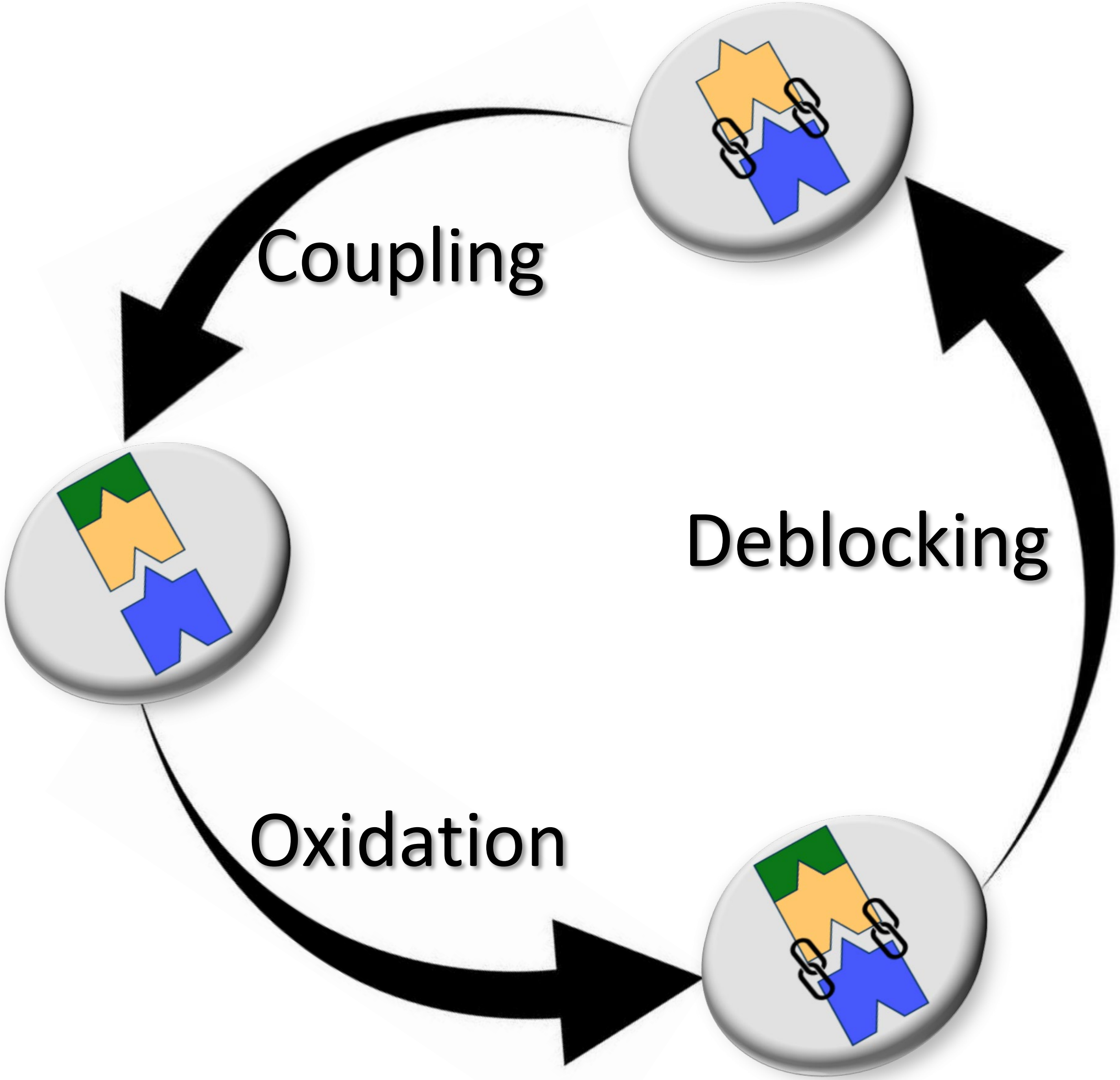


Credits: Gartner Market Trends: Evolving Enterprise Data Requirements - How much is Not Enough?
apud: Preserving our Legacy: An Introduction to DNA Data Storage, by DNA Data Storage Alliance

- Traditional forms of Data Storage may not be enough

Artificial DNA Synthesis 101





Where it all began

“The Coder Model 280” DNA synthesizer, released in 1980
Credits: Vega Biotechnologies

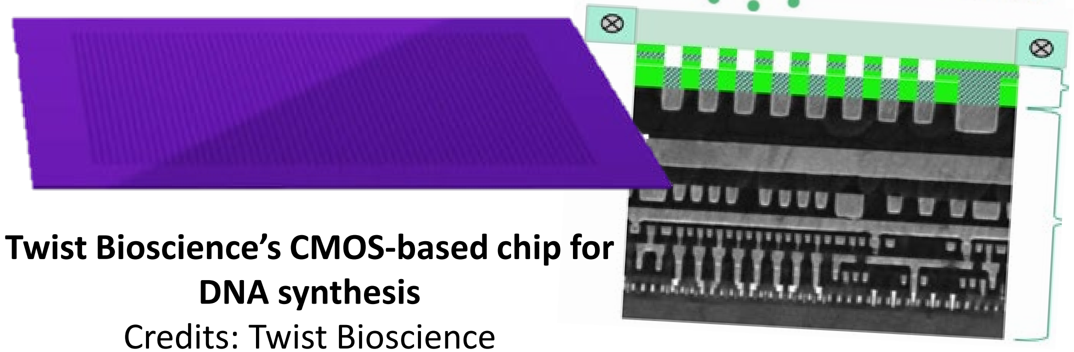
- First ever artificial DNA synthesizer machine
- 15 bases per day (max of 30 bits per day)

Current standard machines for Biotech

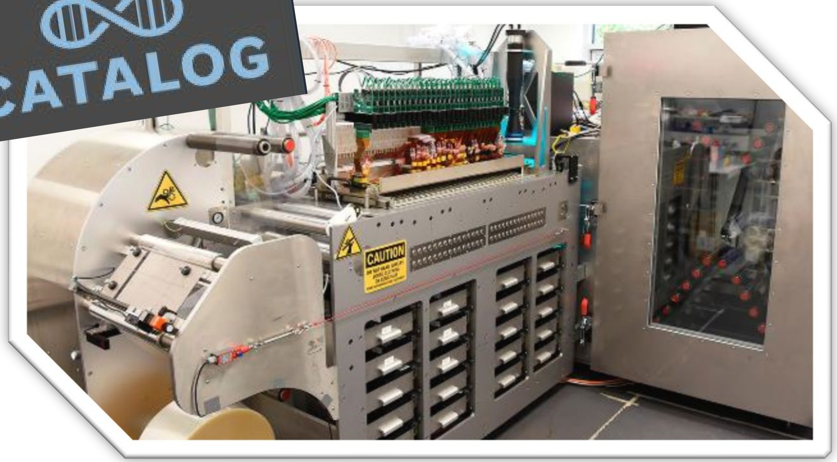
"Dr. Oligo 768XLc" DNA synthesizer, for biotech applications
Credits: Biolytic® Lab Performance, Inc.

