Lighton

A high-fidelity reconfigurable photonic processor for NISQ computing

29/06/2023 - CLEO Europe

A. Cavaillès, P. Boucher, S. Gigan and K. Müller

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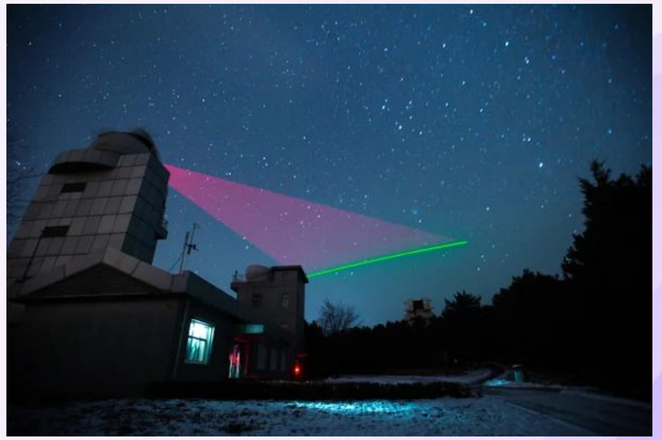
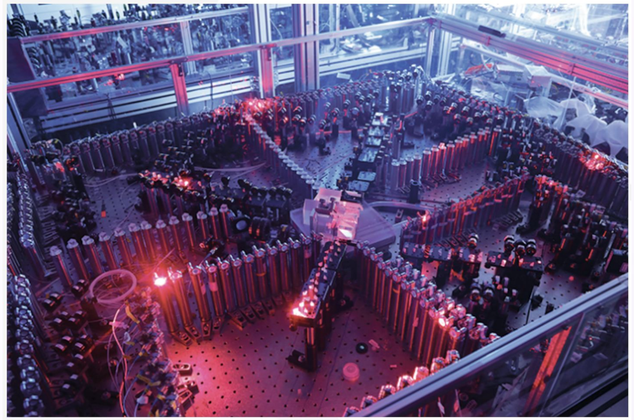
Optical quantum computing

Photons as carriers of quantum information

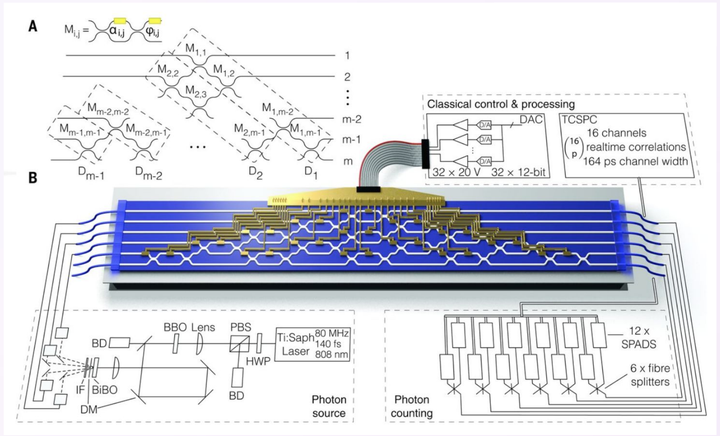
- Quick propagation
- Resistant to decoherence
- Mature infrastructure for control
- Easy interfacing with other quantum systems



Micius satellite for QKD



H.-S. Zhong et al, Science **370**, 1460 (2020)



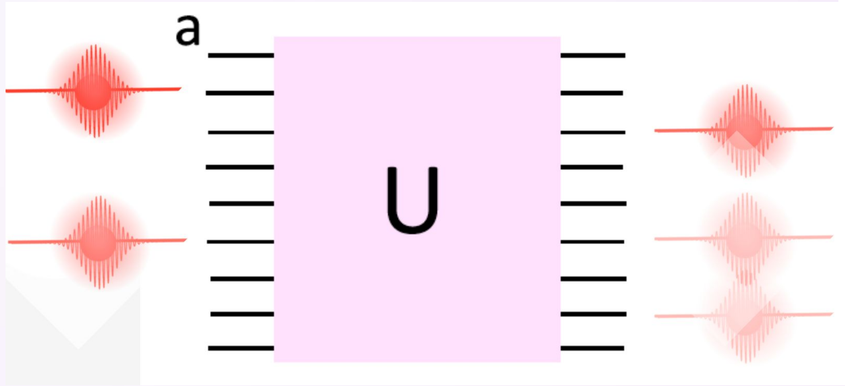
J. Carolan et al, Science **349**, 711 (2015)

Optical quantum computing

Programmable linear optical networks

- Q. state generation
- Q. communication
- Q. information processing
- Q. Machine learning
- …

Linear operation



Quantum sources

ID Quantique

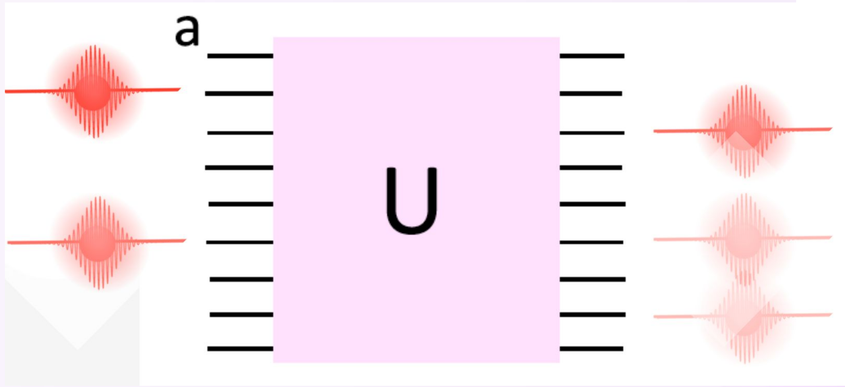
Pi Imaging

Detection

Optical quantum computing

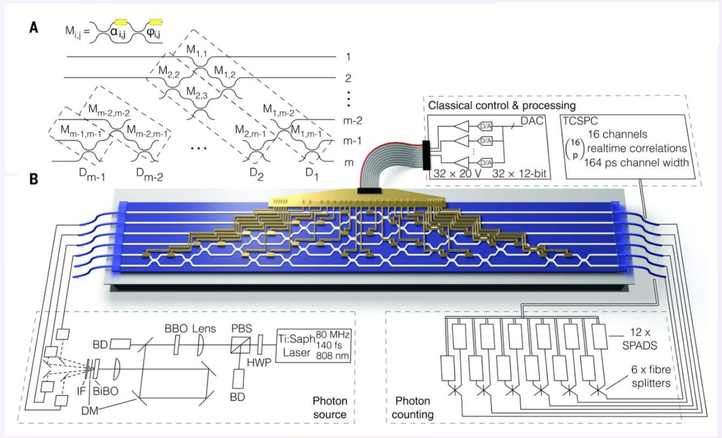
Programmable linear optical networks

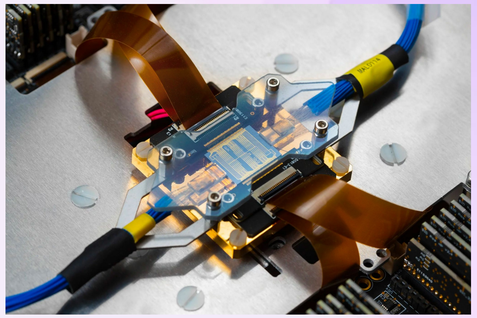
- Q. state generation
- Q. communication
- Q. information processing
- Q. Machine learning
- ...



