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## The problem:

Modern AI systems are inherently limited in their energy efficiency by electronic hardware

AI data centers are expected to be consuming as much as 1,500 TWh of energy per year by 2030<sup>[1]</sup>

**This energy would power the UK for a year!**

We need a paradigm shift away from fully electronic implementations of AI towards hybrid opto-electronic and all optical approaches

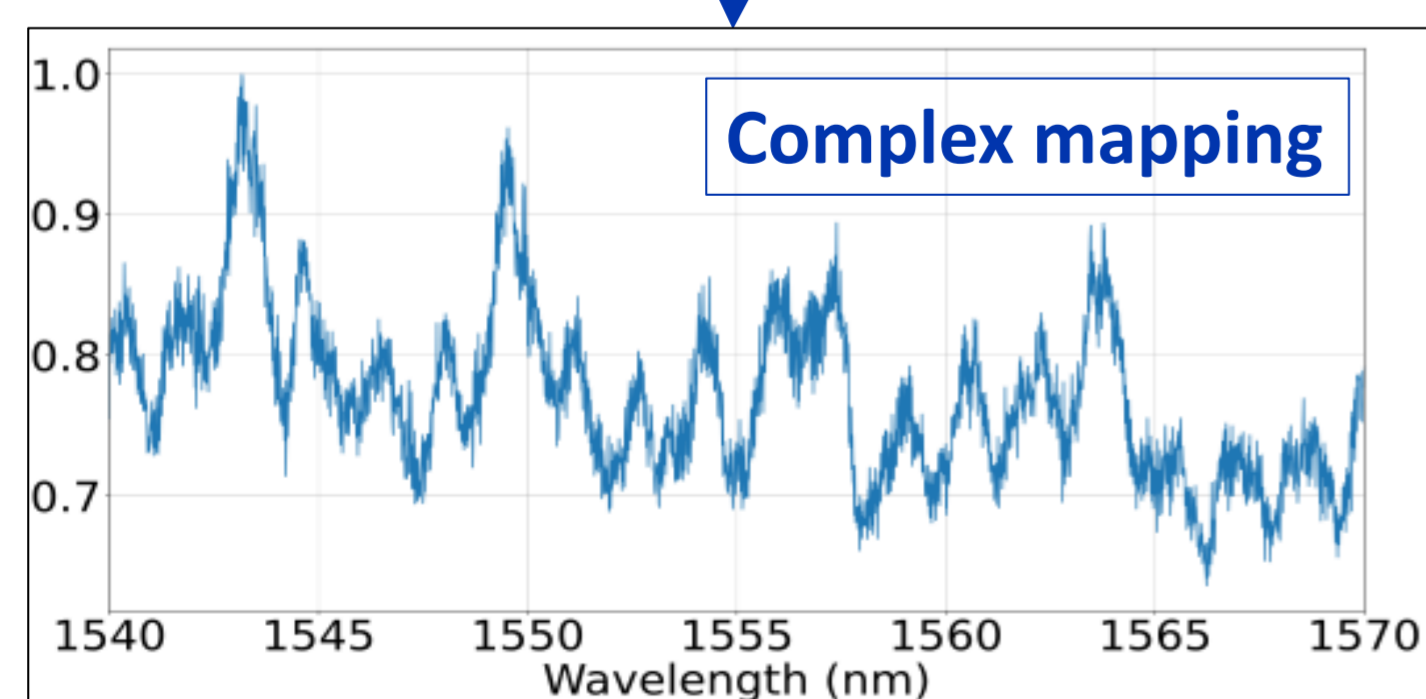
## How do we do AI?

(a) Classic task: object identification (different flowers from *iris* family)



(b) Encode the flowers' features in the wavelength of a laser

(c) The system leverages nonlinear dynamics to efficiently explore the hyperdimensional space of parameters



(d) Use a single-step mathematical transformation to train the AI based on all the stored light patterns

## Integrated Optics: a solution

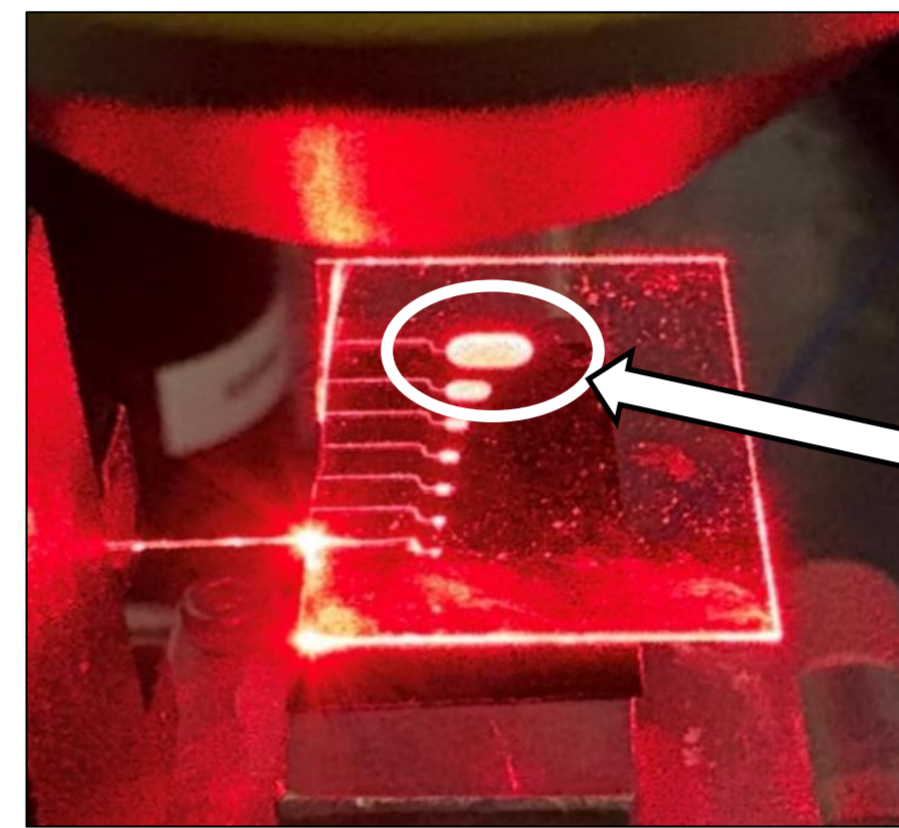
Main source of energy loss in electronics-based AI is in the communication between processor and memory<sup>[2]</sup>

