# A Neural Network Scheduler for Packet Switches

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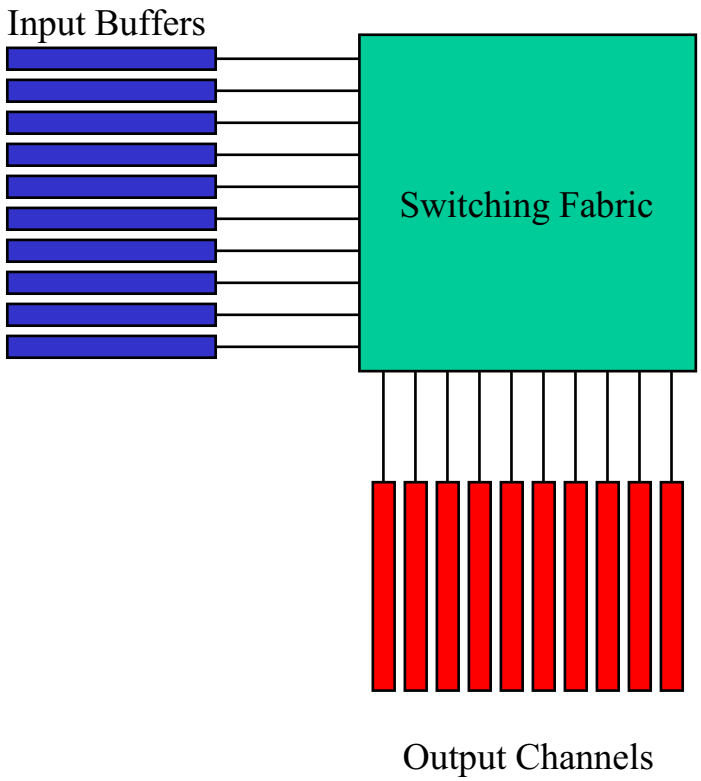
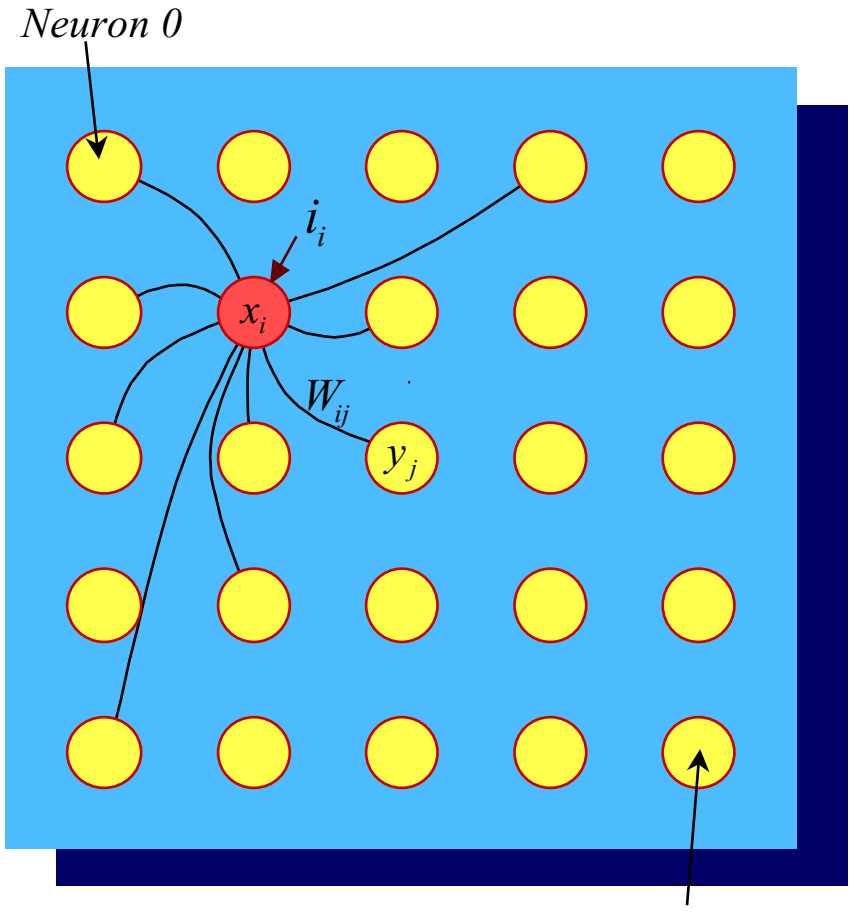
# The Resource Allocation Problem.

- Telecommunications routers require optimised throughput.
- Optimising throughput is a computationally non-trivial problem.
- Resource allocation problems map naturally to the high parallelism of neural networks.
- Interconnection between neurons is the limiting factor in the practical implementation of a neural switch controller.