Typical implementation: integrated circuits

Larger operations -> Complex scaling



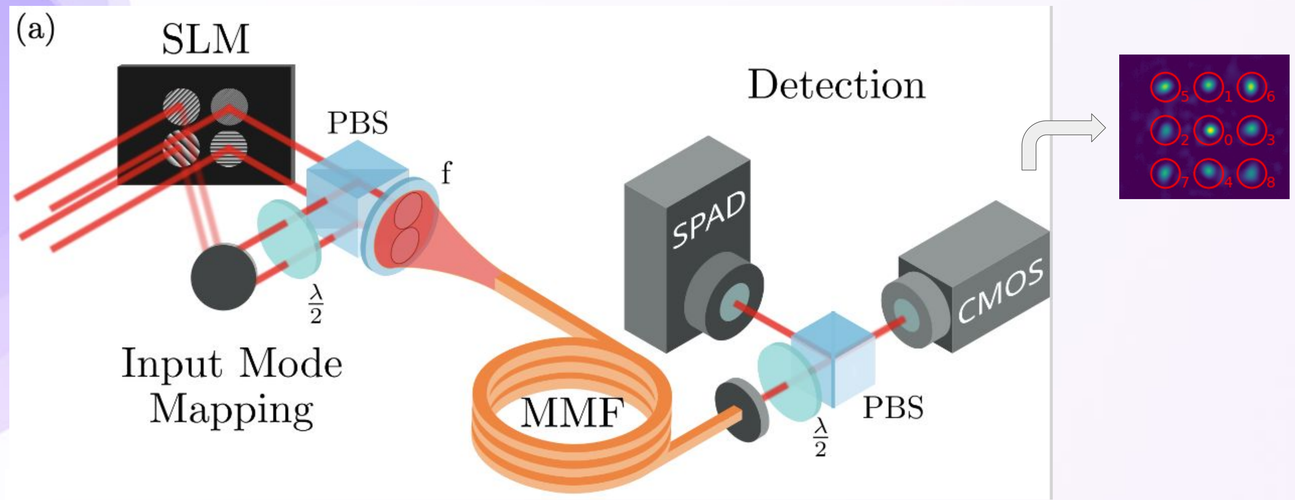


Quix

J. Carolan et al, Science **349**, 711 (2015)

Programmable linear network

Alternative method: mode mixing in complex media



A. Cavaillès et al, Optics Express **30**, 17 30058-30065 (2022)

Programmable linear network

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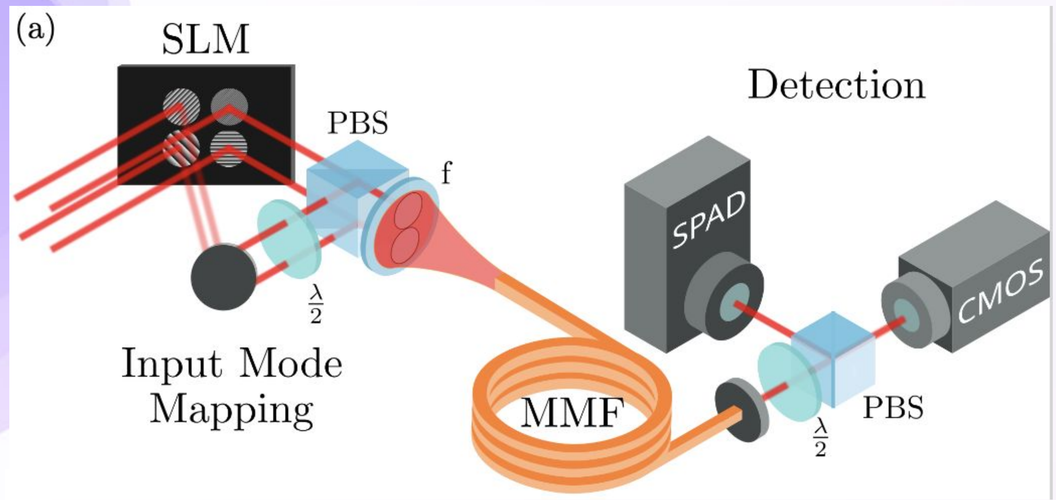