- Tabletop equipment
- Essencially the same design concept as before, just optimized
- 768 oligos per run
- In 24 hrs, it can build strands of 148 nt
- Estimate of 28 kB in a day
  - 2.6 bits/sec

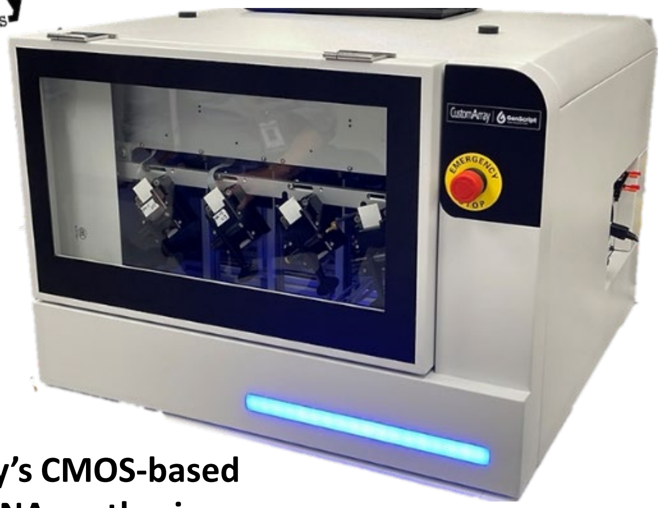
Examples of innovative new devices



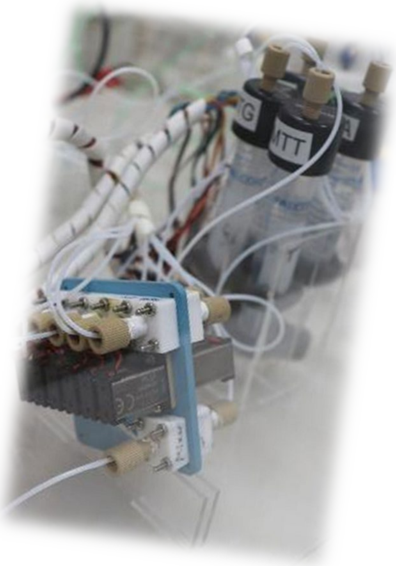
Twist Bioscience's CMOS-based chip for DNA synthesis
Credits: Twist Bioscience



Shannon, CATALOG's prototype DNA writer
Credits: CATALOG



CustomArray's CMOS-based chip for DNA synthesis
Credits: CustomArray Inc.

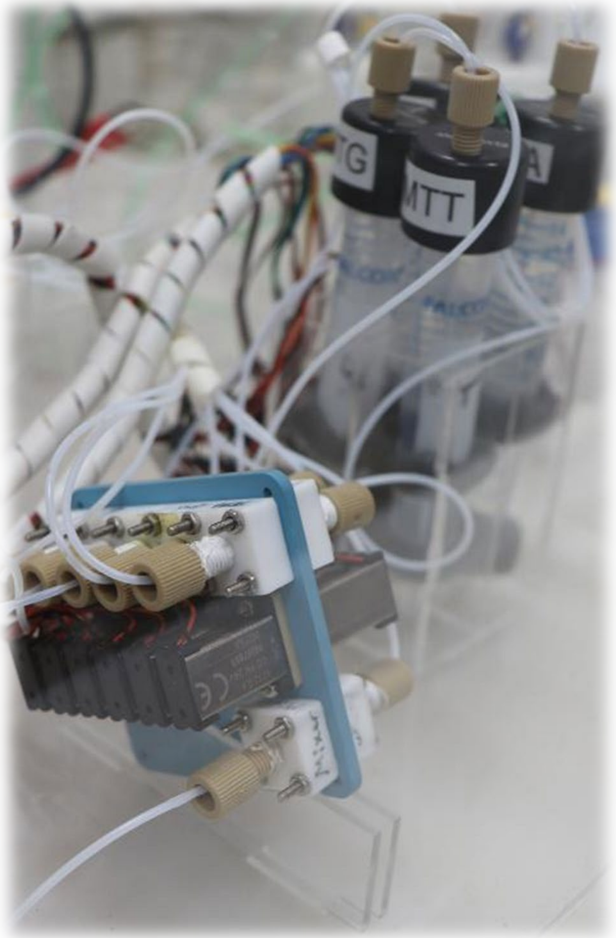


IPT/Lenovo's LTCC-based chips for DNA synthesis

No matter how, it's a fluidic process all the same

"Macrofluidic"

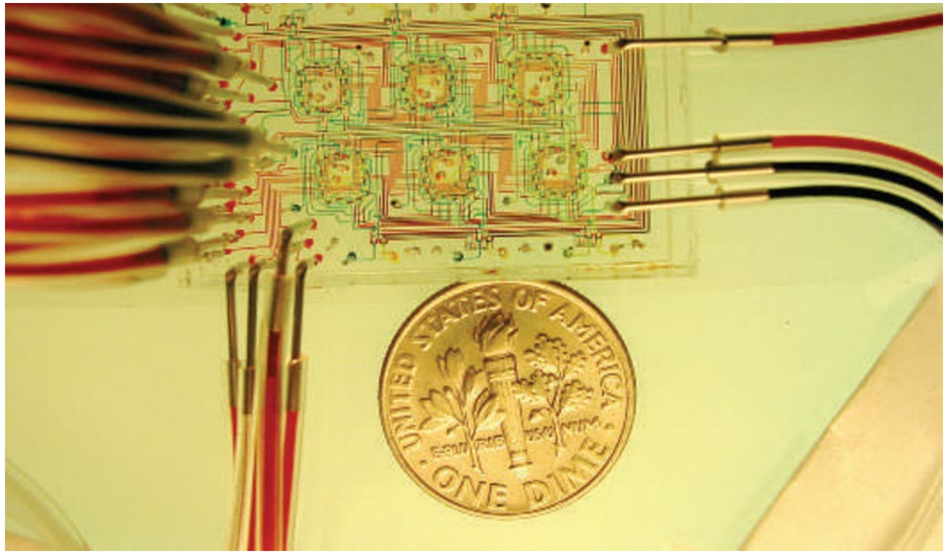
Microfluidic



Microfluidic Technology

Microfluidic technology: Manipulation and control of fluids within environments on a scale of micrometers

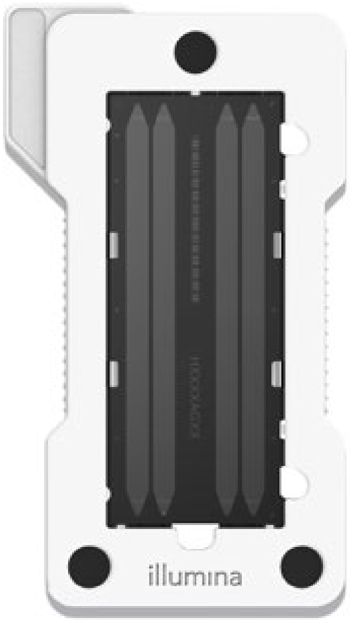
- **Smaller footprints**
- **Reduced reagent volumes**
- **Safer system**
- **More sustainable operation**



Microfluidic chemostat
Science, v. 309, n. 5731, 2005. 10.1126/science.1109173
apud: Nature, v. 442, n. 7101, 2006. doi:10.1038/nature05058

Microfluidic Technology

Microfluidic technology: Manipulation and control of fluids within environments on a scale of micrometers



Illumina’s Flow Cell: Next Seq 500
Credits: Illumina Inc.

