High Performance Optoelectronic Neural Network Scheduler

http://www.optical-computing.co.uk

K. J. Symington, A. J. Waddie, T. Yasue,
M. R. Taghizadeh and J. F. Snowdon.

Outline

- Packet switch scheduler.

- Previous demonstrator has proven feasibility.

- Current demonstrator enhances functionality and performance.

- Motivation.

- Implementation and scalability.

- Conclusions.

The Assignment Problem

Can be found in situations such as:

- Network service management.

- Distributed computer systems.

- Work management systems.

- General scheduling, control or resource allocation.
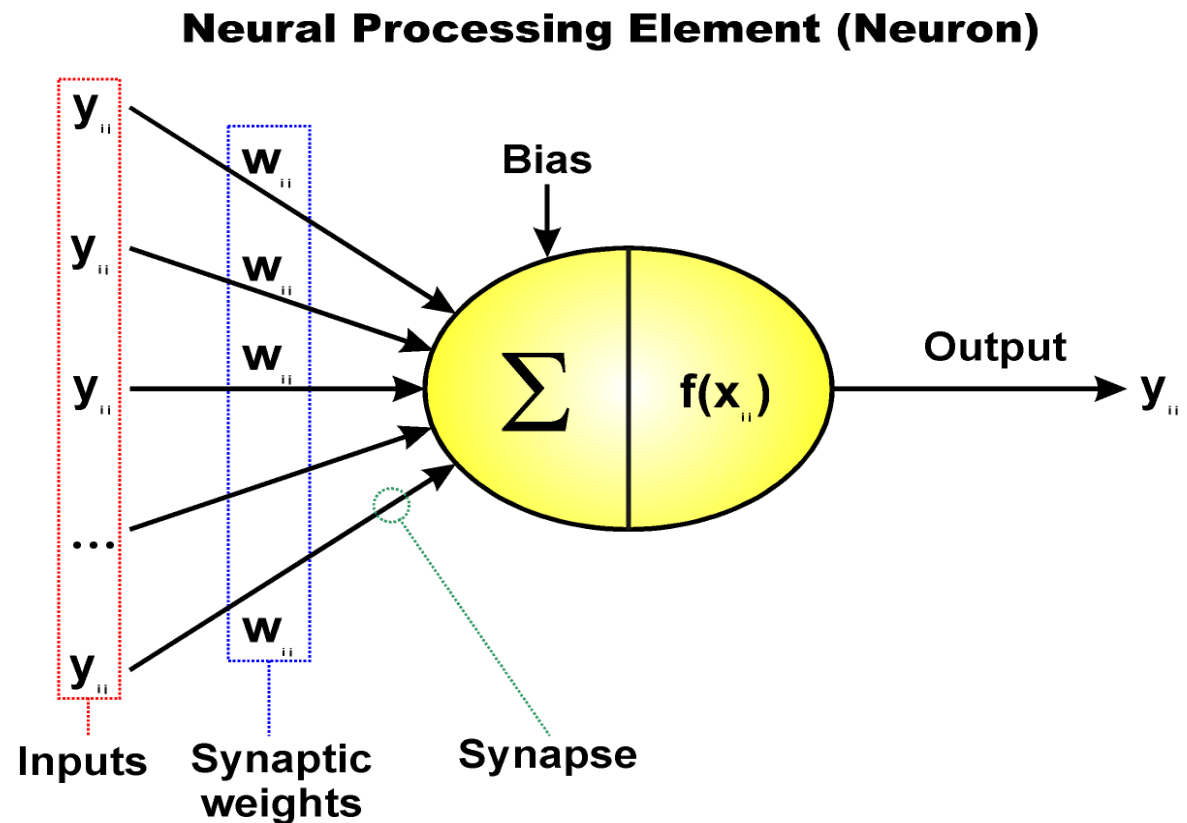
Solution is computationally intensive.

Neural networks are capable of solving the assignment problem.

