

The optimal strategy for photonic quantum tomography

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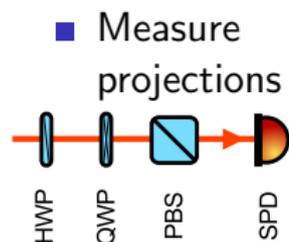
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QUANTERA
HYPER-U-P-S

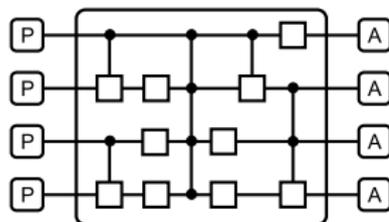
DV quantum characterization

- State characterization



- Device characterization

- Probe inputs
- Analyze outputs



n -qubit devices equivalent to $2n$ -qubit states

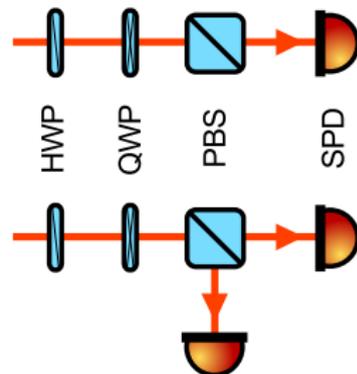
Partial or complete information desired

- Witnesses
- Reduced tomography (matrix-product states etc.)
- Full tomography

Photonic quantum platforms

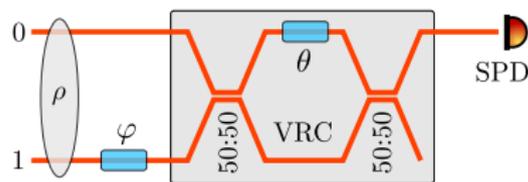
Wave-plate realizations

- Polarization DOF
- Projections tied to wave plate angles



On-chip devices

- Phase in interferometric schemes
- Projections tied to **voltage**



Complexity scaling

Full characterization scales **non-polynomially** with the size of the system:

$N_n = N_1^n$, $N \dots$ no. of measurements, $n \dots$ system size

	n	2	3	4	5	6
$N_1 = 6$		36	216	1296	7776	46656

Number of measurements directly affects duration.

⇒ Great incentive to **reduce**

Ordering-dependent tomography duration

The six polarimetric projections, using wave plates:

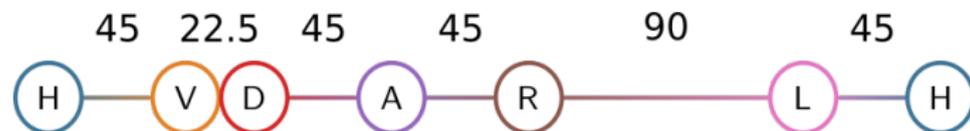
projection	HWP angle (deg)	QWP angle (deg)
H	0	0
V	45	0
D	22.5	0
A	-22.5	0
R	0	45
L	0	-45

Transition time between two projections depends on the projections in question.

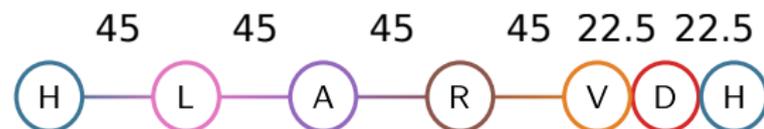
⇒ **Total duration is ordering-dependent.**

One-qubit example

Conventional sequence: $\tau_{\text{conv}} = 292.5^\circ$



Optimized sequence: $\tau_{\text{optim}} = 225^\circ$



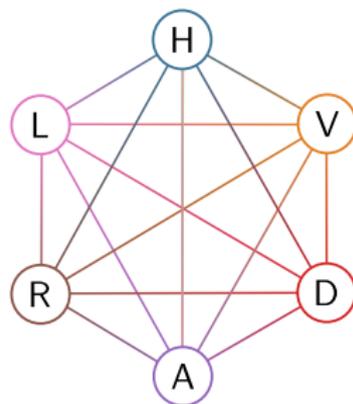
Speedup factor

$$s = \frac{\tau_{\text{conv}}}{\tau_{\text{optim}}} = 1.3$$

TSP in tomography optimization

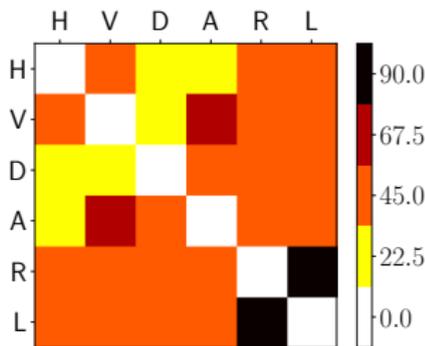
Traveling salesman problem (TSP)