Droplet generator
Credits: Dolomite

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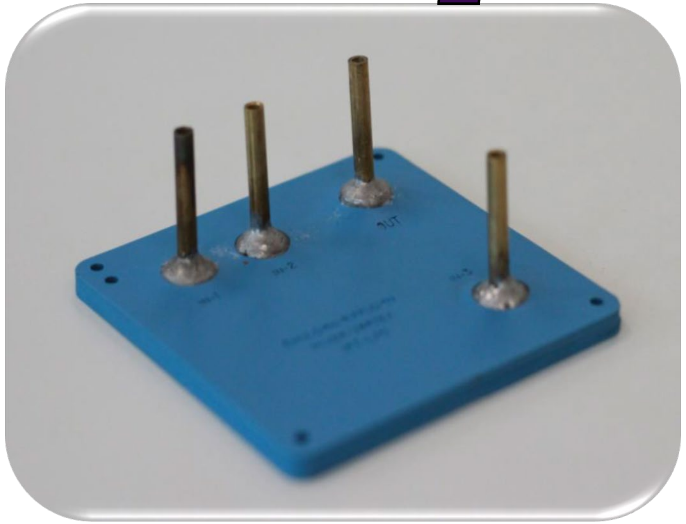
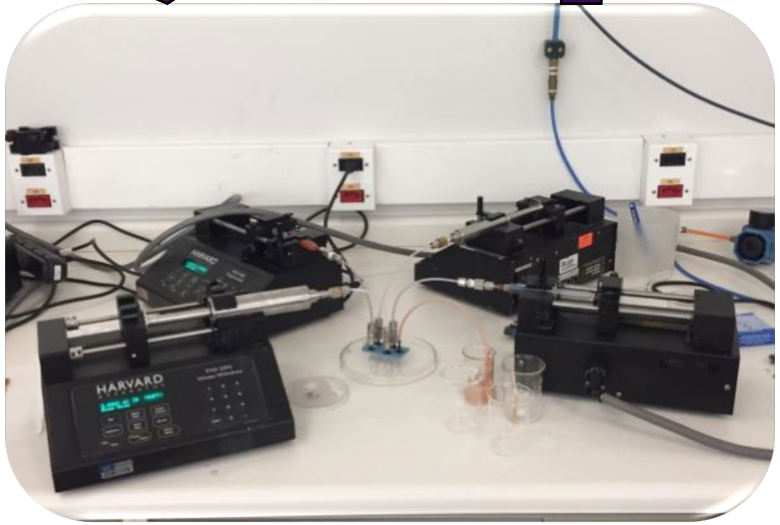
Microfluidic Technology

- Is microfluidic suitable for industrial applications?



Microfluidic chip
Research level

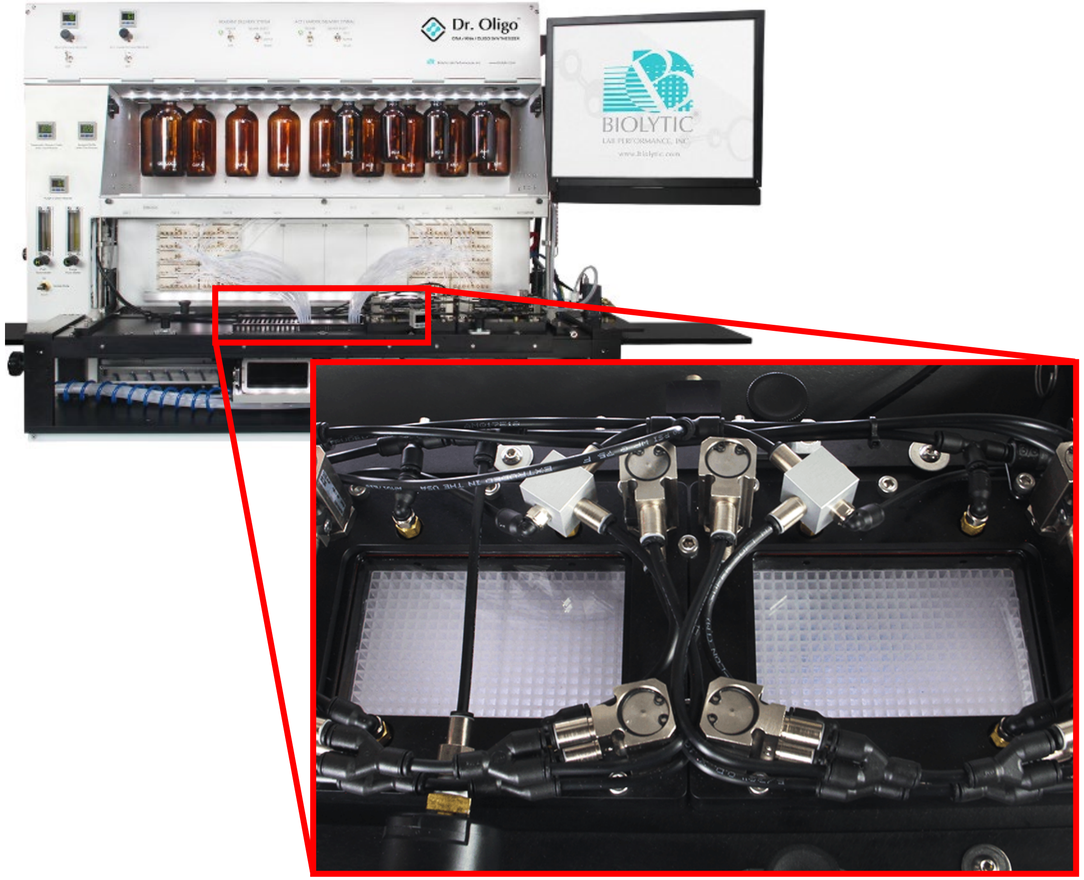


Lab-scale prototype
Development level

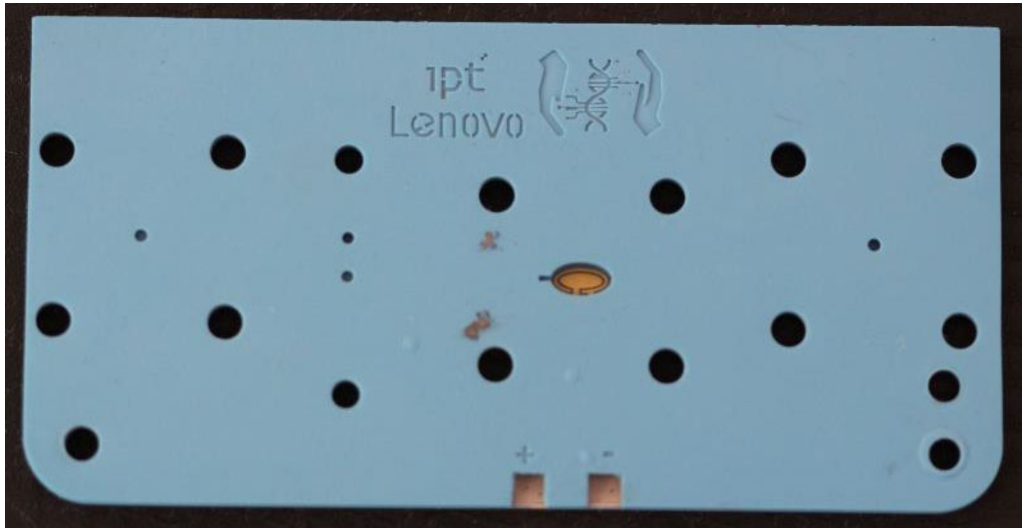
Full/Industrial-scale prototype
Deployment level

Microfluidic Technology

- Is microfluidic suitable for DNA synthesis?



"Dr. Oligo 768XLc" DNA synthesizer, for biotech applications
Credits: Biolytic® Lab Performance, Inc.