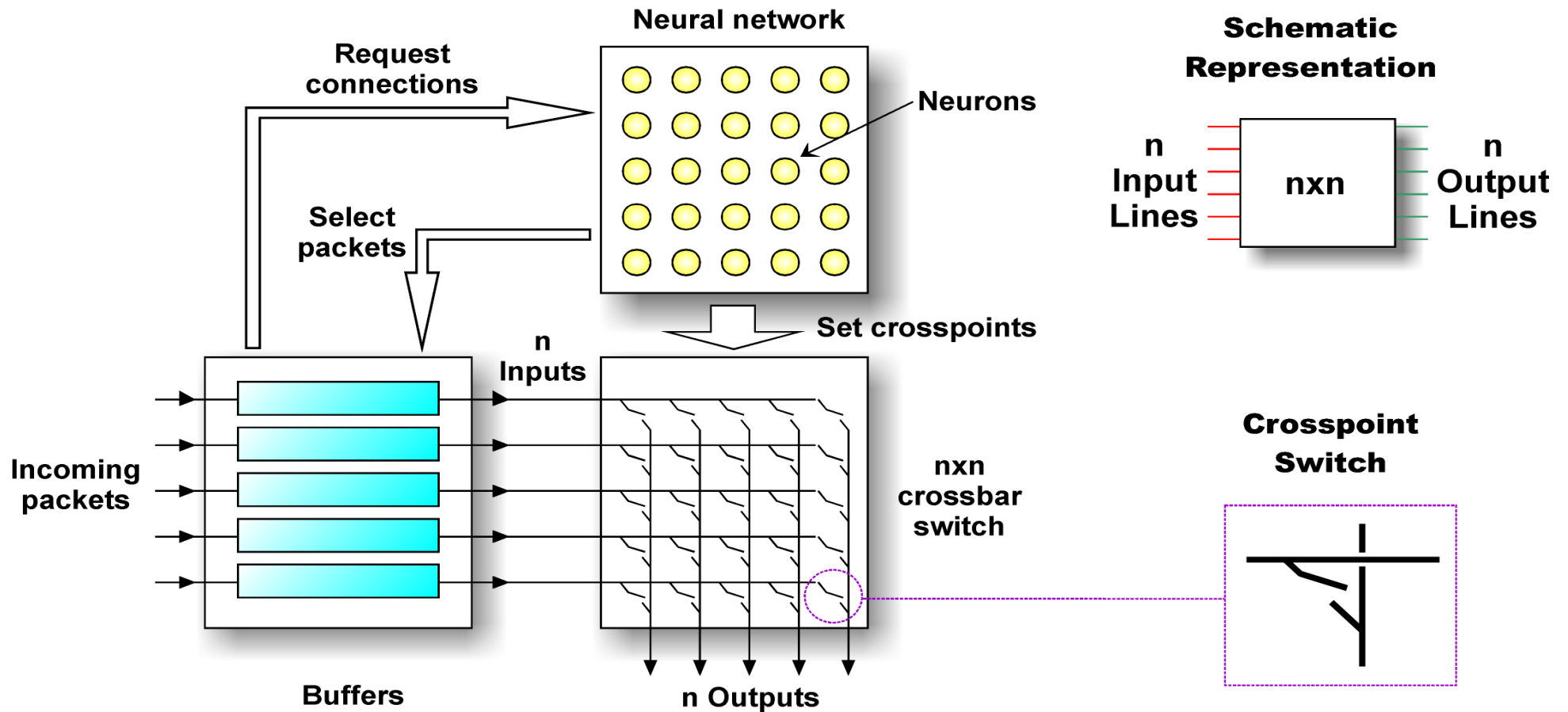Their inherent parallelism allows them to outperform any other known method at higher orders.

Optoelectronic Neural Networks

- Neural network scalability limited in silicon.

- Free-space optics can be used to perform interconnection.

- Optoelectronics allows scaleable networks.