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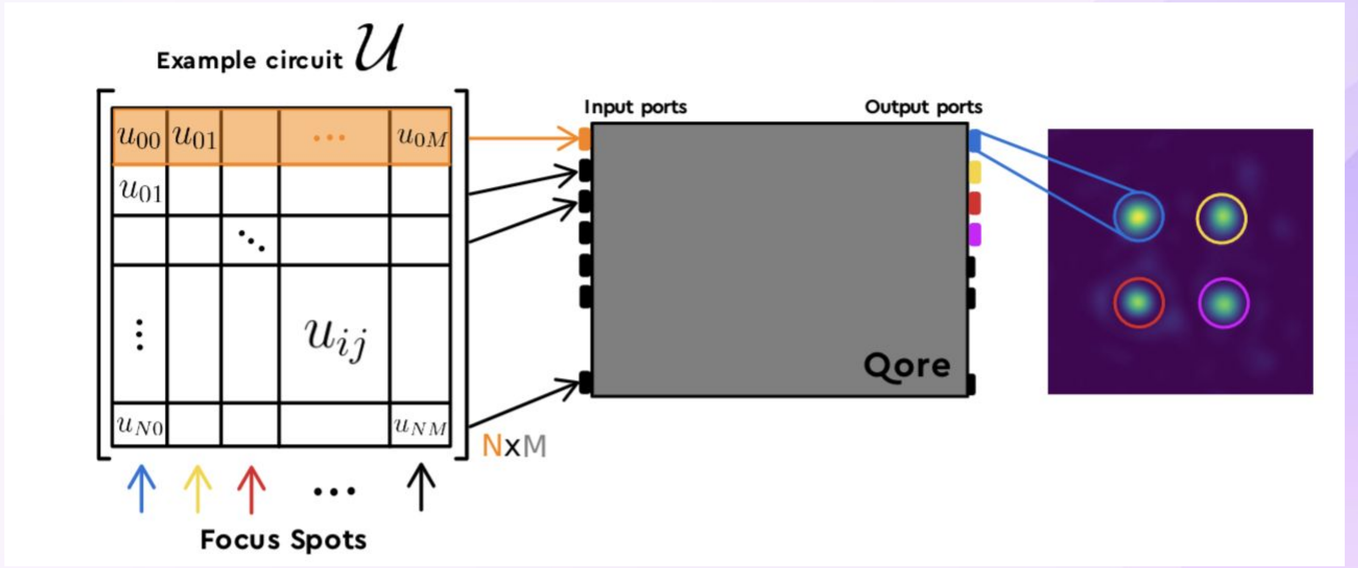
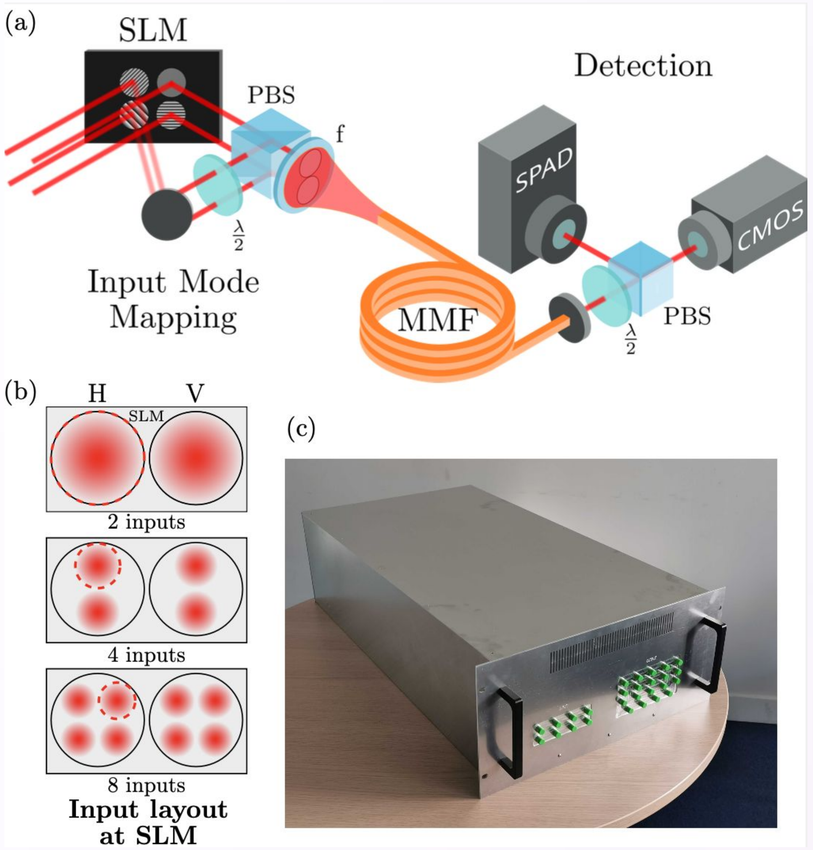
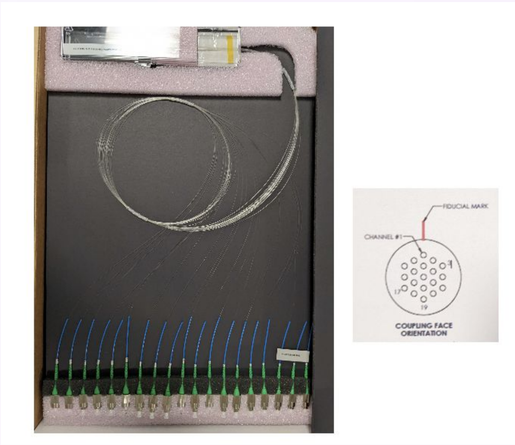