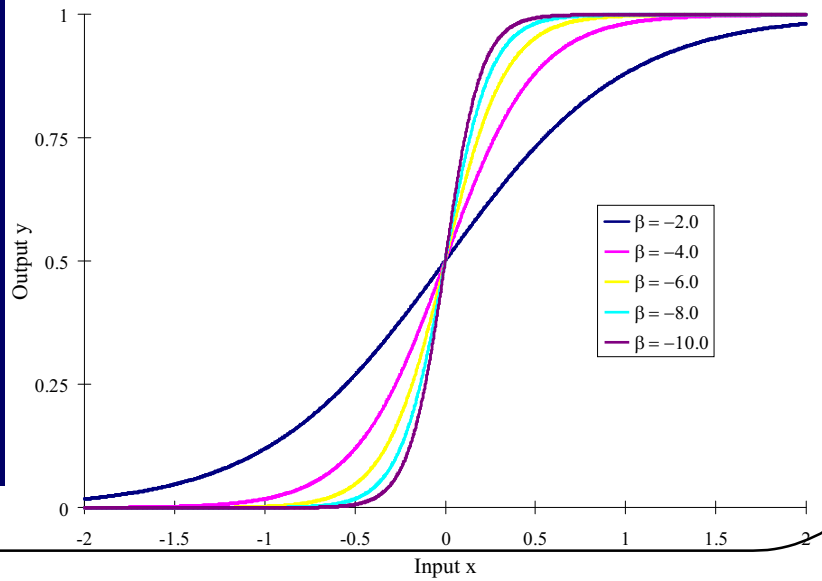


# The Hopfield Neural Network

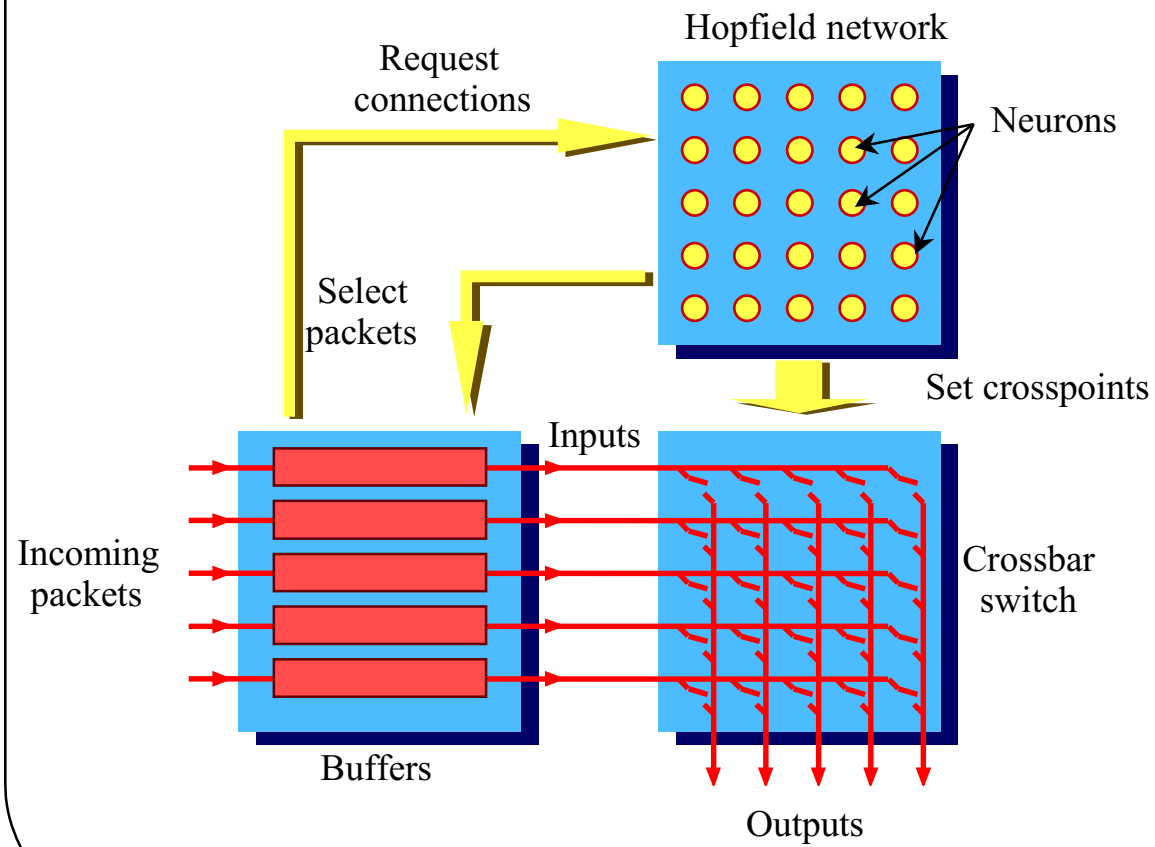



$$\frac{dx_i}{dt} = i_i\left(-\lambda x_i - \sum_{j=0}^{N-1} W_{ij} y_j + c_2 t_i\right)$$

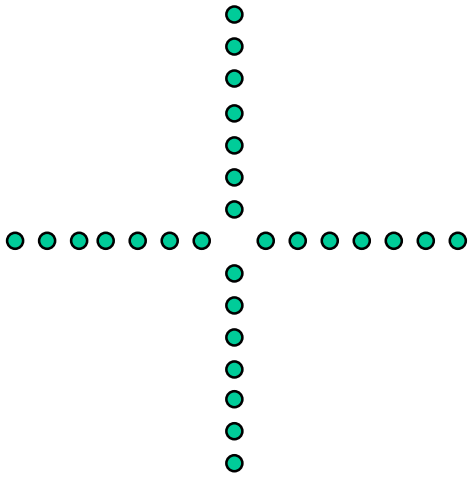
$$y(x) = O_{\min} + \frac{O_{\max} - O_{\min}}{1 + \exp(\beta x)}$$