- Input summation is also done in an inherently analogue manner.
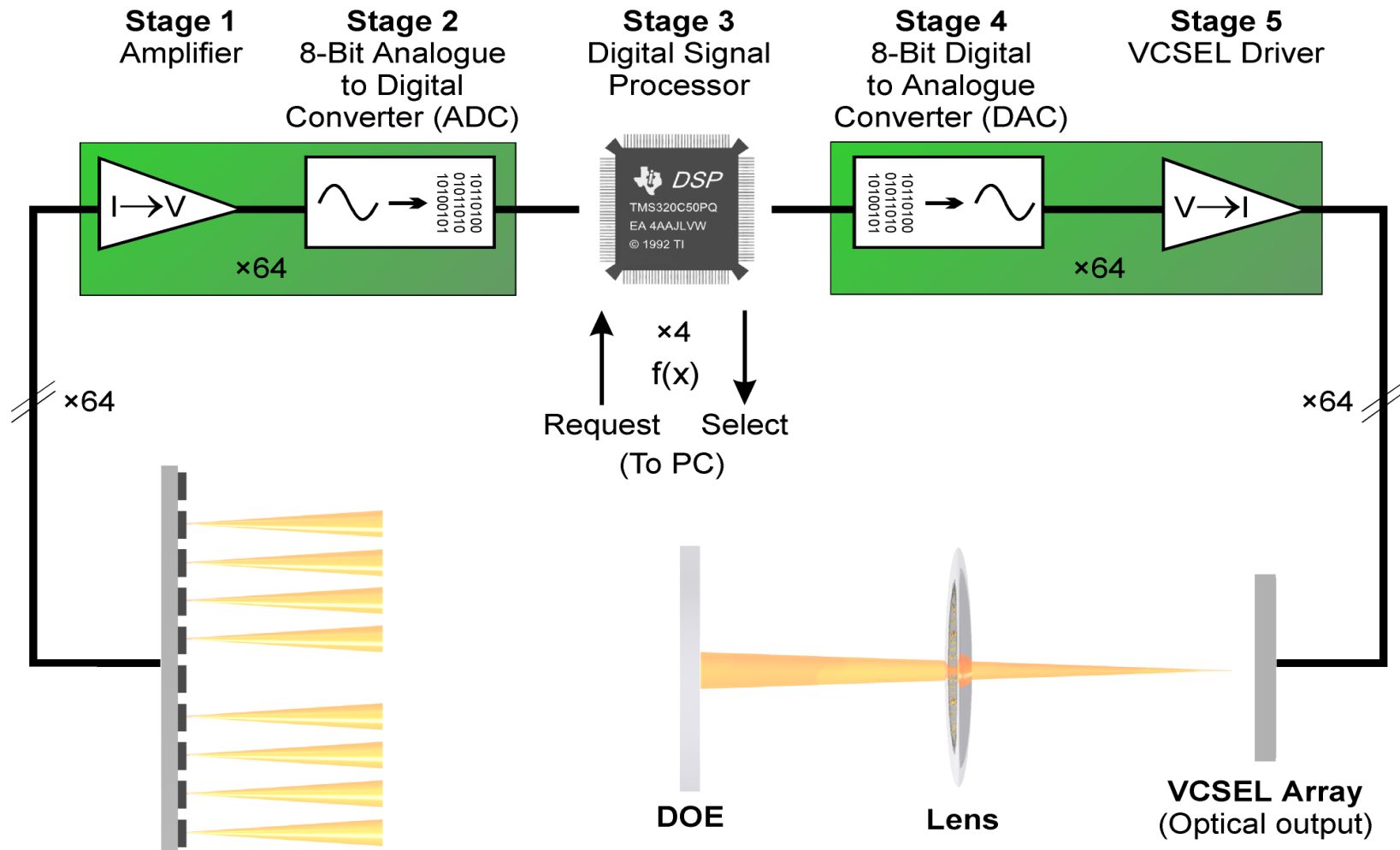
- Noise added naturally.

Neural Processing Element (Neuron)

Crossbar Switching

Request connections

Neural network

Neurons

Select packets

Set crosspoints

Incoming packets

Buffers

n Inputs

nxn crossbar switch

n Outputs

Schematic Representation