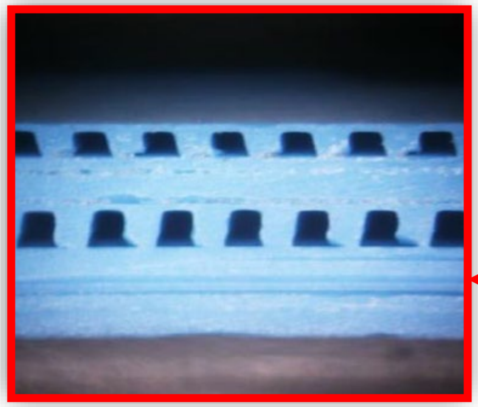


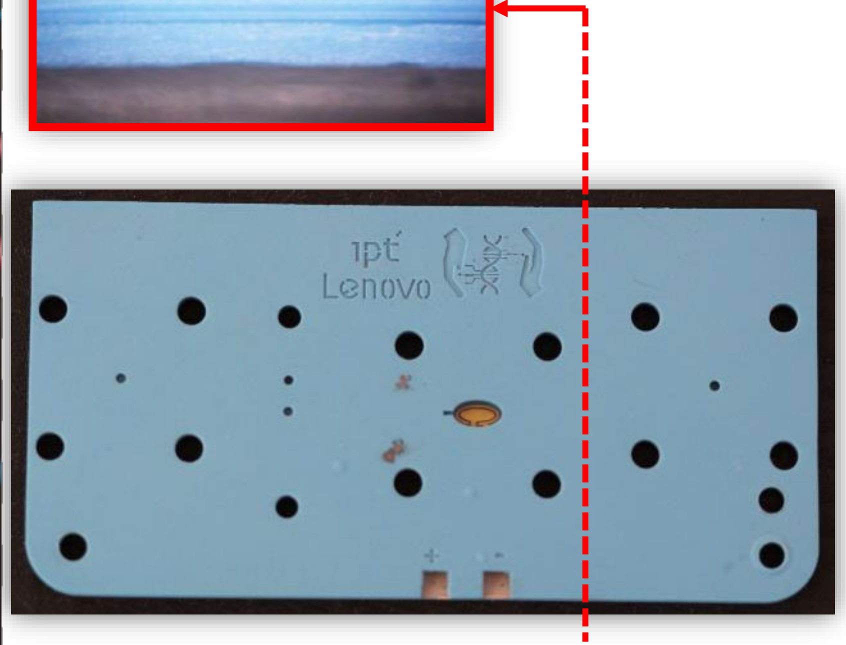
IPT/Lenovo's LTCC-based chips for DNA synthesis PoC

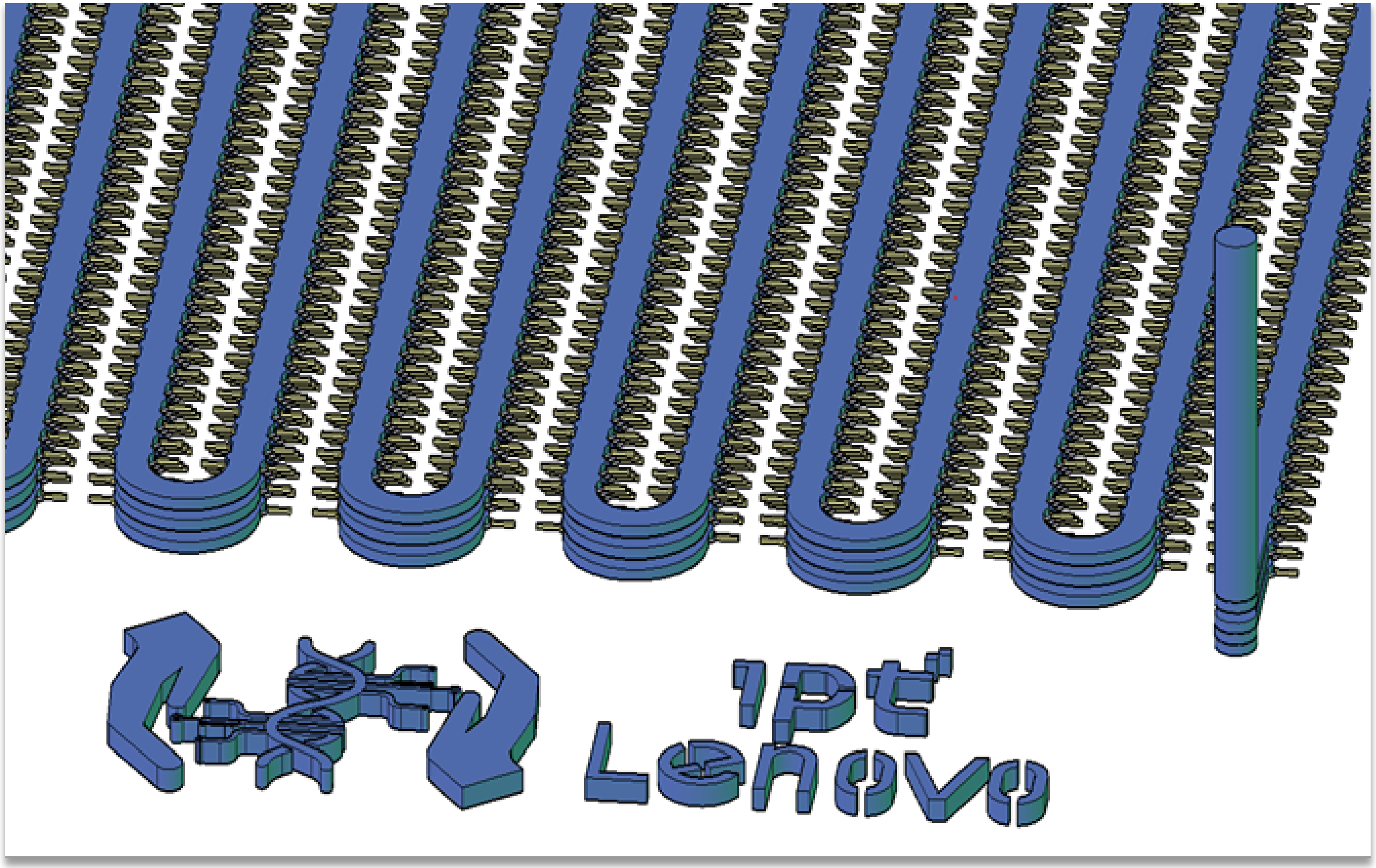
IPT/Lenovo Ceramic "DNA writer"
Device: 1.1 cm^3 (0.67 in^3)
Well: 6 mm^3

Microfluidic Technology

- Is microfluidic suitable for DNA synthesis applied to Data Storage?