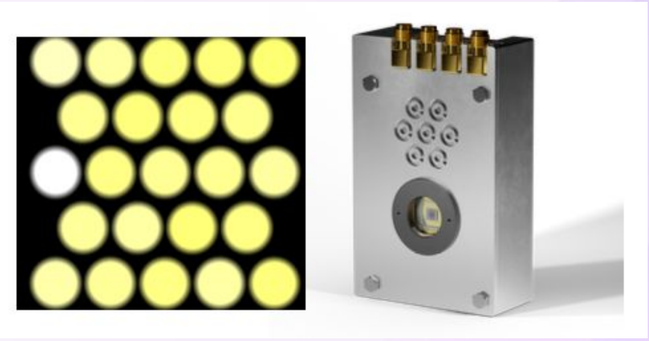
Circuit implementation

Programmable linear network

Alternative method: mode mixing in complex media







Pii Imaging

Output detection: fibered or free space

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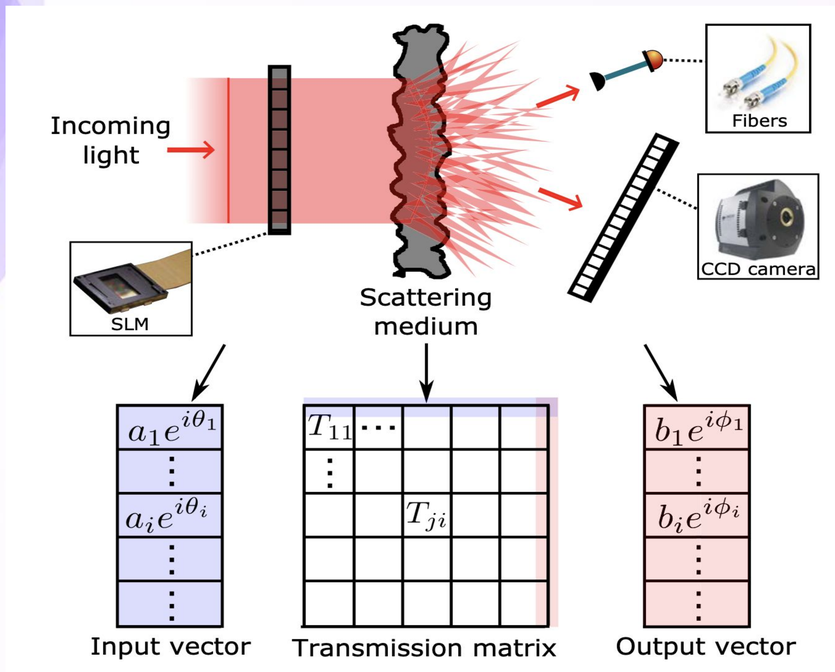
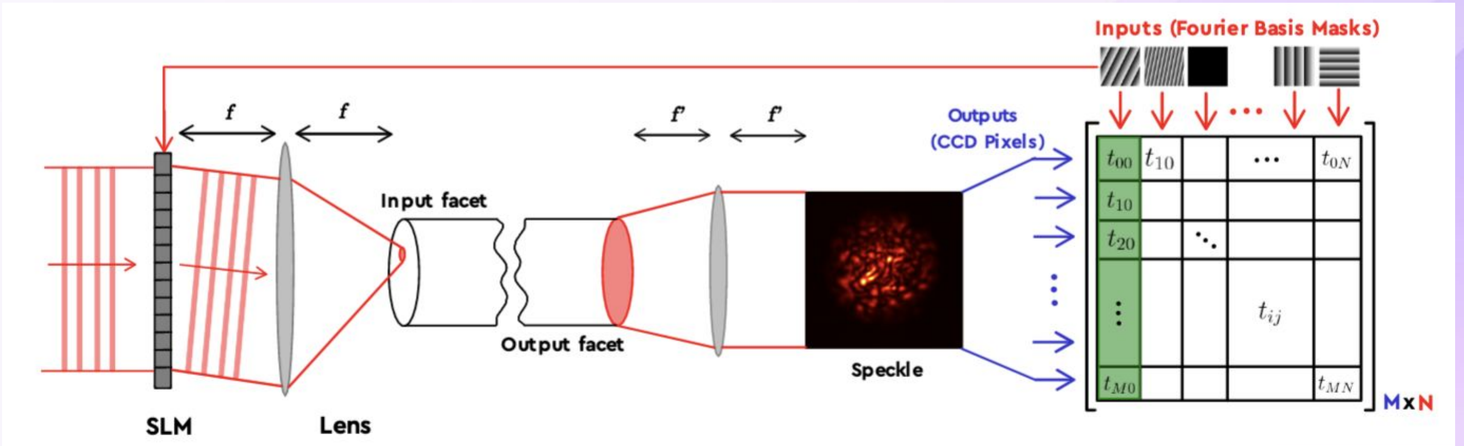
Programmable linear network

The process

- **Holography: measure medium's transfer matrix**





Hugo Defienne, Quantum walks of photons in disordered media (2015)

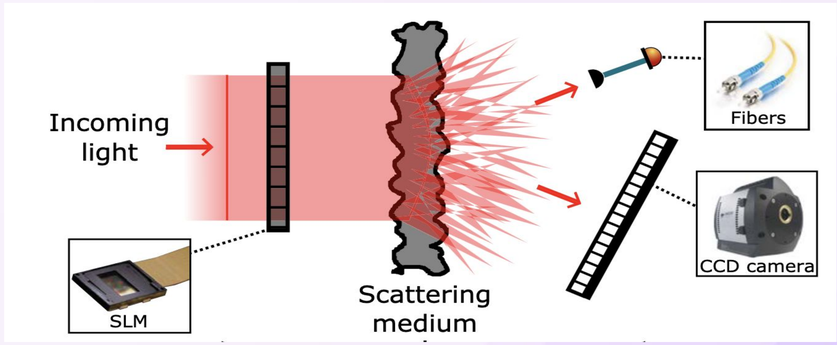
Programmable linear network

The process

- Holography: measure medium's transfer matrix
- Implement desired output by applying inverse of TM using SLM

$$|out> = TM\,|in>$$

$$|out> = TM * TM^{-1}U\,|in>$$



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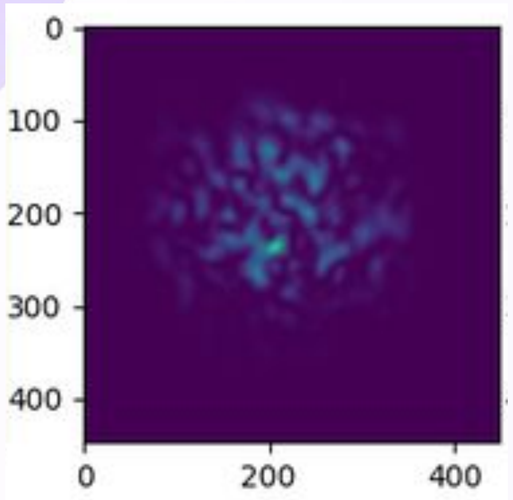
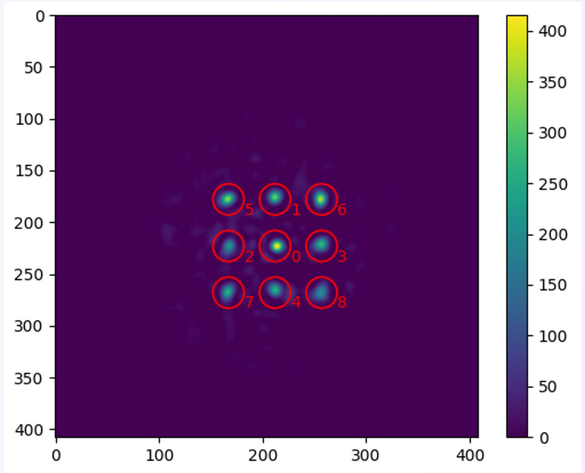
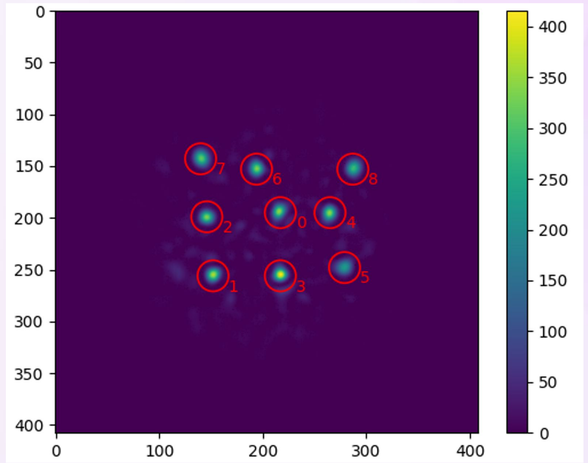