n Input Lines

nxn

n Output Lines

Crosspoint Switch

Current System

Electronic System

Stage 1
Amplifier

Stage 2
8-Bit Analogue
to Digital
Converter (ADC)

Stage 3
Digital Signal
Processor

Stage 4
8-Bit Digital
to Analogue
Converter (DAC)

Stage 5
VCSEL Driver

Detector Array
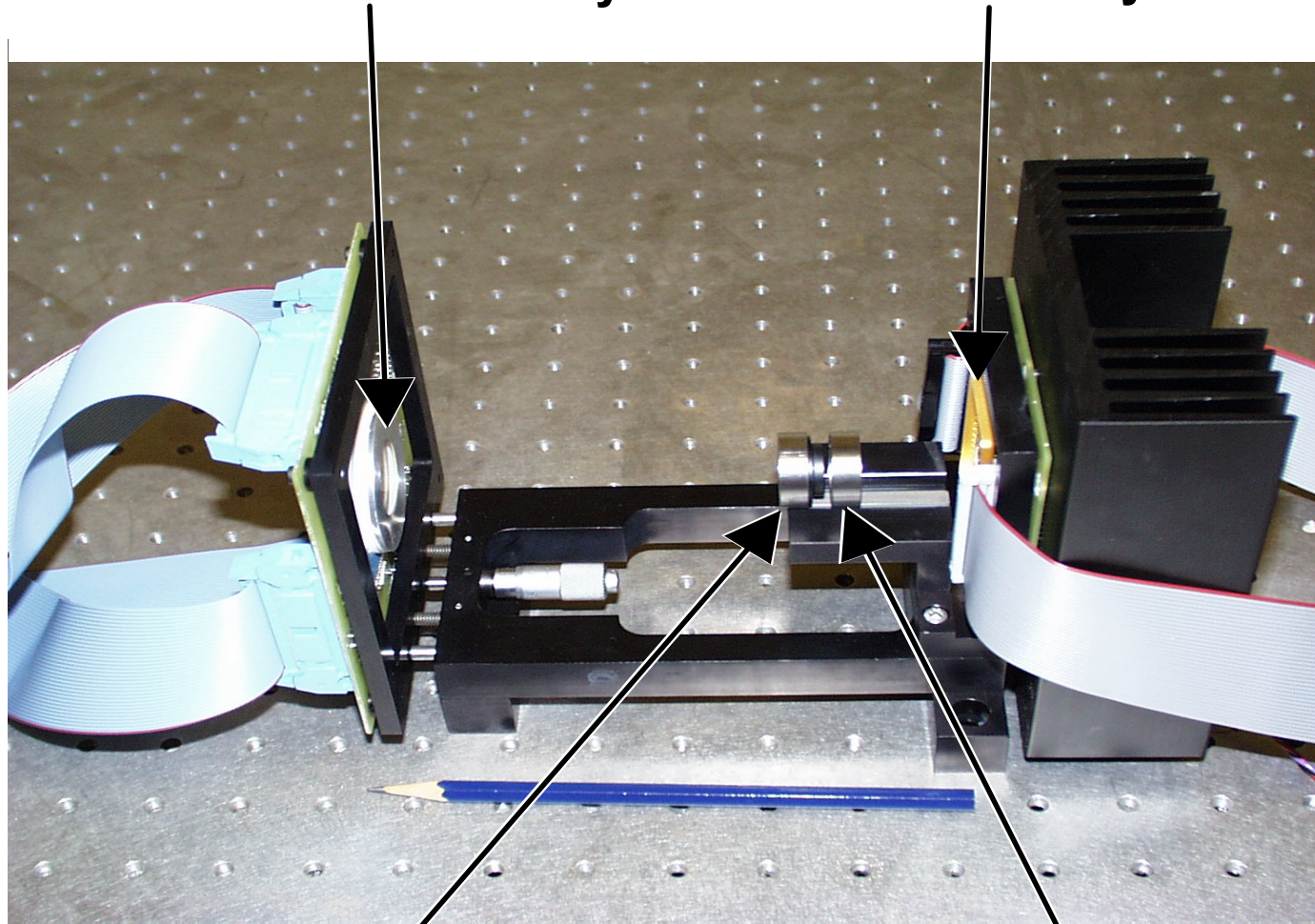(Optical input)