- Graph-theoretical interpretation
 - Graph nodes: tomographic projections
 - Graph edges: duration of transition between projections
- ⇒ adjacency matrix



The workflow

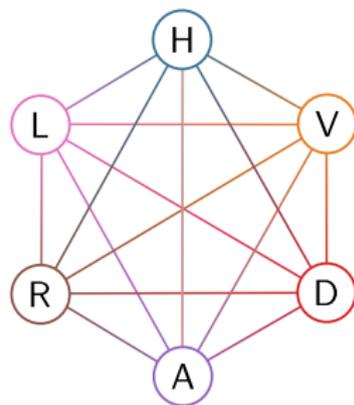
- 1 Compute the adjacency matrix of n -qubit tomography
- 2 Use a TSP solver
- 3 Compare TSP-optimized duration to conventional



TSP in tomography optimization

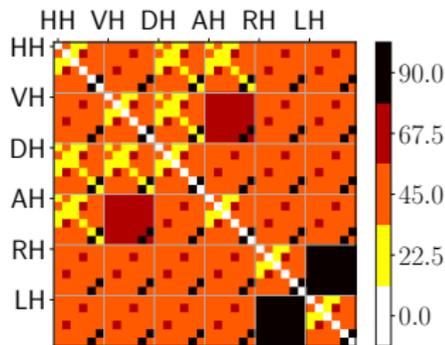
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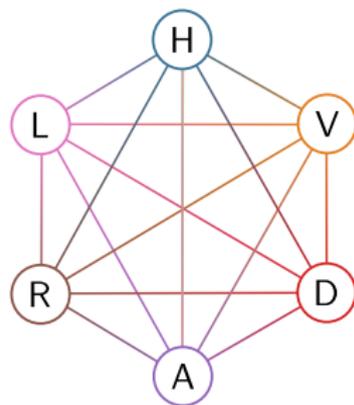
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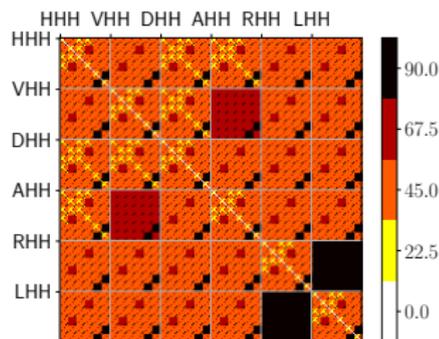
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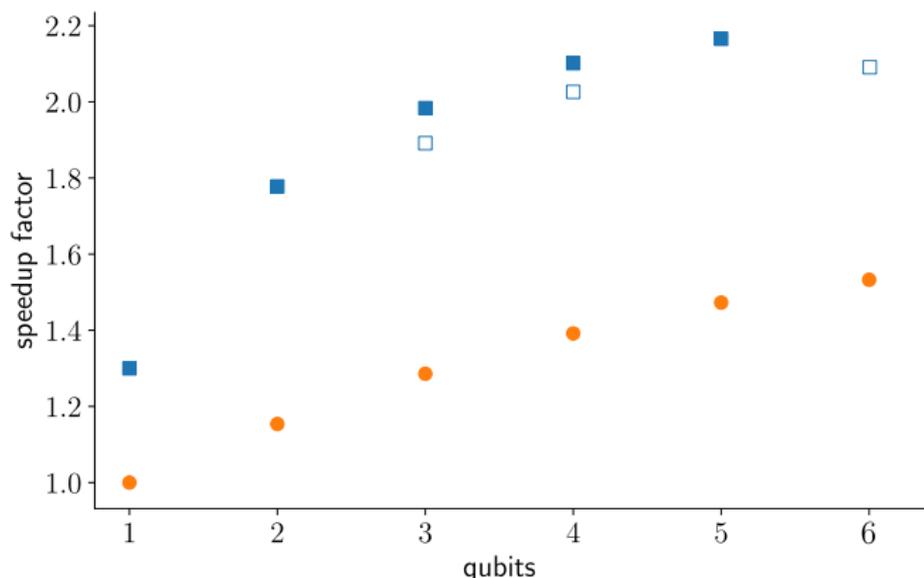
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Optimization results: speedup factor