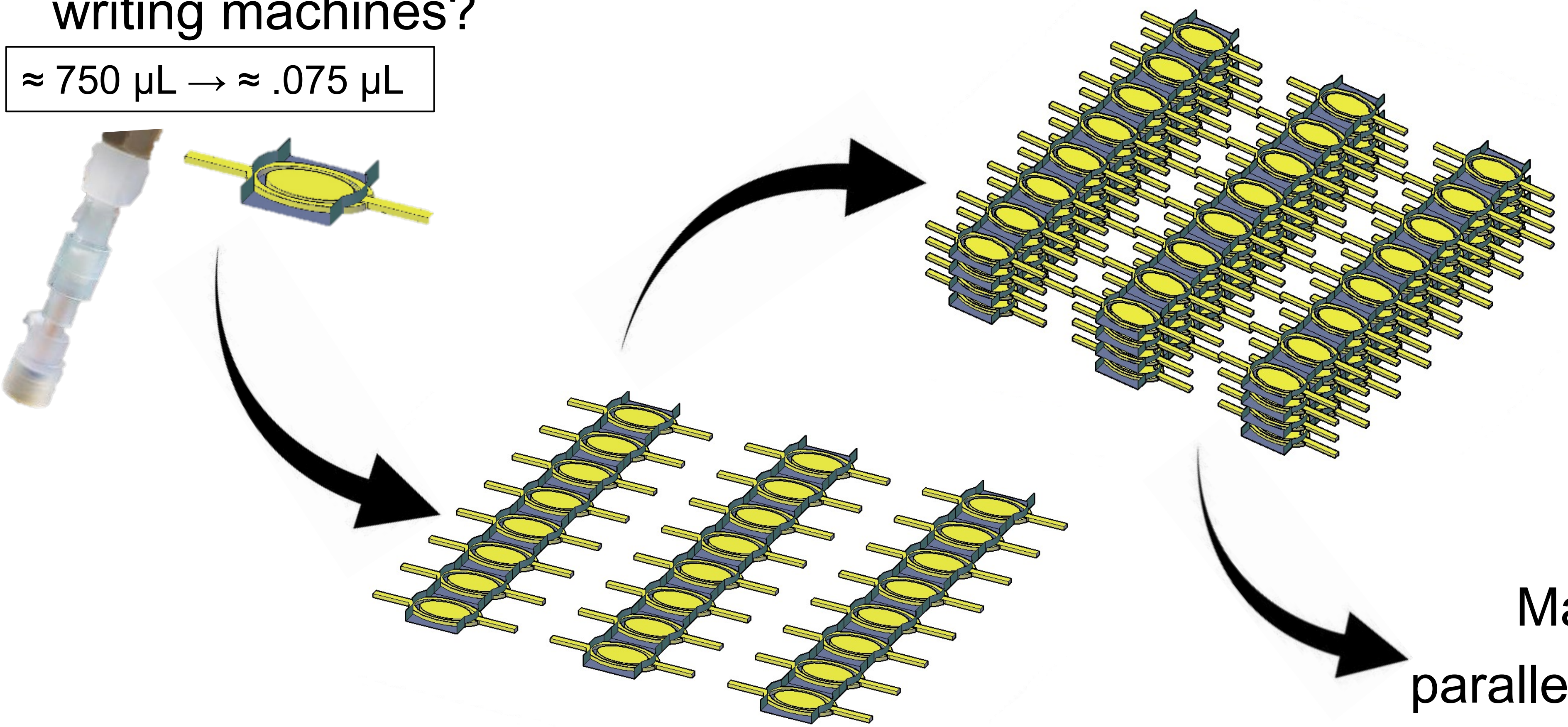




Microfluidic Technology

- How will the microfluidic technology enable the development of bit-to-DNA writing machines?

≈ 750 μL → ≈ .075 μL

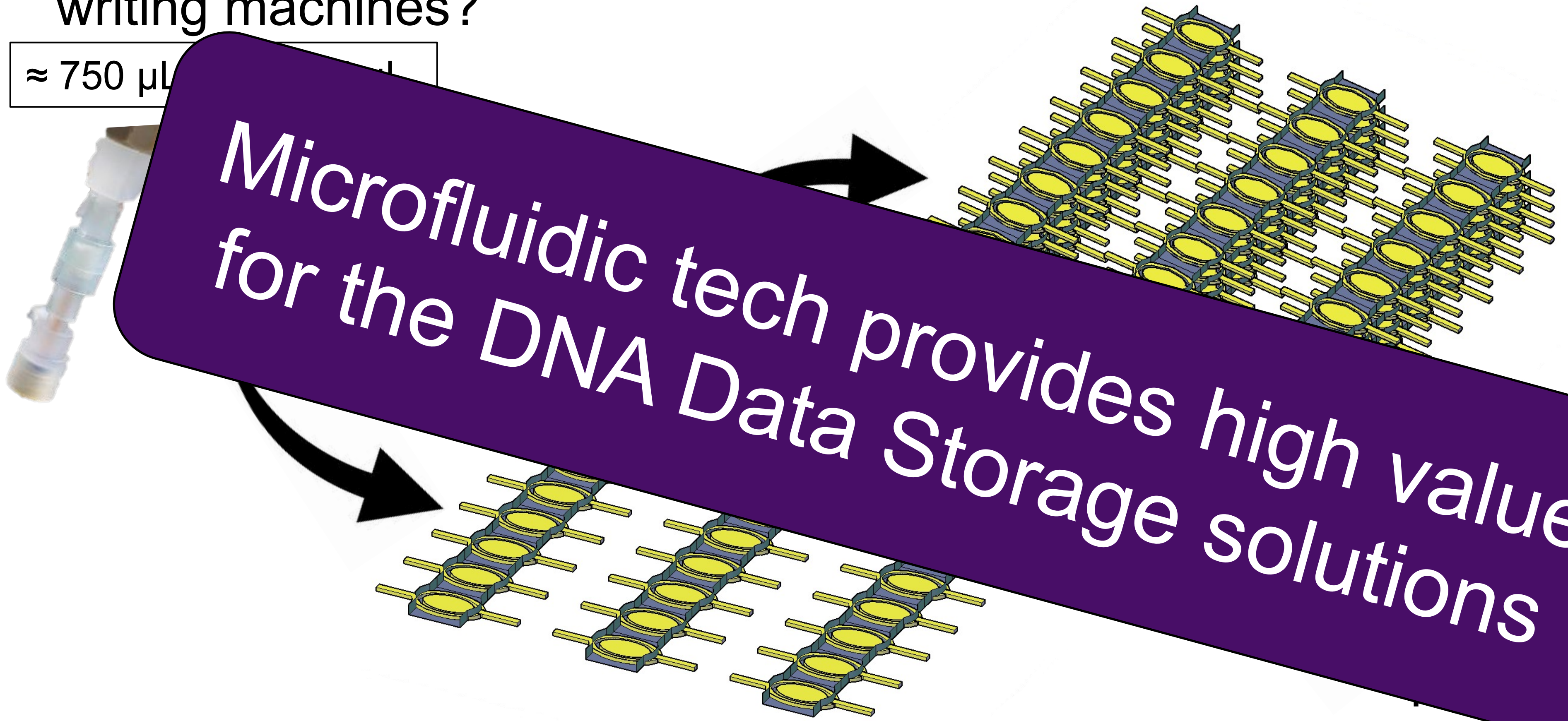


Mass parallelization!

Microfluidic Technology

- How will the microfluidic technology enable the development of bit-to-DNA writing machines?

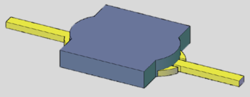
≈ 750 µL



Microfluidic tech provides high value for the DNA Data Storage solutions

ation!

Pushing further the TRL of the bit-to-DNA writing machines



- How far are we from a commercially viable Bit-to-DNA writing machine?

Research

1. Basic principles observed
2. Technology concept formulated
3. Experimental proof of concept

Development

4. Technology validated in lab
5. Technology validated in simulated environment
6. Technology demonstrated in simulated environment

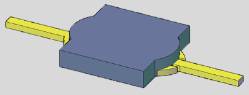
Deployment

7. System model/prototype demonstration in operational environment
8. System complete and qualified
9. Actual system proven in operational environment

Innovative new devices (TRL 3–5)

* TRL = Technology Readiness Level

Pushing further the TRL of the bit-to-DNA writing machines



- Are the bit-to-DNA writing machines ready for deployment into real data centers?