Output without control



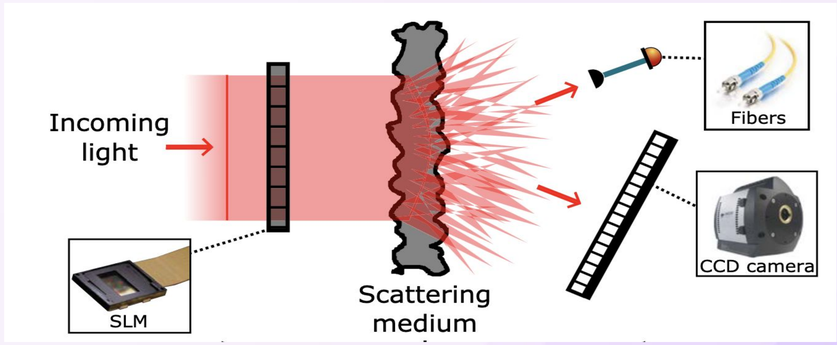


Controlled output via SLM

Programmable linear network

The process

- **Holography: measure medium's transfer matrix**
- **Implement desired output by applying inverse of TM using SLM**



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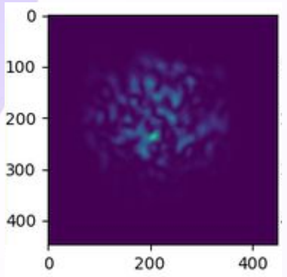
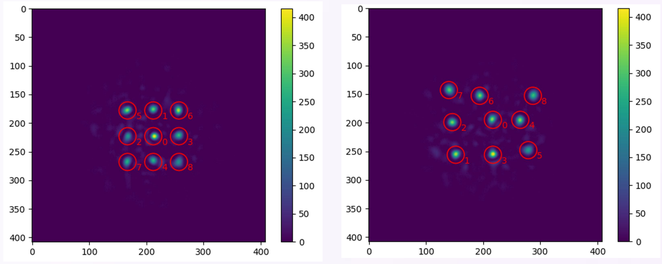
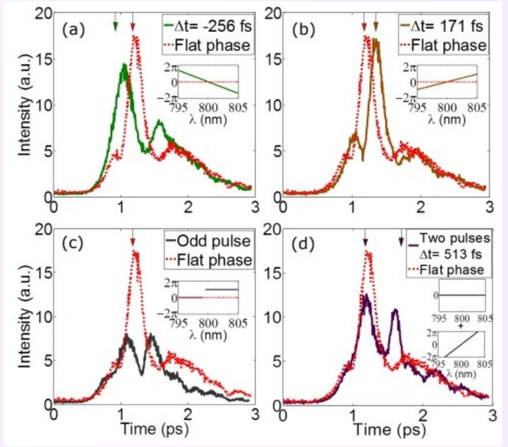


Output without control



Controlled output via SLM



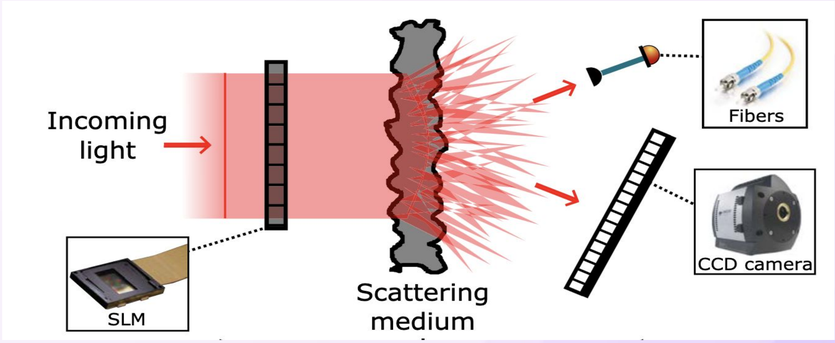
M. Mounaix, Phys Rev Lett 116, 253901 (2016)

Spatial, spectral and polarisation shaping accessible

Programmable linear network

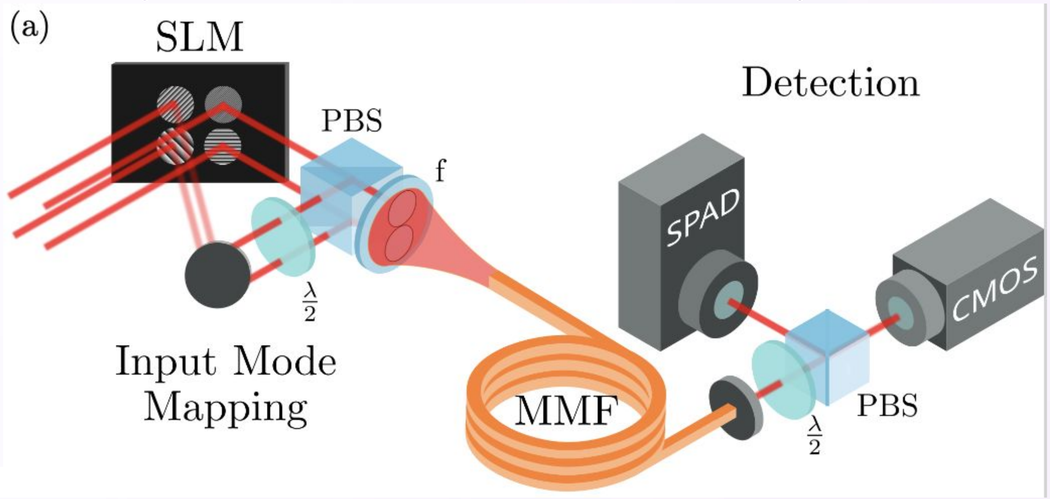
The process

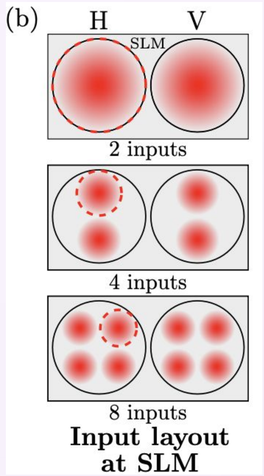
- **Holography: measure medium's transfer matrix**
- **Implement desired output by applying inverse of TM using SLM**

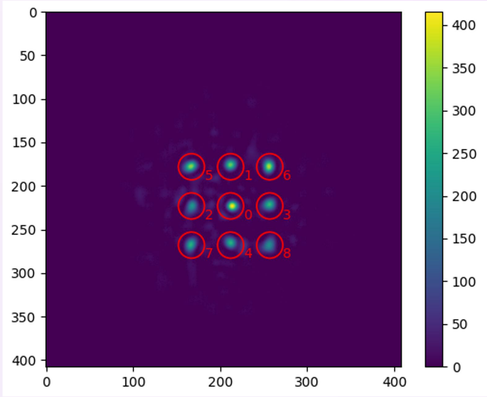


Hugo Defienne, Quantum walks of photons in disordered media (2015)