DOE

Lens

VCSEL Array
(Optical output)

Optical System

Optical System

Photodetector Array
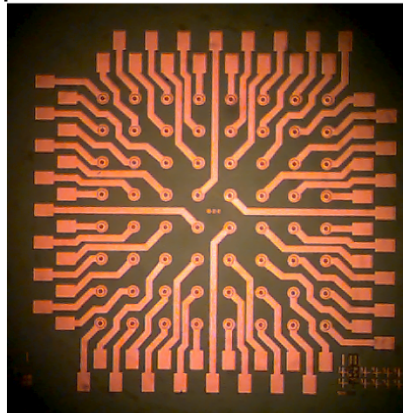
VCSEL Array

DOE Ø15mm
Period 90µm

Lens Ø10mm
f=100mm-150mm

The VCSEL Array

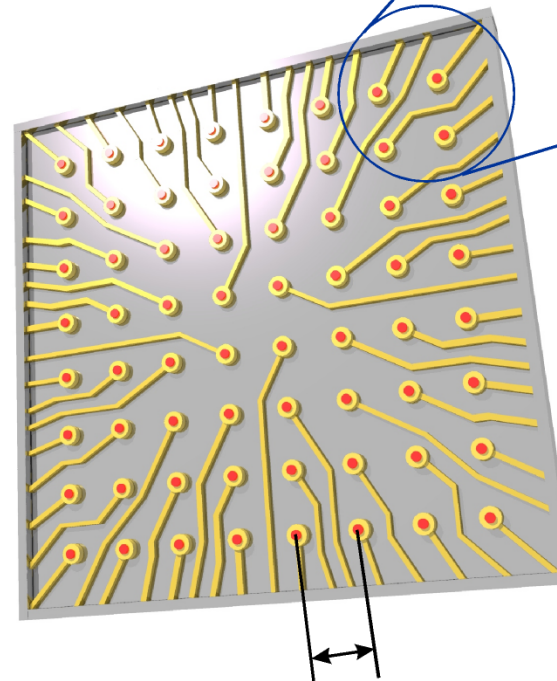The VCSEL (Vertical Cavity Surface Emitting Laser) is a laser diode that emits from the surface of the substrate.

Capable of GHz operation.

Magnified

8x8 VCSEL array (CSEM now Avalon)

VCSEL array photograph 2.8mm

λ=960nm, P~2mW @ 8mA.