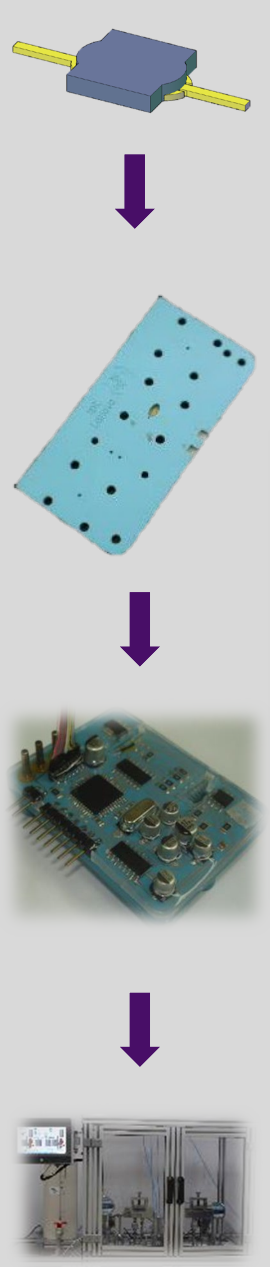
- Meet data center requirements:
  - Compatible writing throughput;
  - Small footprint;
  - Simple and low cost data center facility retrofitting;
  - No need for high specialized personnel;
  - Low complexity and low cost reagents handling;
  - Environment conditions similar to the current data center facilities.

For reference:

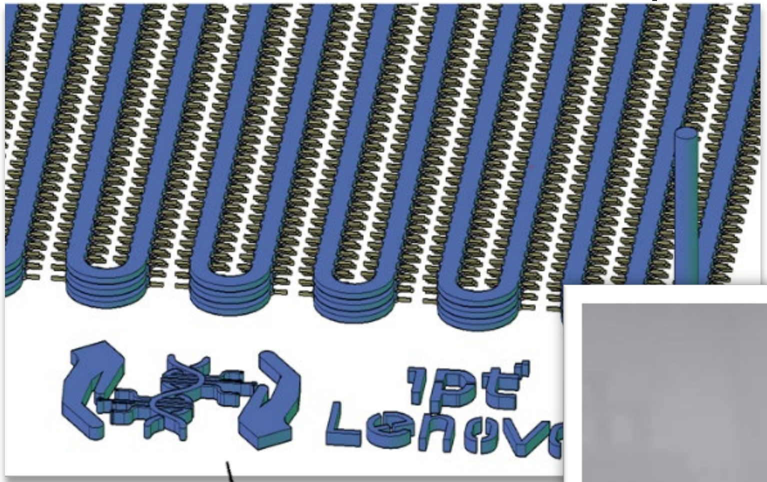
LTO Tapes (± 18TB)
≈ 400 Mb/sec
≈ 220 cm^3 (±13,4 in^3)

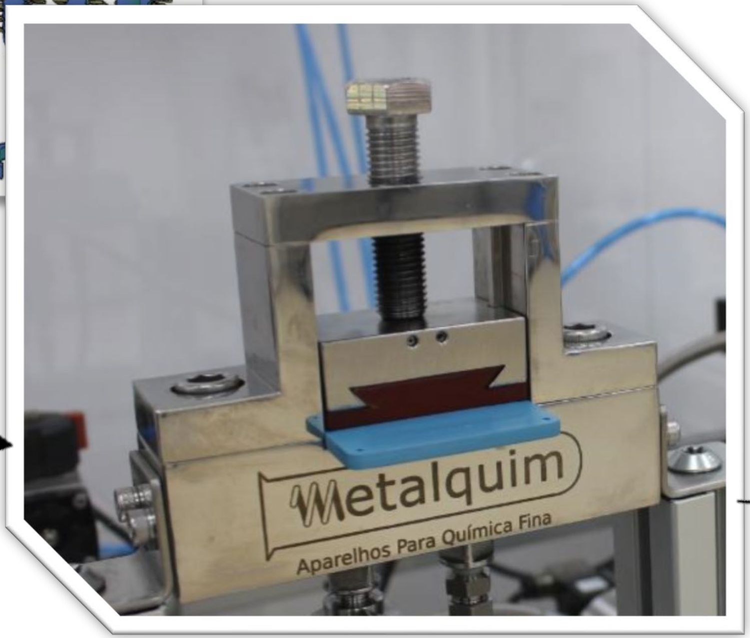
Dr. Oligo 768 wells
≈ 2.6 b/sec
≈ 422000 cm^3 (25750 in^3)

Pushing further the TRL of the bit-to-DNA writing machines

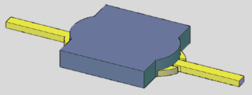


- Pushing the maturity level to TRL 5 and beyond:
  - Focus on the outer parts/surrounding of the chips

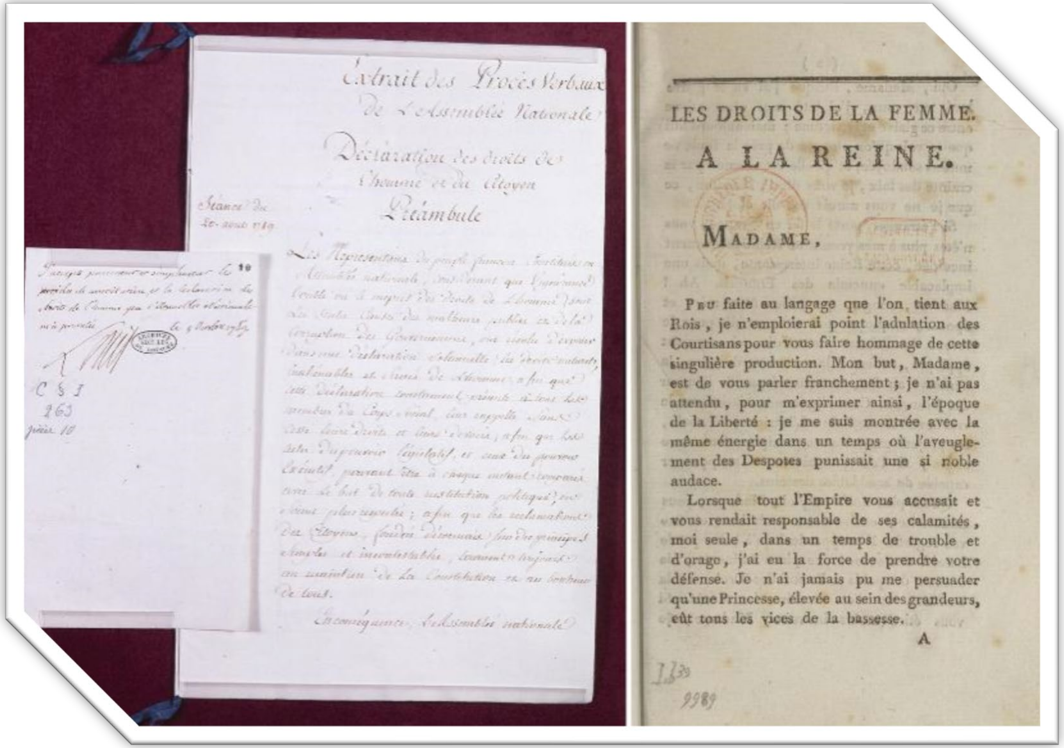




Pushing further the TRL of the bit-to-DNA writing machines



- Pushing the maturity level to TRL 5 and beyond:



Extrait des Procès Verbaux de l'Assemblée Nationale

Déclaration des droits de l'homme et du citoyen

Préambule

LES DROITS DE LA FEMME.