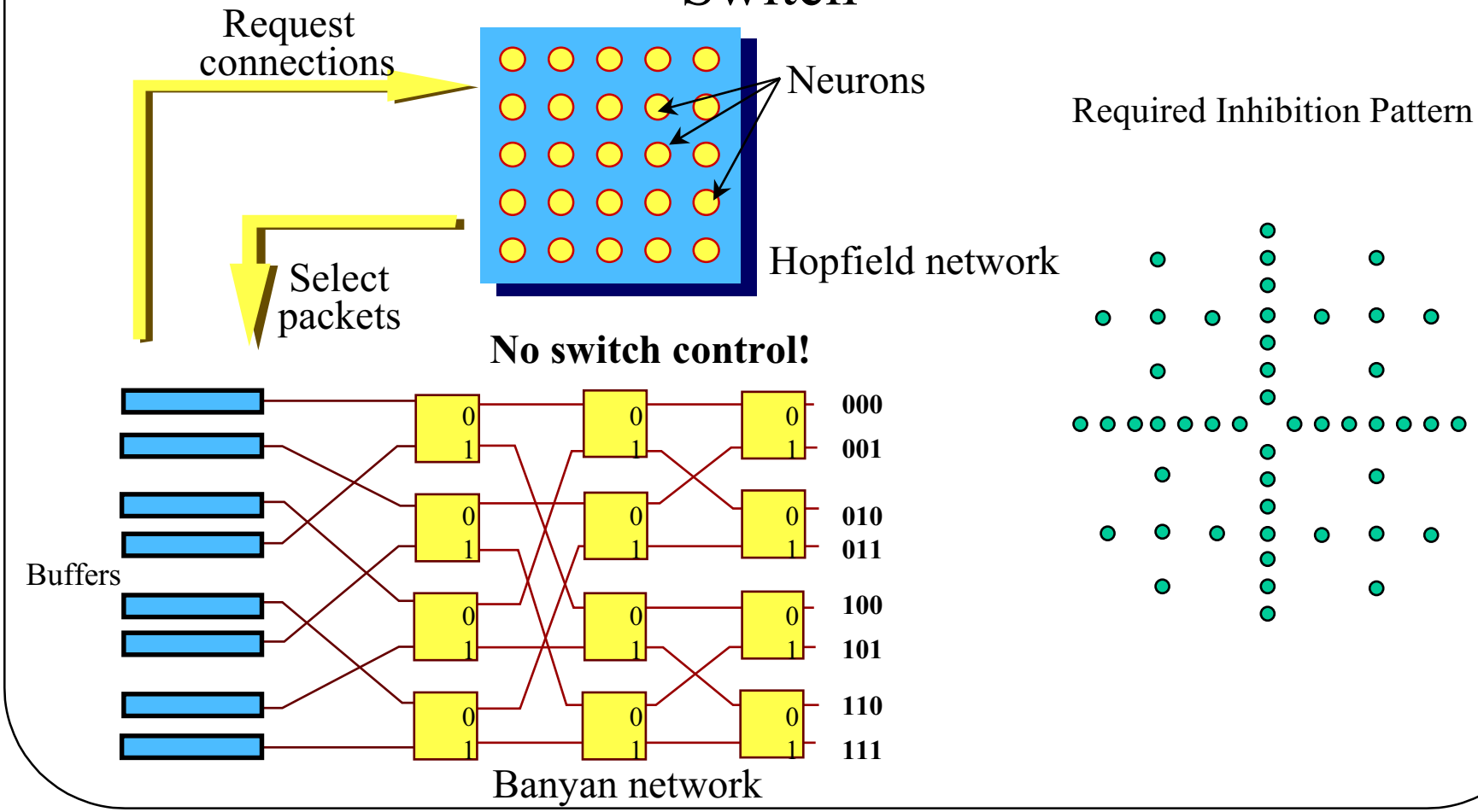
# Hopfield Network Controller for Crossbar Switch