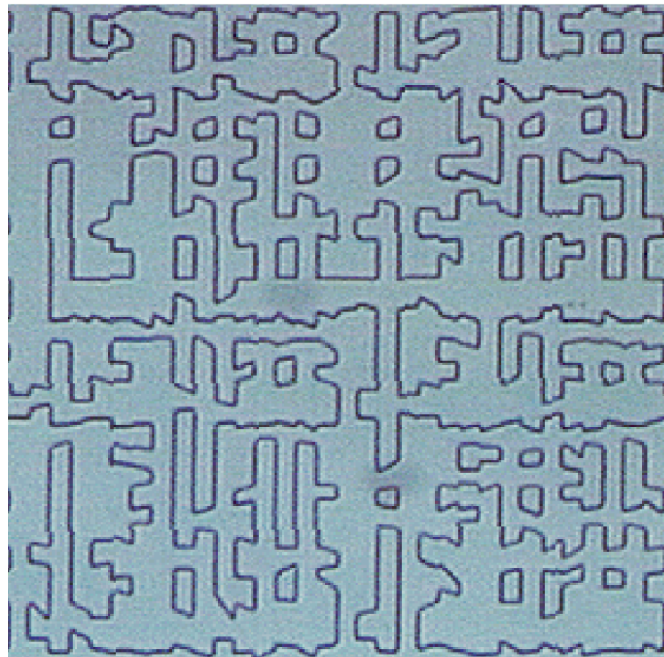**VCSEL contact**

VCSEL output Ø=10µm

Interconnect

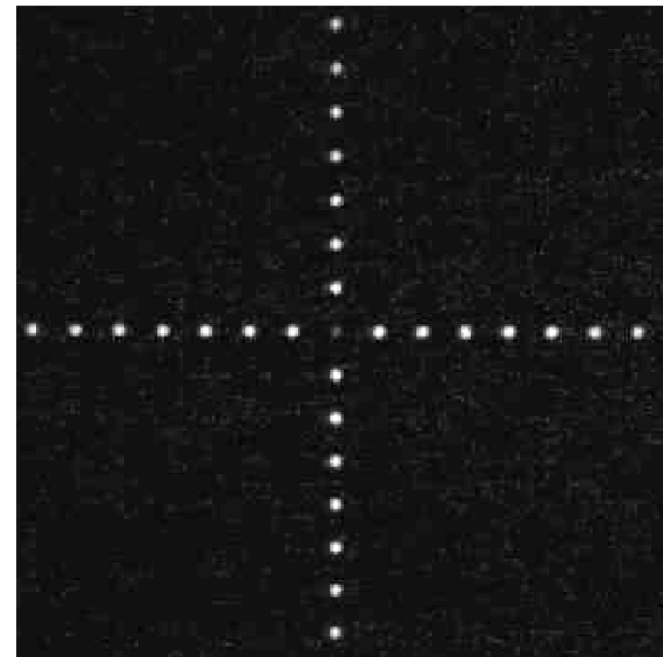**Substrate (GaAs)**

Spacing: 250µm

Diffractive Optic Elements (DOEs)

- Binary DOE.

- Efficiency: ~50-60%.

- Non-uniformity: <3%.

- Period Size: 90μm.

- Large fan-out possible.

Sample Binary DOE

DOE Output (Single beam input)

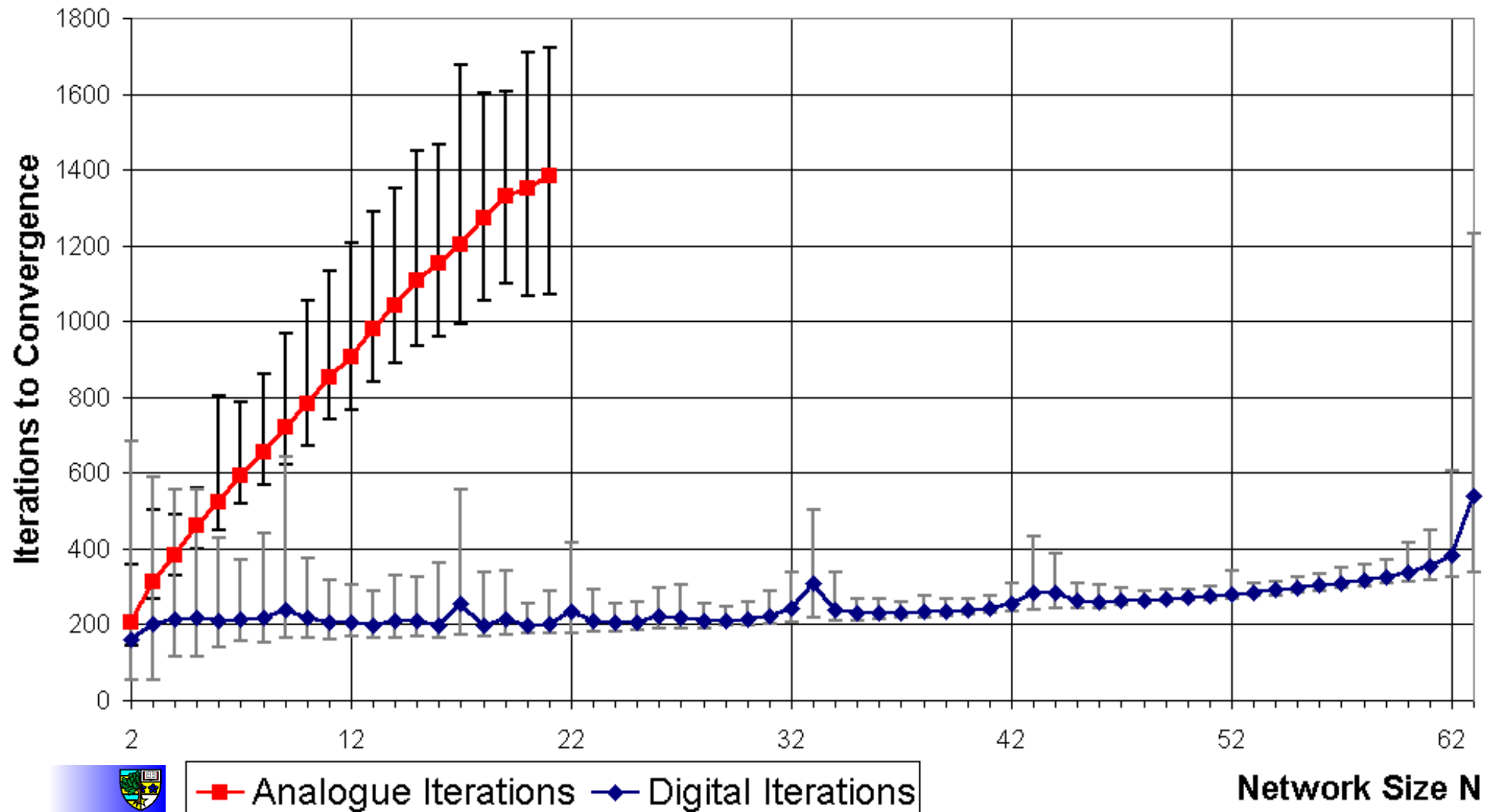These elements are used as array generators and interconnection elements.