Our study: Extend to several inputs







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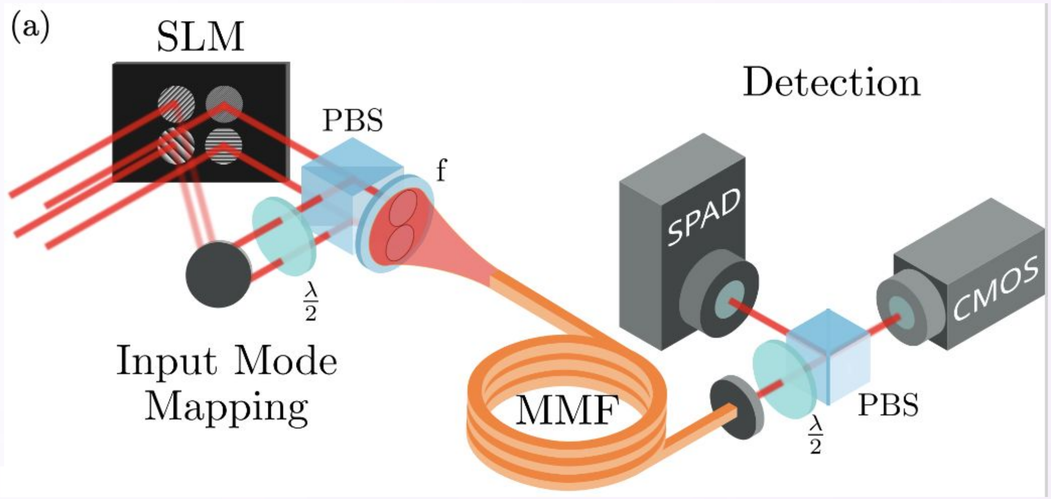
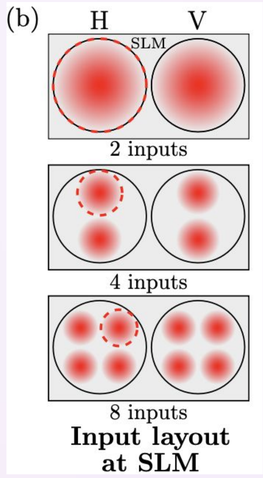
Results

Goals

- Exploring scalability
- Assess performance (fidelity and losses)

$$\mathcal{F} = \frac{1}{D}\mathrm{Tr}(|\mathcal{L}_{exp}||\mathcal{L}_{target}|)$$





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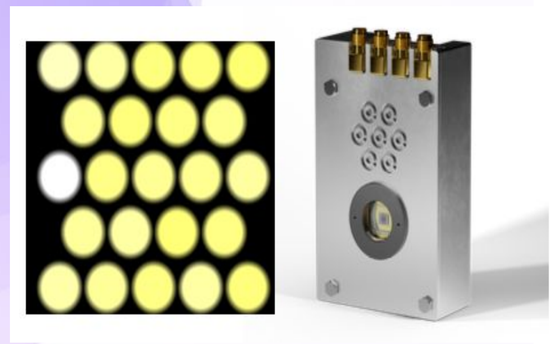
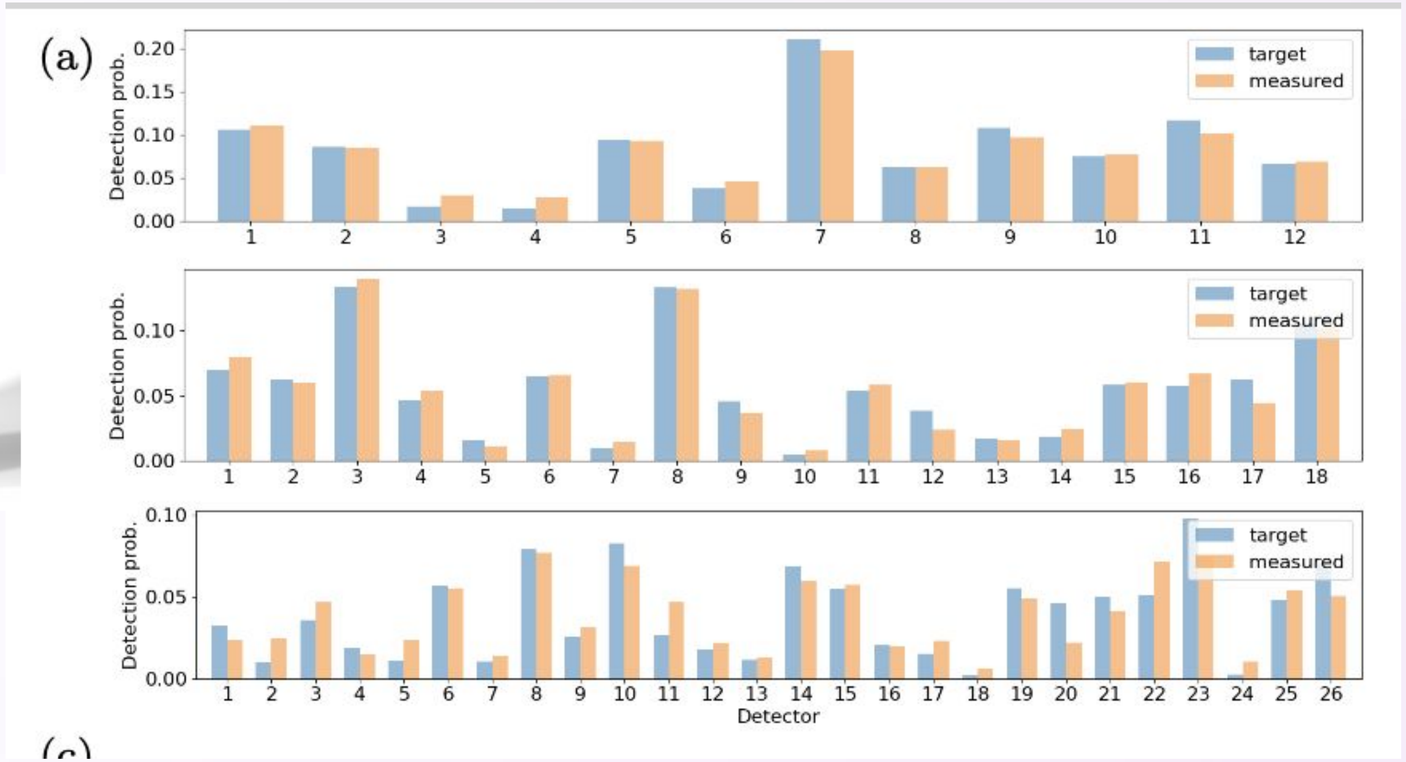
Results