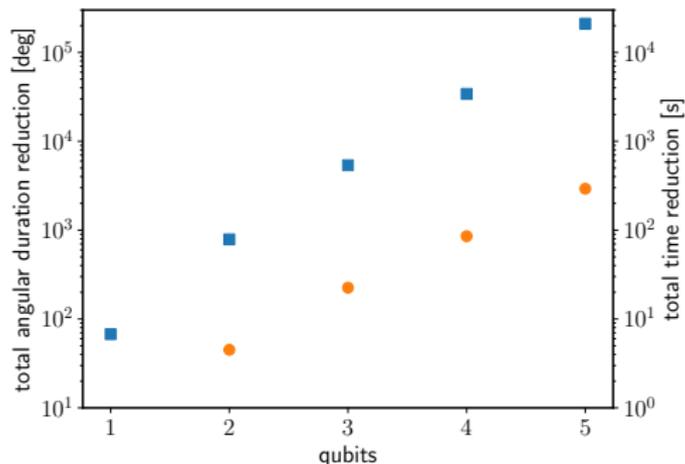
Speedup reaches 2 for four qubits already.



R. Hořák, R. Stárek, and M. Ježek, "Optimal reordering of measurements for photonic quantum tomography," *Opt. Express* 26, 32878-32887 (2018).

Optimization results: temporal reduction

3-qubit device characterization duration reduced from 23 hours to 11 hours.



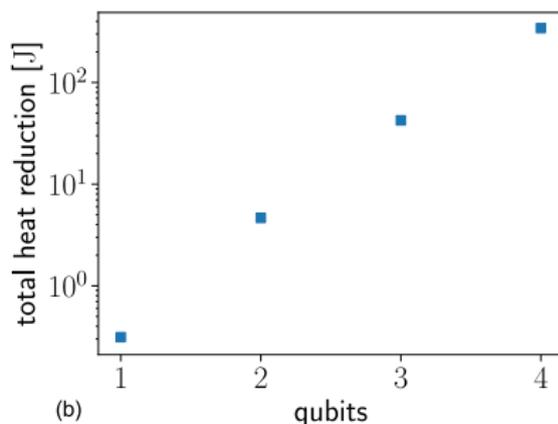
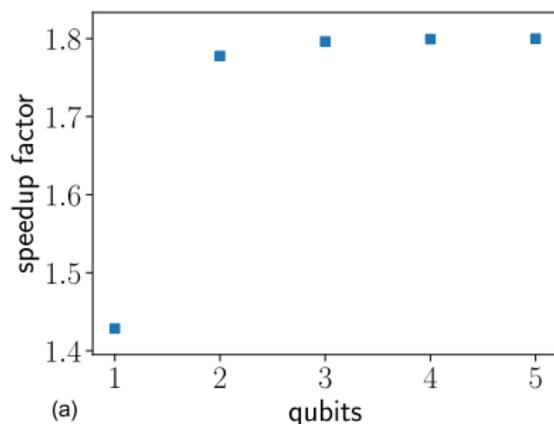
R. Stárek et al. “Experimental implementation of three- and four-qubit photonic quantum logic circuits,” presented at IQIS conference in Catania, Sep 17.-20. (2018).

R. Stárek et al. “Nondestructive detector for exchange symmetry of photonic qubits,” npj Quantum Inf. 4:35 (2018).

Going beyond

On-chip polarization-encoded qubits

- Voltage-controlled phase in interferometric scheme
- Difference-dependent voltage level transition time
 - Temporal TSP optimization possible (a)
- Another optimization target: heat dissipation (b)



Conclusion

- Duration of tomography practically halved
- Zero-cost application (no hardware changes needed)
- Versatile approach, custom scenarios possible
- Applicable to full or partial tomography
- Code available: github.com/rhosak/tomo-tsp

Thank you for your attention!