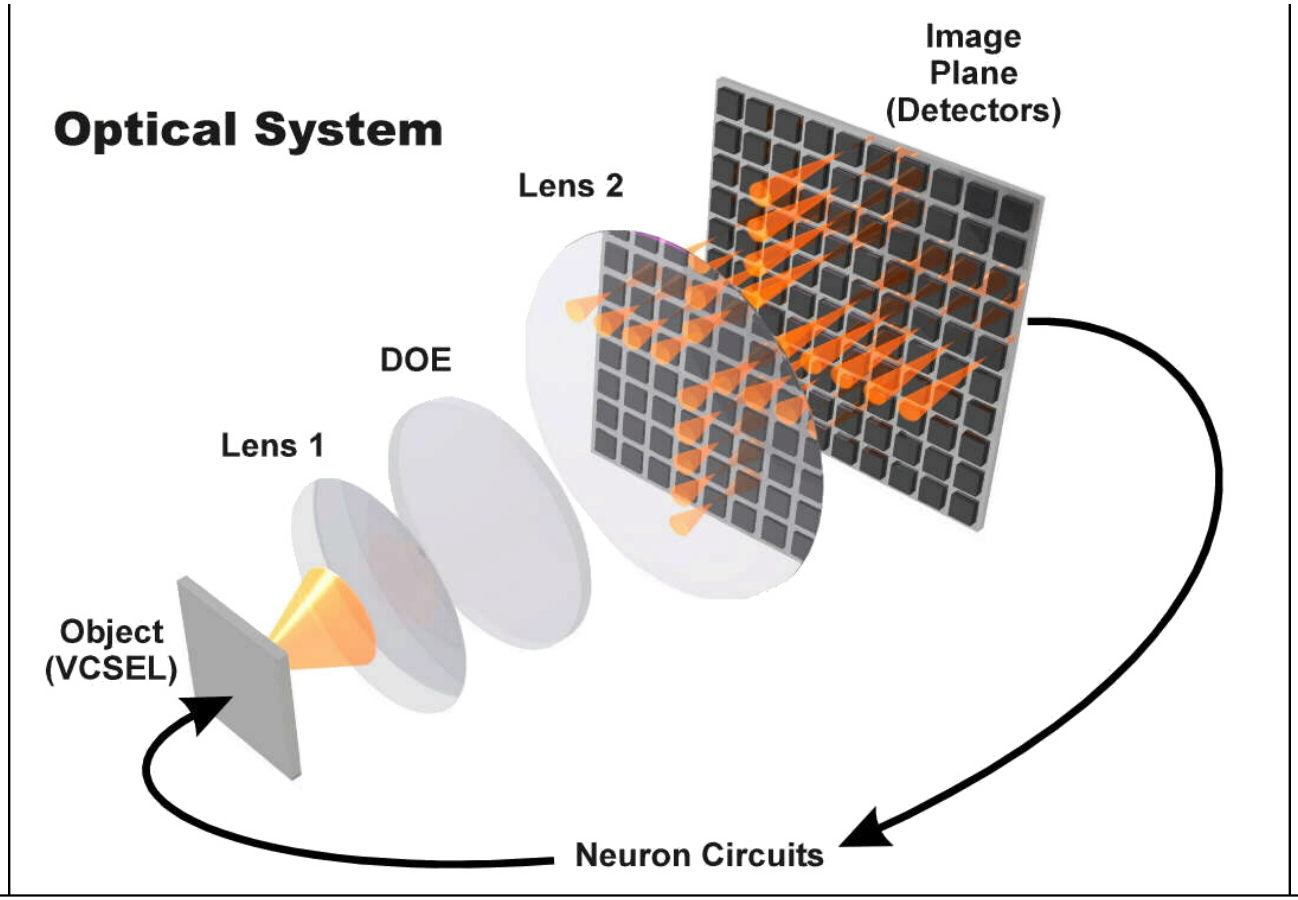

Required Inhibition Pattern



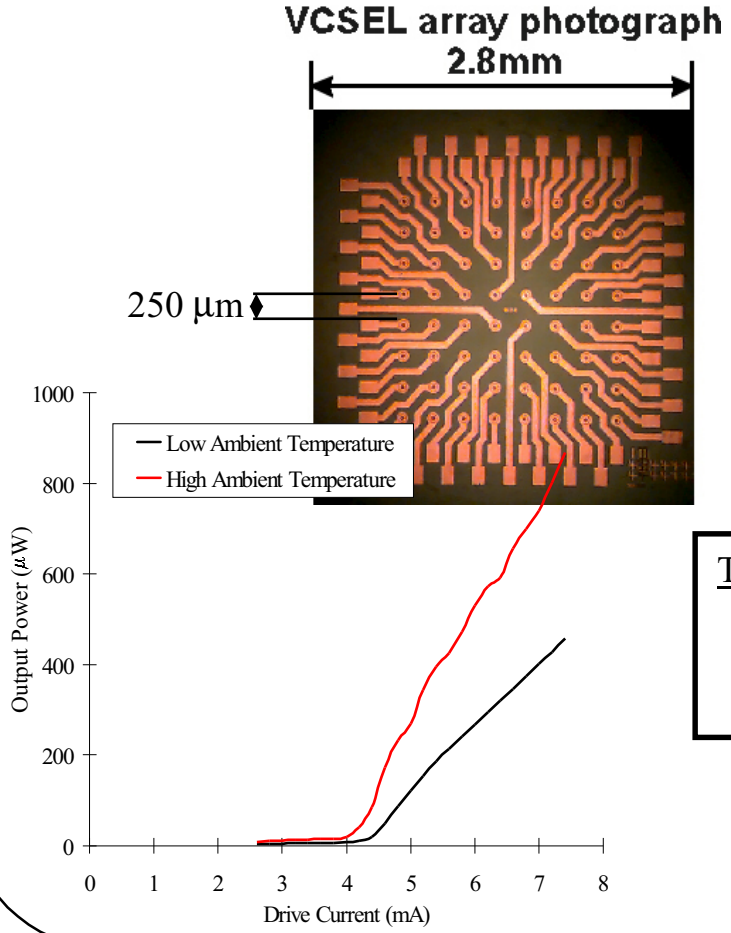
# Hopfield Network Controller for Self-Routing Switch