Using Array of 23 APDs





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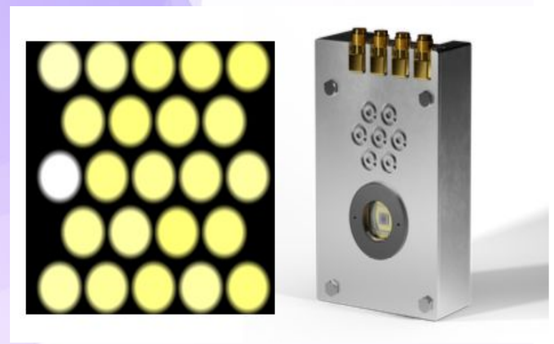

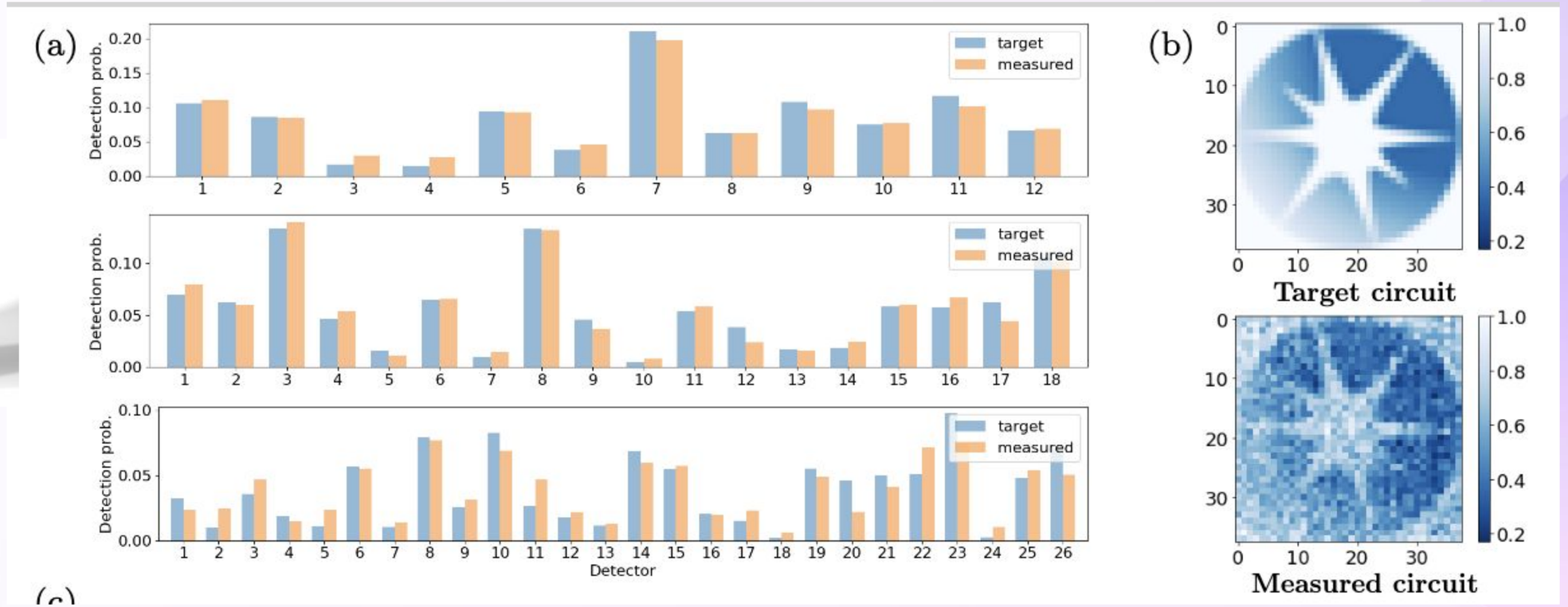

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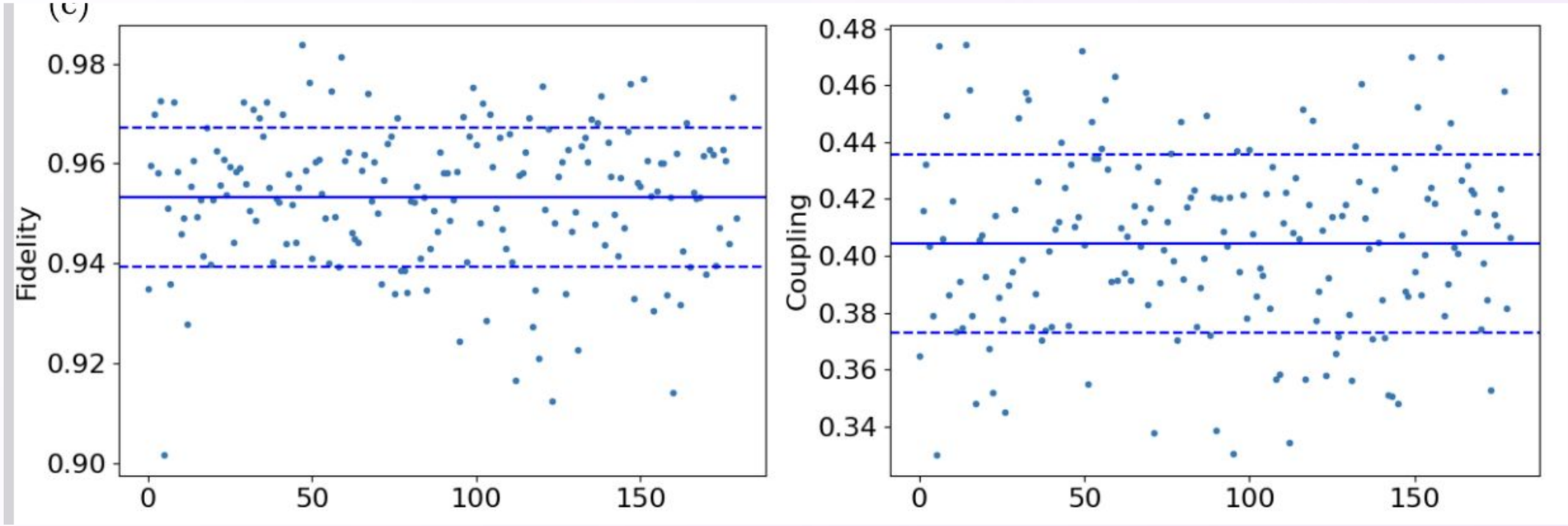