Integrated optics offers a revolutionary solution in the form of chaos billiards, exploiting the natural behavior of light to make vector-matrix multiplications more efficient

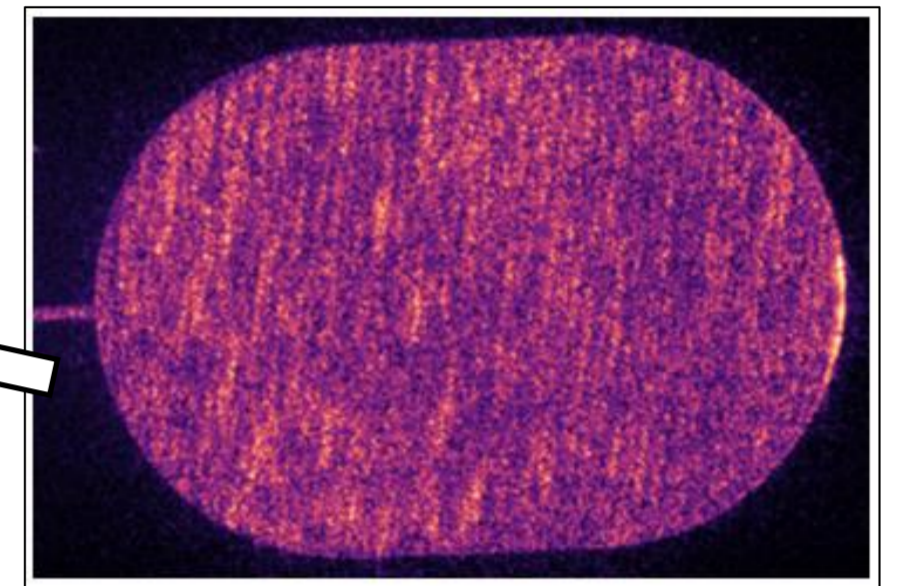
Electronic AI



Photonic AI



Photonic microprocessor



Can encode information in wavelength, polarization, phase, and position. It is a very versatile system for multi-dimensional operation!

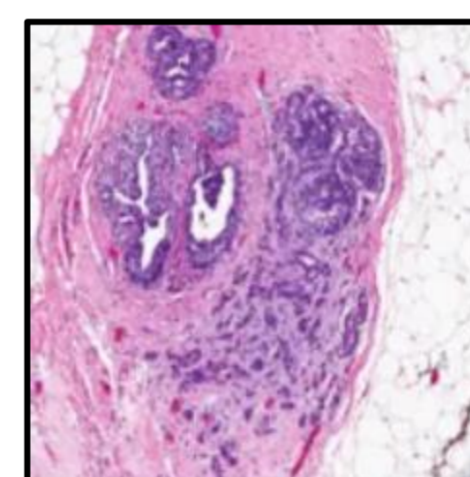
## Classification: why does it matter?

Classification is an incredibly important category of task that AI is asked to perform

It involves identifying an object or signal based on certain characteristics known as "features"

## Results and Impact:

Classification accuracy above 90% across 3 different classic machine learning benchmark tasks:



Iris flowers ✓  
Breast cancer diagnosis ✓  
Handwritten digits ✓



Our system has an energy consumption of only **513mJ per symbol!**<sup>[3]</sup>

First results are already comparable in performance and energy budget to standard electronic hardware for machine learning

## Looking to the Future:

We will optimize our system, increasing energy efficiency by orders of magnitude

We will target tasks with real world data sets and a clear route for impact: spectrometry<sup>[4]</sup> and environmental sensing

## References

- [1] C. Bogmans, *et al* (2025) "Power hungry: how AI will drive energy demand", IMF Working Papers, 81, 10.5089/9798229007207.001
- [2] D. A. B. Miller, (2017) "Attojoule Optoelectronics for Low-Energy Information Processing and Communications," *Journal of Lightwave Technology*, vol. 35, no. 3, pp. 346-396.
- [3] M.R. Wilson, *et al* (2025) "On-chip wave chaos for photonic extreme learning", *Opt. Lett.*, 50, 7227-7230.
- [4] M.R. Wilson, *et al* (In preparation) "On-chip nanostructured chaotic billiards for speckle spectrometry".

Task

AI

PC

LinkedIn:



Our Paper:



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