Detector Arrays

Photodetectors act as input devices and are currently available in a wide range off-the-shelf.

They are already responsive enough to handle input from any emitter (speed >1GHz): however the faster they are driven the more power they require.
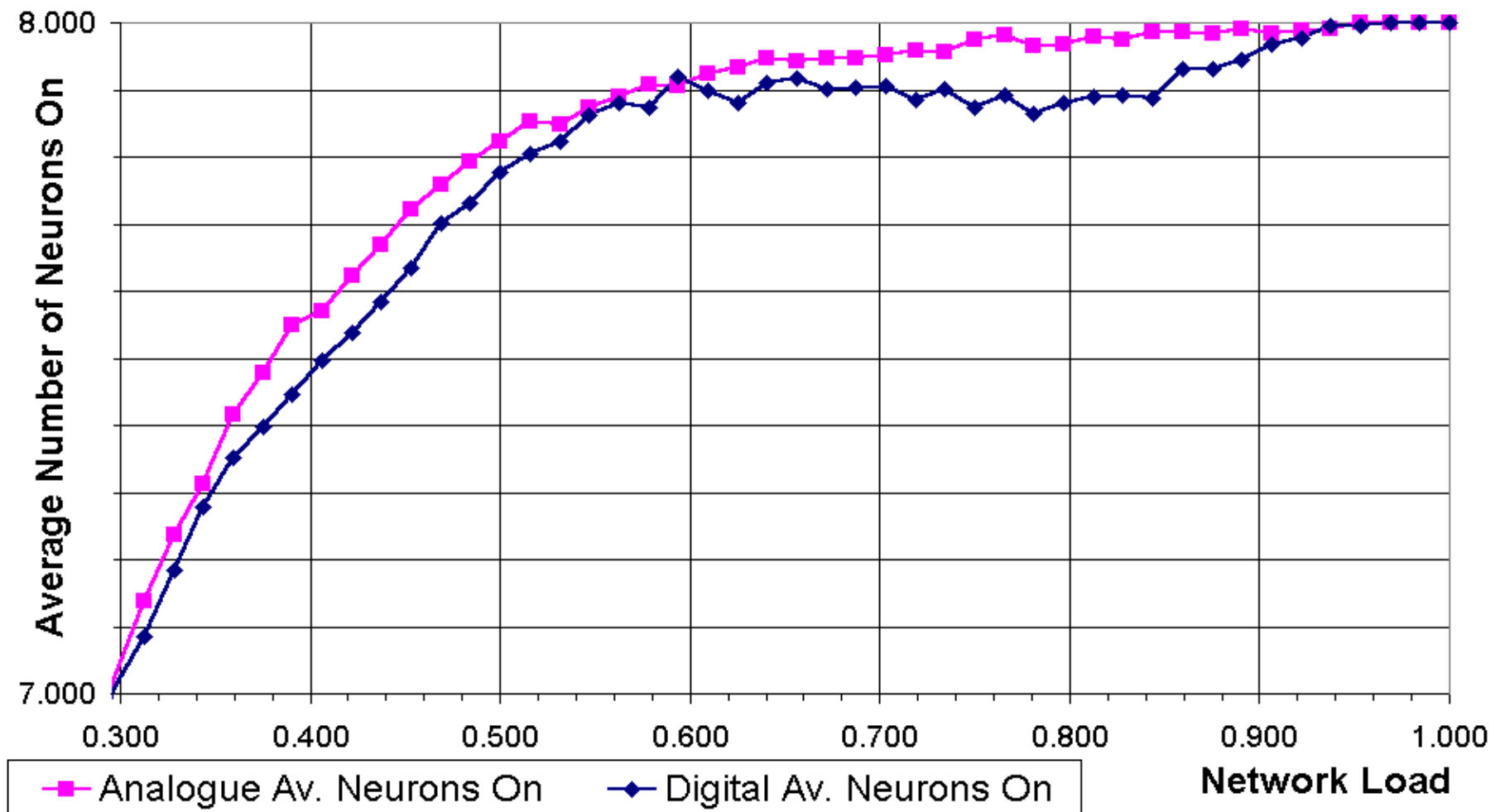
10x10 Centronic MD100-5T