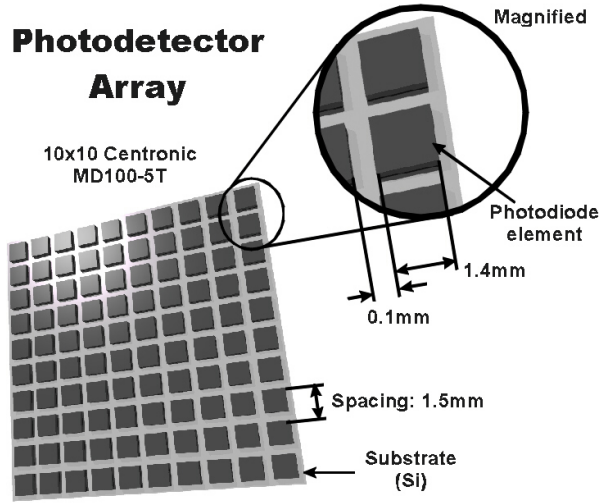


# Optical Implementation of a Hopfield Neural Network



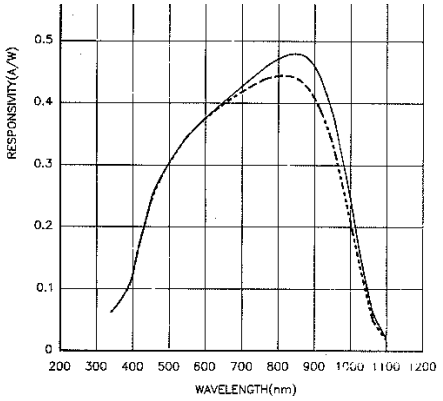
# Optoelectronic Hardware



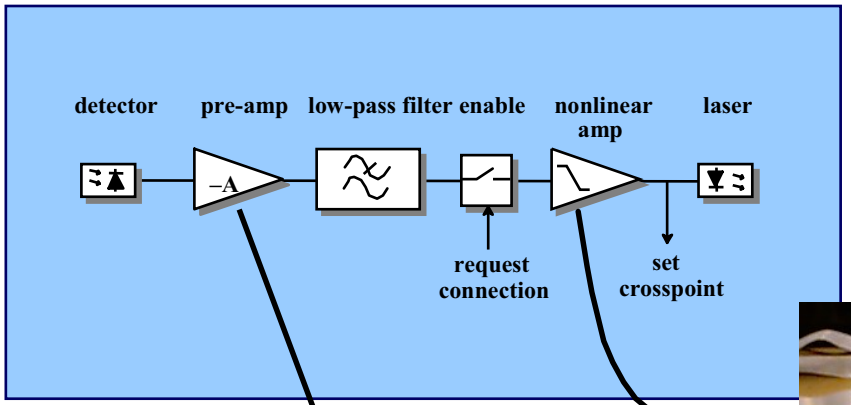

Typical switching times

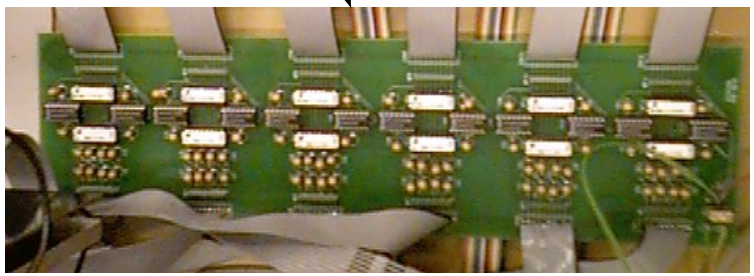
VCSEL - 1-10 ns
Photodetector - ~30ns

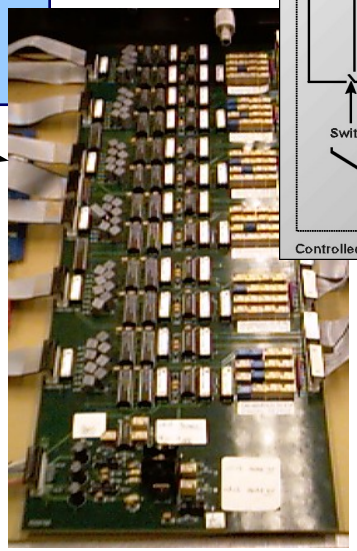


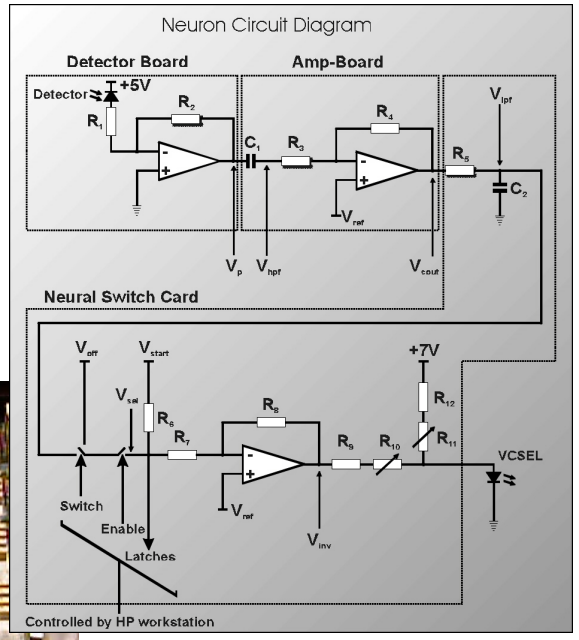
# Electronic Hardware

Neural Feedback Circuit








Neuron switching is governed by the time constant of the electronic circuits. This circuit switches in ~200µs.

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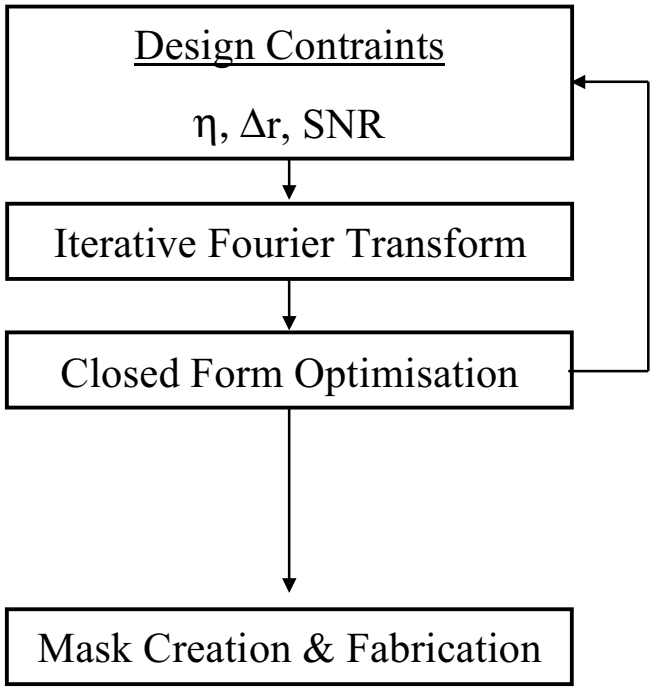
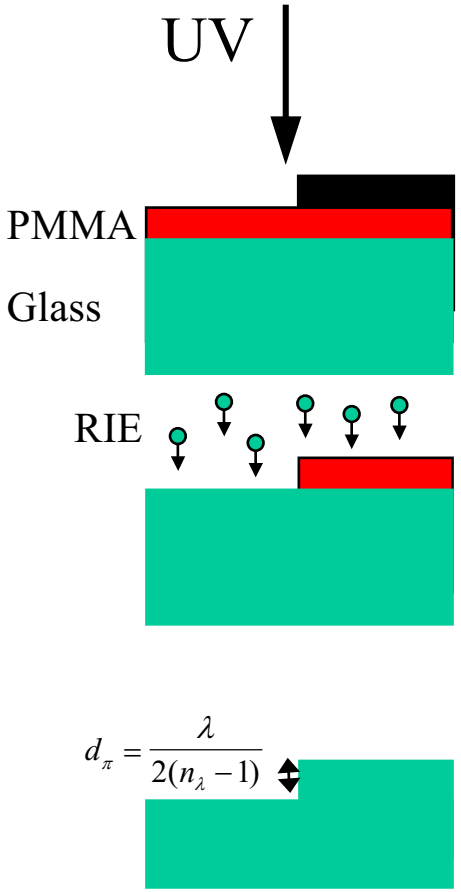
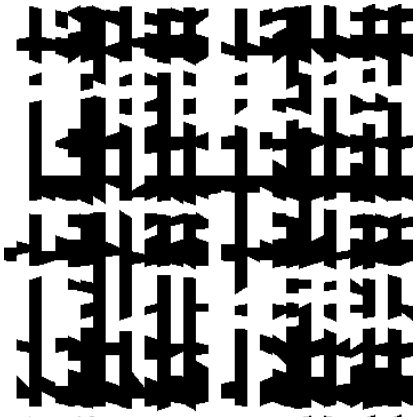
# DOE Optimisation and Fabrication