A LA REINE.

MADAME,

Peu faite au langage que l'on tient aux Rois, je n'emploierai point l'adulation des Courtisans pour vous faire hommage de cette singulière production. Mon but, Madame, est de vous parler franchement; je n'ai pas attendu, pour m'exprimer ainsi, l'époque de la Liberté : je me suis montrée avec la même énergie dans un temps où l'aveuglement des Despotes punissait une si noble audace.

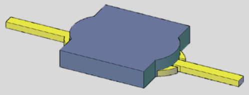
Lorsque tout l'Empire vous accusait et vous rendait responsable de ses calamités, moi seule, dans un temps de trouble et d'orage, j'ai eu la force de prendre votre défense. Je n'ai jamais pu me persuader qu'une Princesse, élevée au sein des grandeurs, eût tous les vices de la bassesse.

A

Credits: French National Archives, AE/II/2983 and AE/II/2982
Apud: CNRS News website

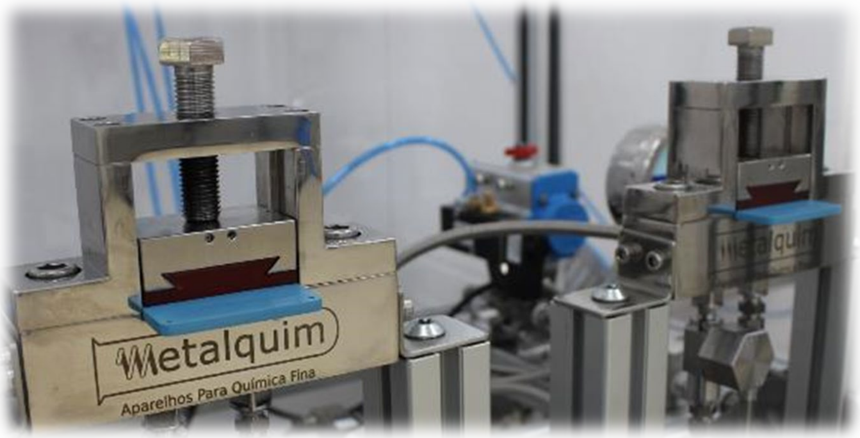
Credits: Stéphane Lemaire, from CNRS – Sorbonne Université
Apud: CNRS News website

- Frozen Storage is the perfect target client for first level DNA Data Storage systems



Pushing further the TRL of the bit-to-DNA writing machines

- Pushing the maturity level to TRL 5 and beyond:
  - Parallelize existing devices instead of proposing new chip designs



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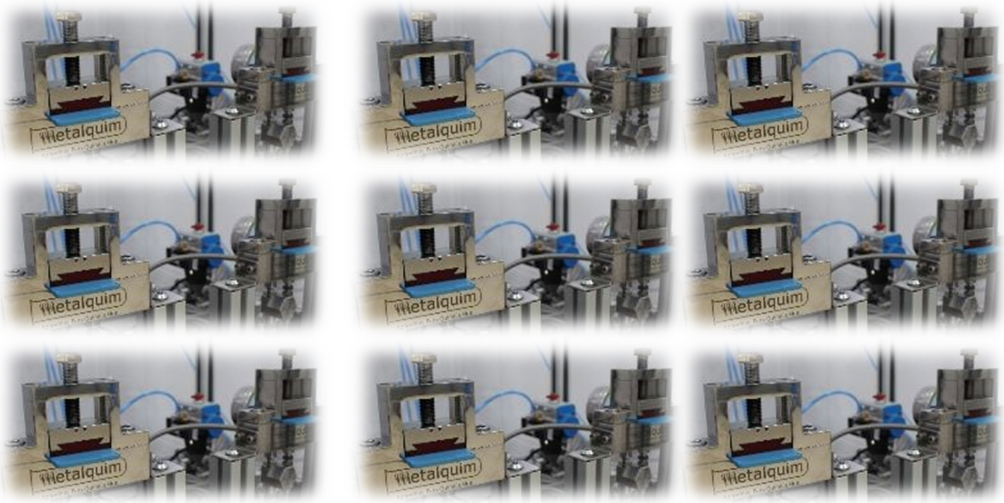

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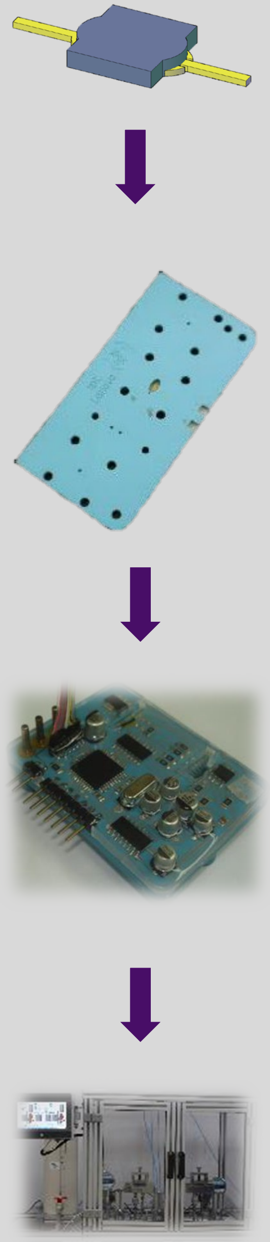
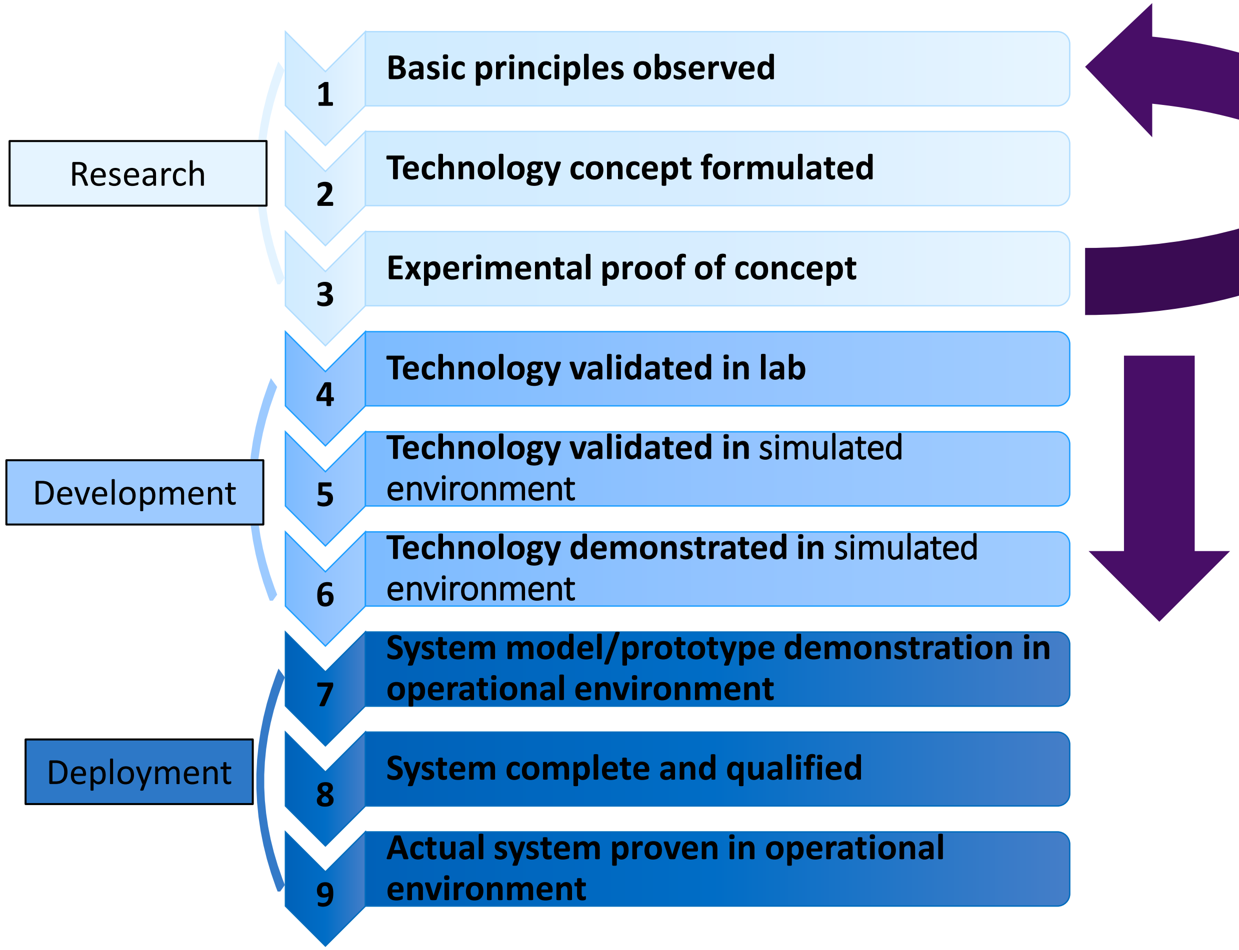
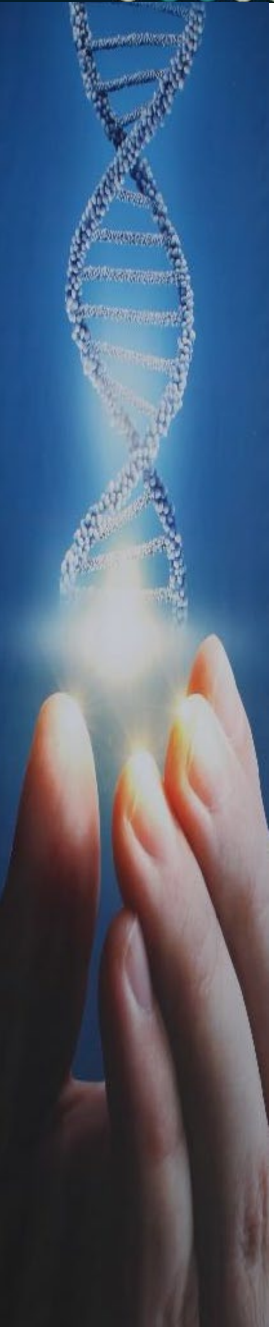
First generation of writing machines ⟷ Multiple microfluidic chips