Photodiode element

Magnified

1.4mm

0.1mm

Spacing: 1.5mm

Substrate (Si)
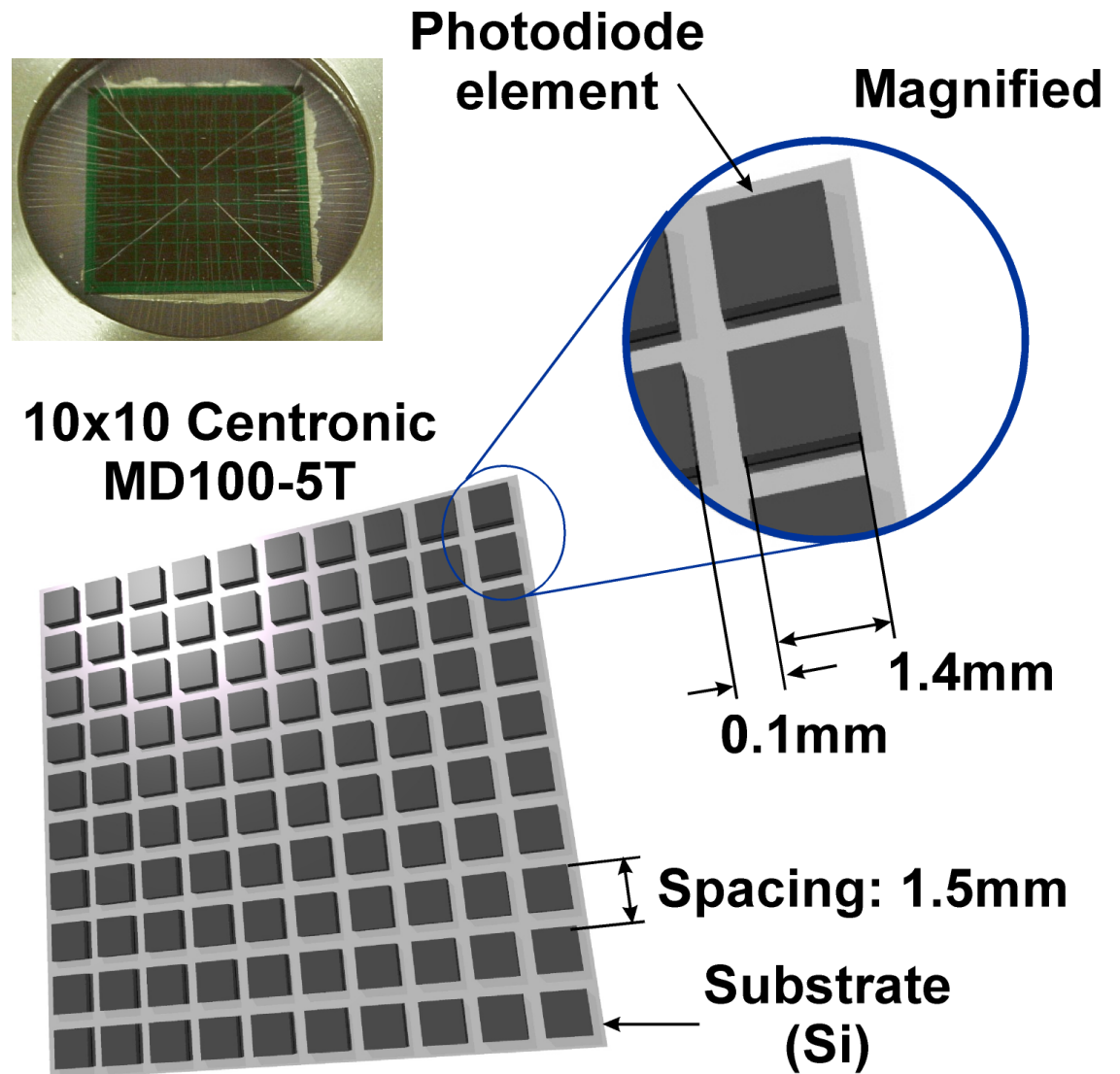
System Scalability

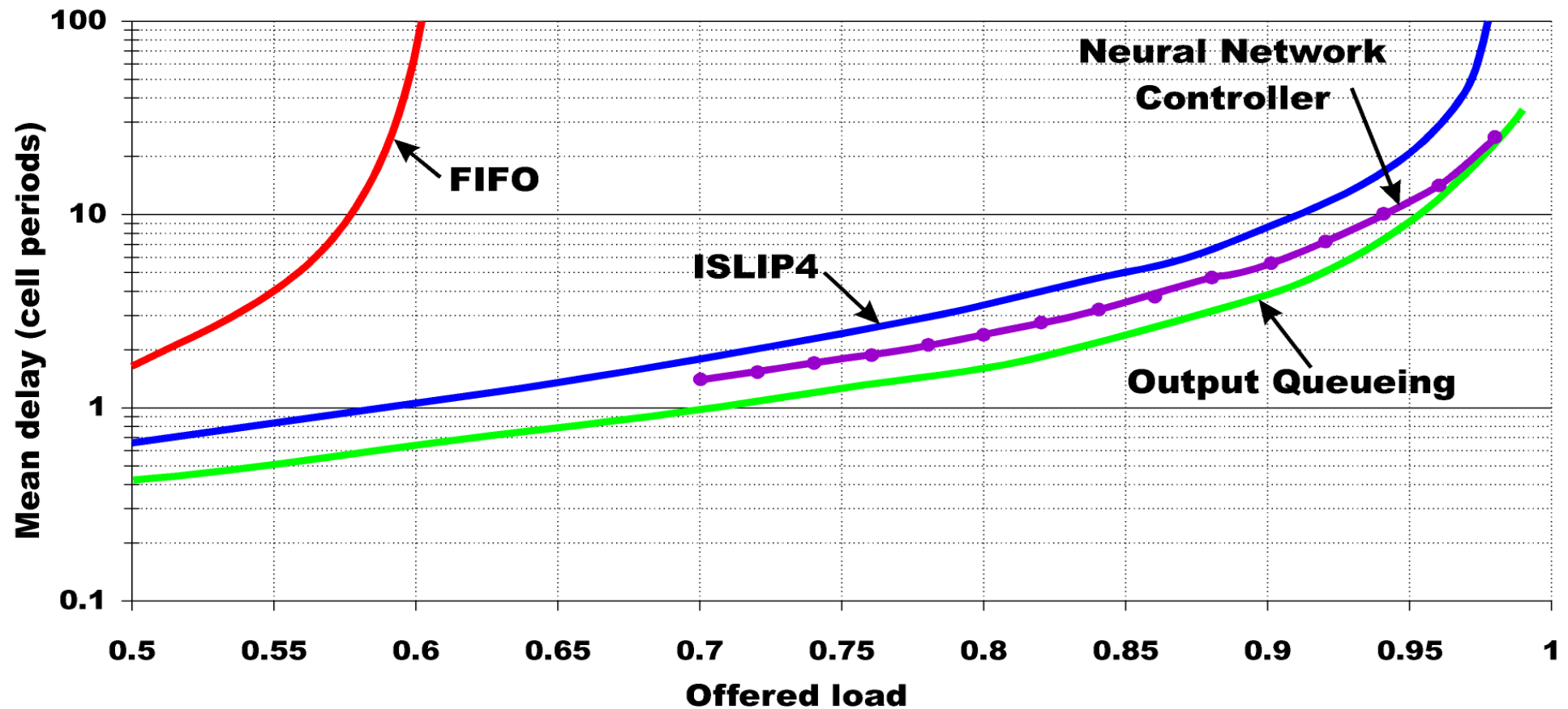## Iterations to Convergence Against Network Size N

Digital vs. Analogue

Comparison of Digital and Analogue Drivers

Analogue: Optimal ~97%. Digital: Optimal ~91%.

Mean Packet Delay

Conclusions

- Performance of 100MHz feasible, 1GHz foreseeable.

- Scalability mainly limited by VCSEL array size (N=16).

- A digital system running at 1GHz could supply 2.5 million switch configurations per second.

- Scalability independent of number of inputs/outputs (N).

- Further work:
  - Smart pixel implementation and packaging.
  - Examination of QoS provided by scheduler.
  - FPGA or custom ASIC implementation using optical interconnects.
  - Novel neural algorithms and learning.