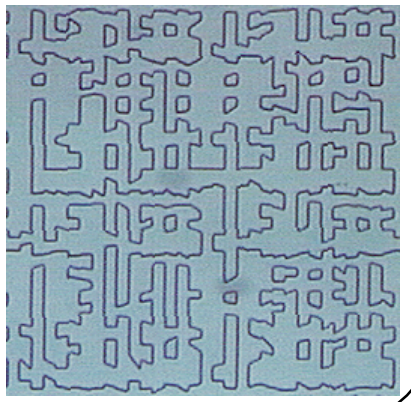



Theoretical Profile

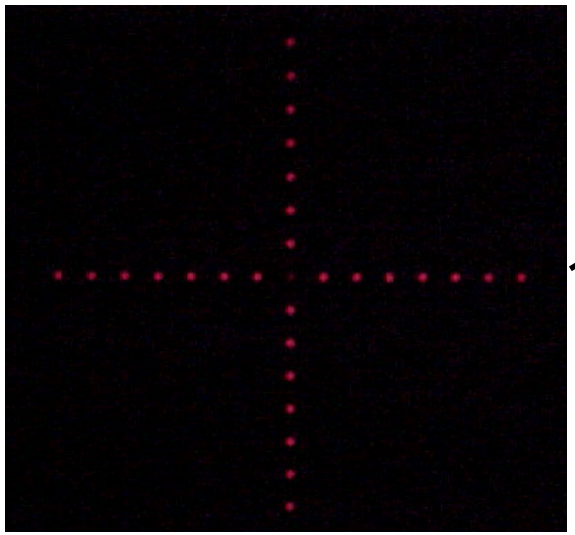


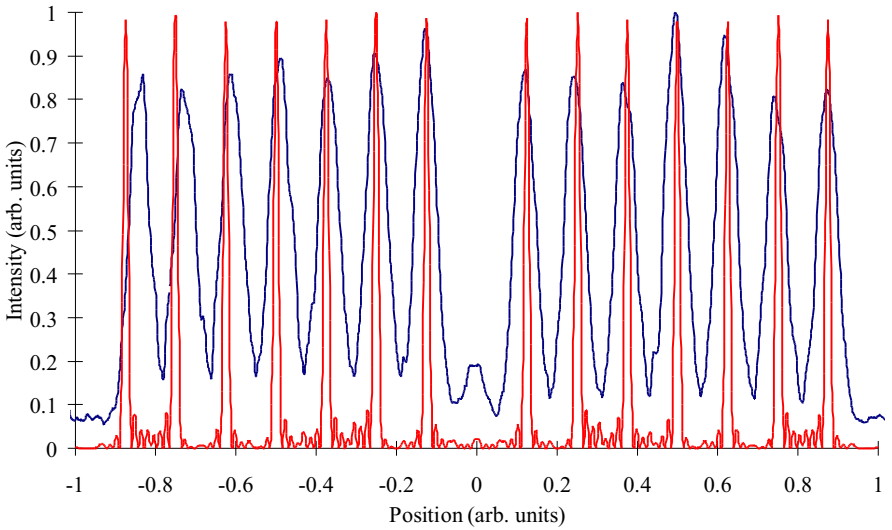
Actual Profile



# Diffractive Optical Elements

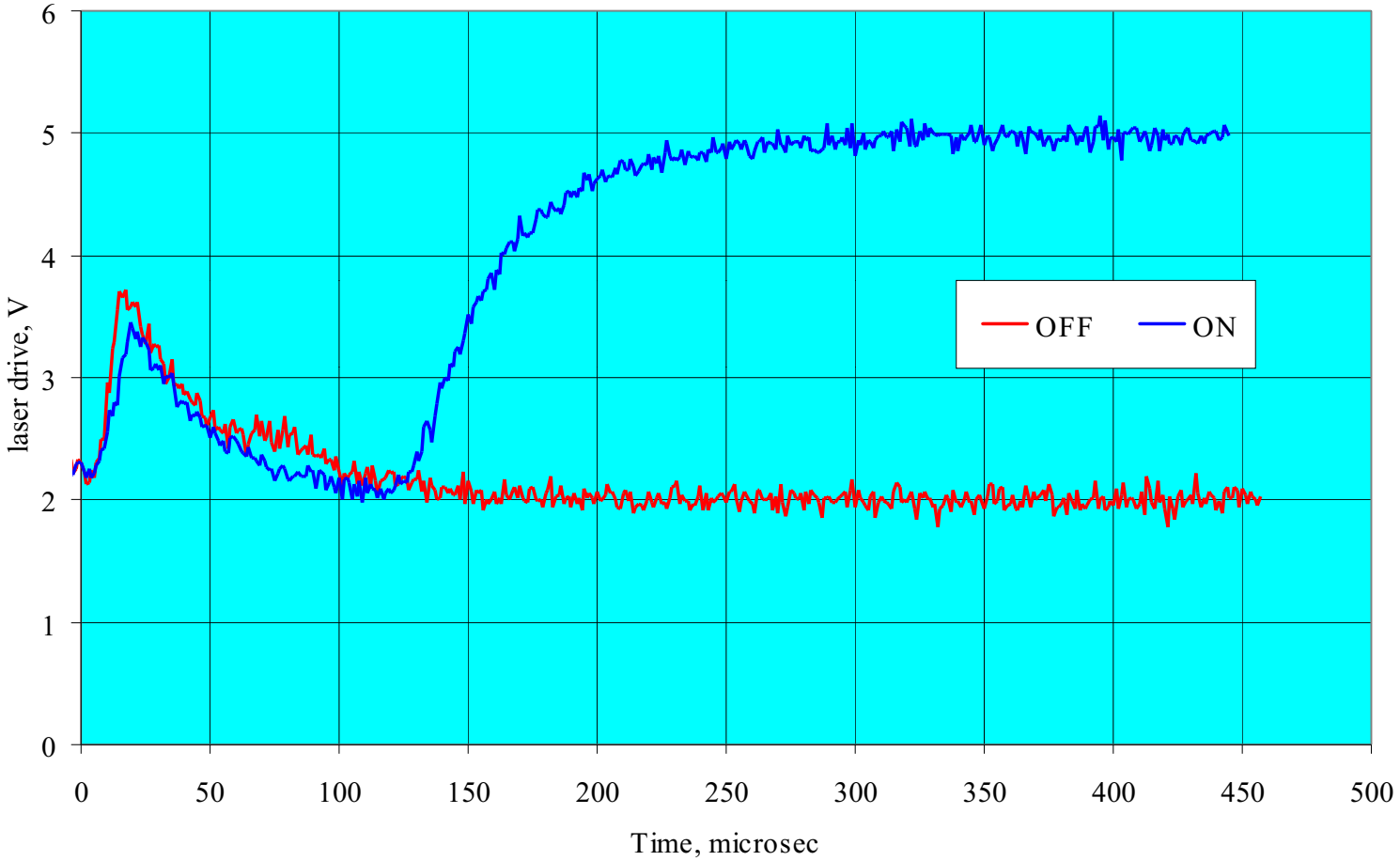
Element for Crossbar Switch Controller