Fidelity and coupling measured for a number of randomly selected circuits

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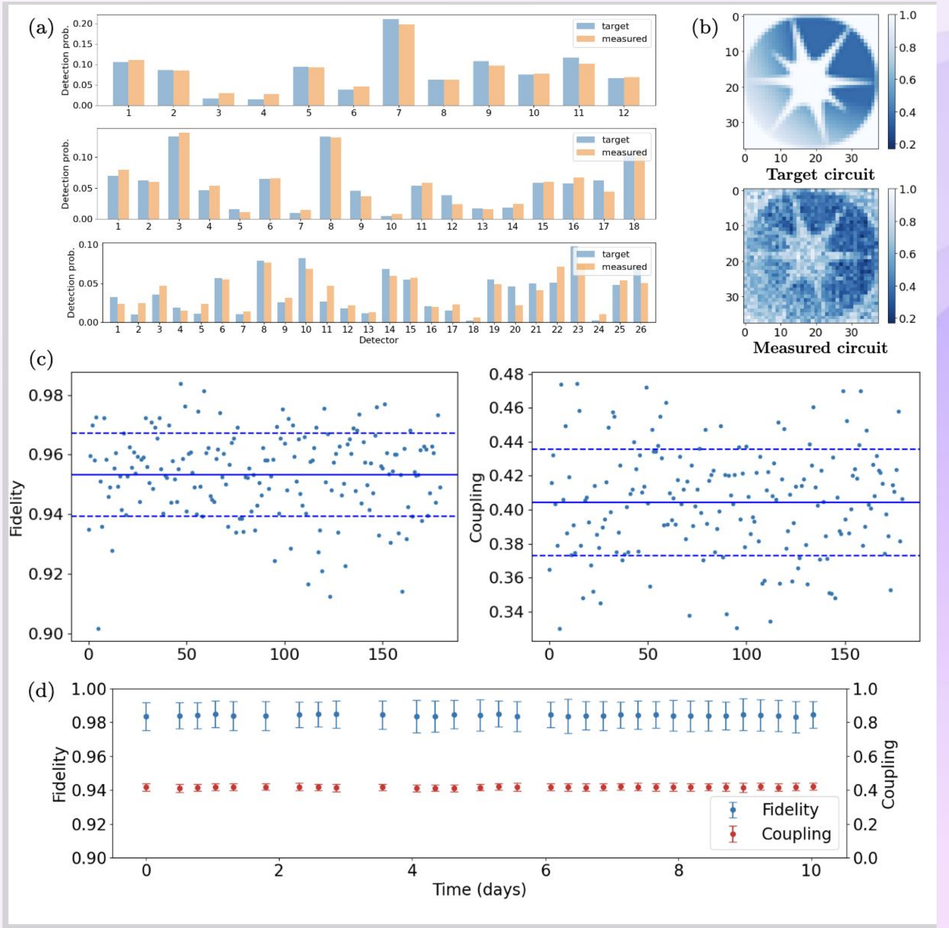
Results

Performance

- Amplitude fidelity in excess of 93%
- Losses increase quickly with increase of inputs
- Stability over > 10 days

		2 inputs	4 inputs	8 inputs
Fidelity	**14 outputs**	97.1% ± 1%	96.6% ± 1%	96.3% ± 1%
	26 outputs	95.3% ± 1%	94.7% ± 1%	94.2% ± 1%
	38 outputs	93.7% ± 1%	93.5% ± 1%	92.9% ± 1%
Losses	**14-38 outputs**	4.0(3.5*)dB ± 0.5dB	5.1(4.6*)dB ± 1dB	6.2(5.7*)dB ± 1.2dB



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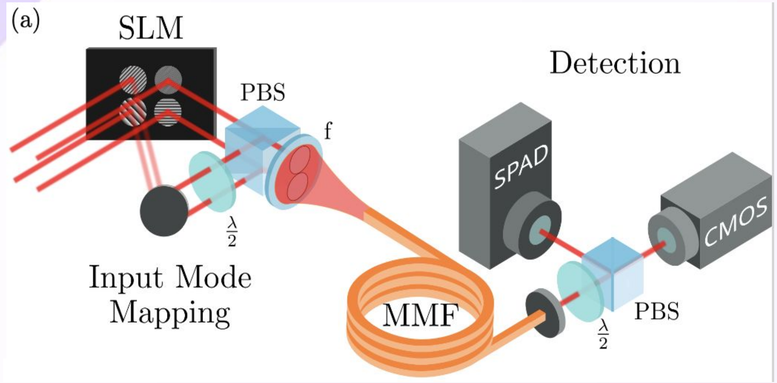
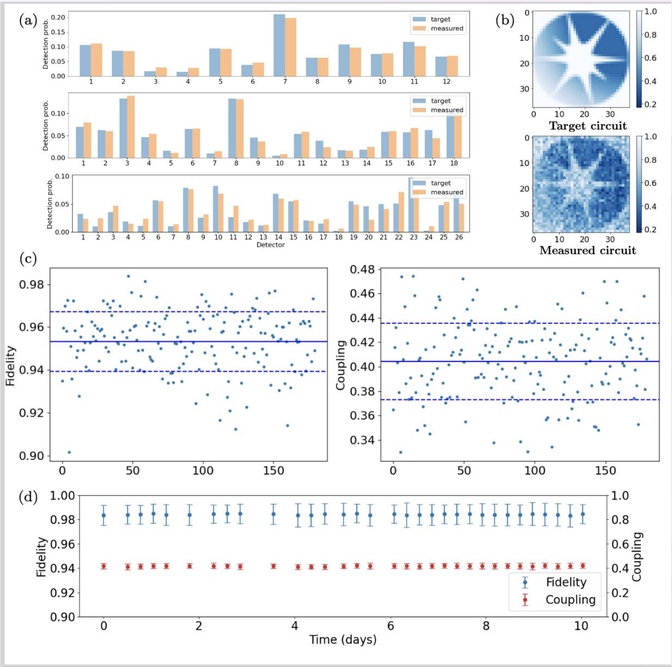
Takeaways

Performance

- Promising alternative platform
- Reconfigurability at speed and complexity independent of scale of circuits
- Mitigation of losses a must for NISQ applications





This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 899794