Pushing further the TRL of the bit-to-DNA writing machines



- How far are we from a commercially viable Bit-to-DNA writing machine?





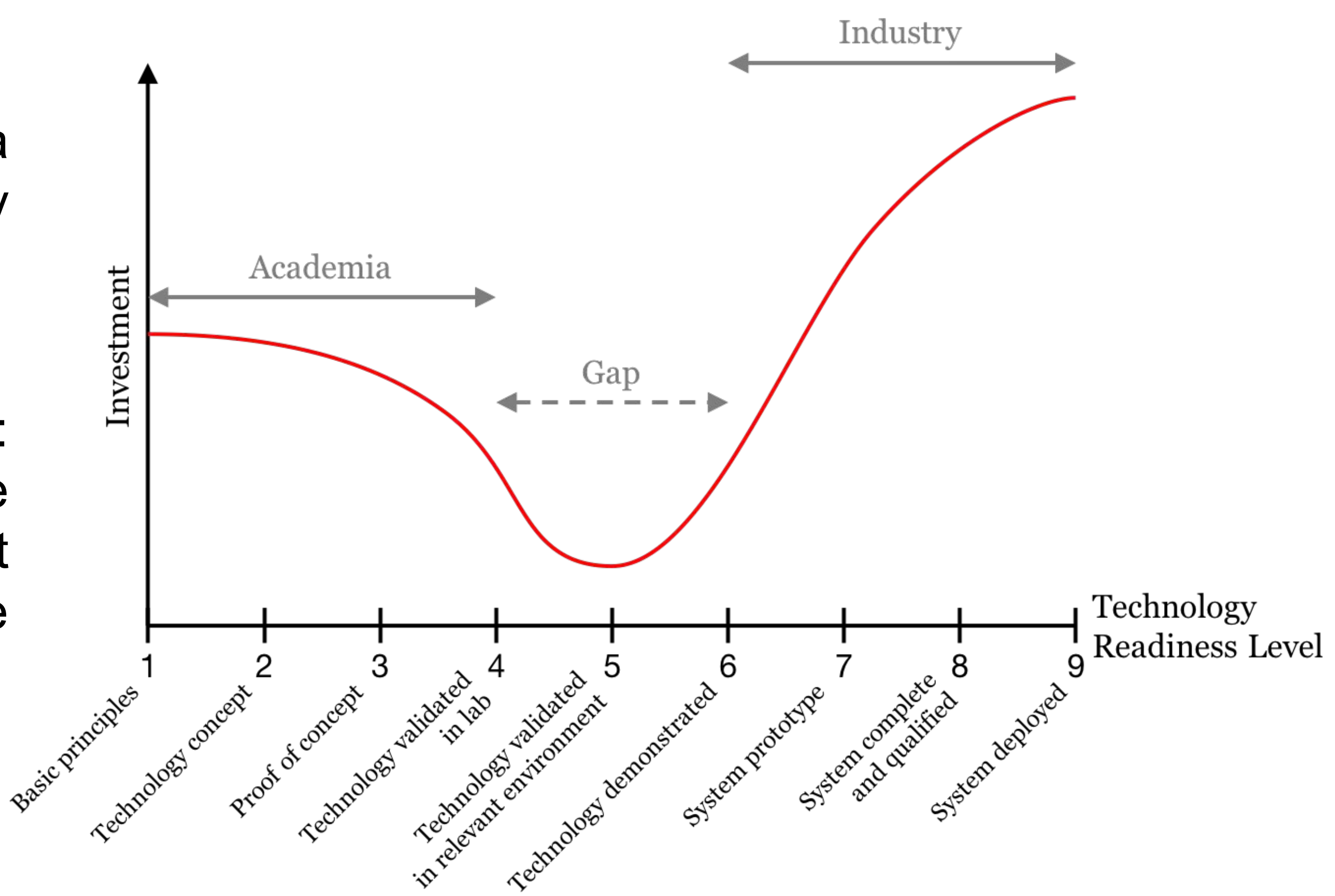
Closing thoughts

- Microfluidic technology is one of pillars to make commercially viable bit-to-DNA writing machines
  - Massive parallelization will lead to miniaturized manipulation of fluids
  - Microfluidic can be used to produce commercially viable products
  - Promising microfluidic chips proposed by many groups
- There is still room for improvements for higher yields and throughput (to explore the full potential of DNA Data Storage)

Closing thoughts

- Technology status: academia (research TRLs) and industry (deployment TRLs) are closer

- Next step to bridging this gap: focus on the surrounding of the microfluidics chips and start working with real data storage routines



Technological "valley of death"

Credits: Alessandro Rossini, Bridging the technological "valley of death", PwC Norway

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