Order separation, $s = \frac{f\lambda}{T}$

# Results from Hopfield Network Controller : Neuron Switching

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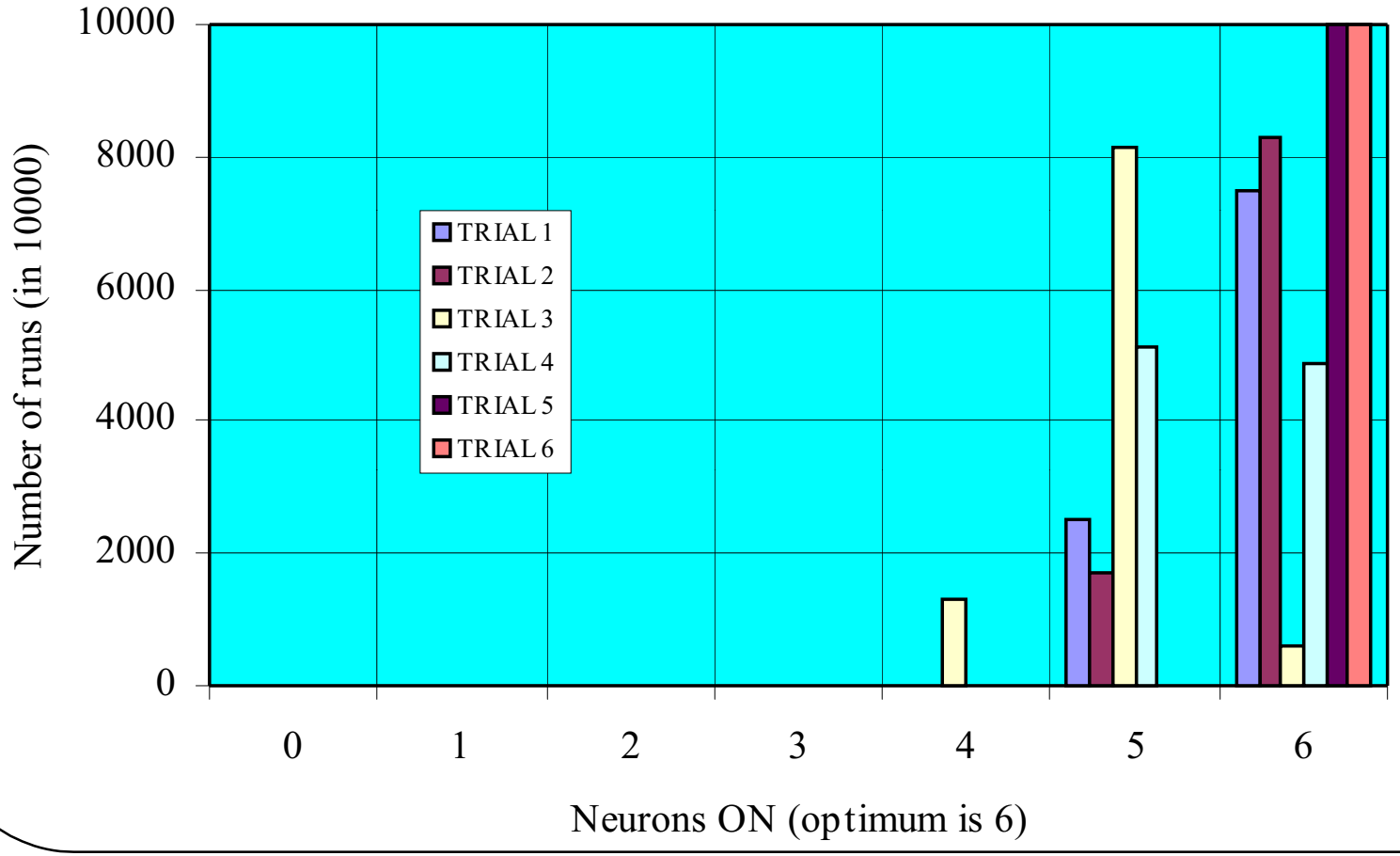
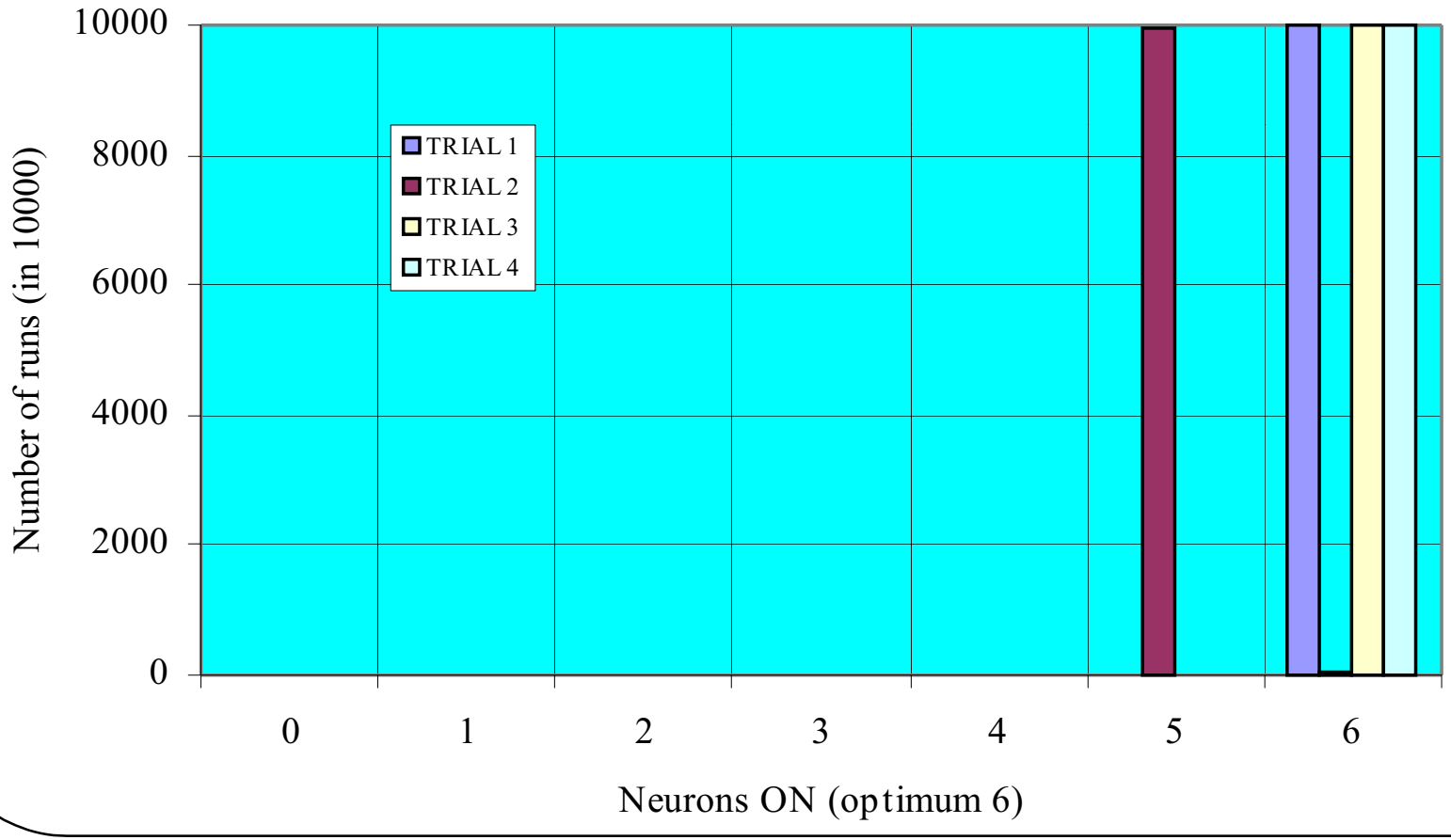
# Results from Hopfield Network Controller Crossbar Switch



# Results from Hopfield Network Controller Self-Routing Switch

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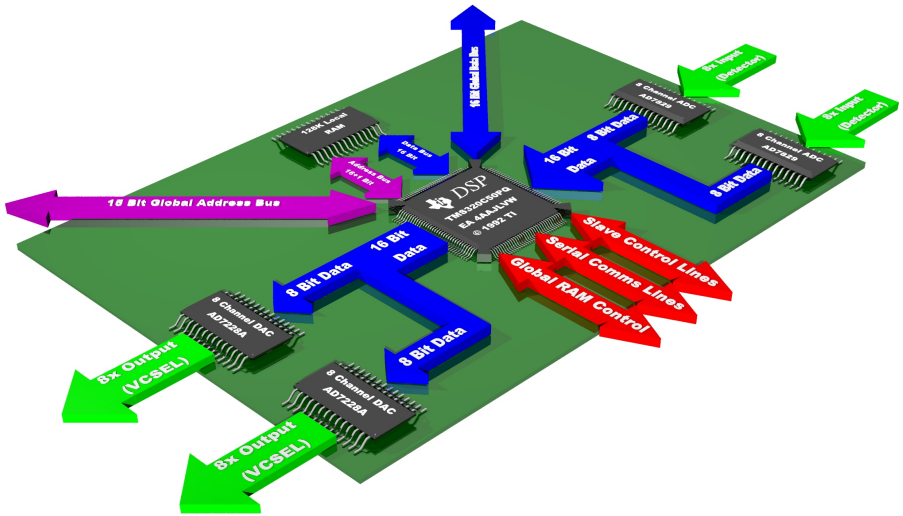
# The Next Generation Hopfield Demonstrator.

- The current demonstrator is physically large, slow and intolerant to variations in operating parameters.
- A faster, more tolerant demonstrator based around programmable DSP chips is being designed at Heriot-Watt.
- The DSP chips combined with higher efficiency VCSELs driven by analogue ASICs will reduce the overall size of the demonstrator.
- DSP programmability allows neuron response to be varied and system behaviour altered, e.g. prioritisation.

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# Conclusions

- Hopfield neural networks are an efficient method of optimising the throughput through a switching fabric.
- Diffractive Optics provide the necessary non-local interconnect bandwidth to implement a usefully large network.
- The decision speed of an optically interconnected Hopfield network is primarily controlled by the RC constant of the electronics, the optoelectronic conversion times being negligible.
- The next generation Hopfield network demonstrator will use high-speed DSP chips to provide programmable neuron responses.