Certifying an irreducible 1024-dimensional photonic state using refined dimension witnesses

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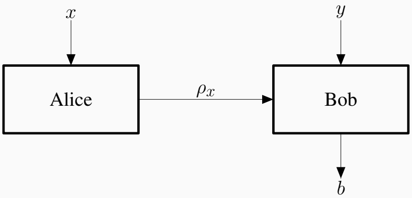
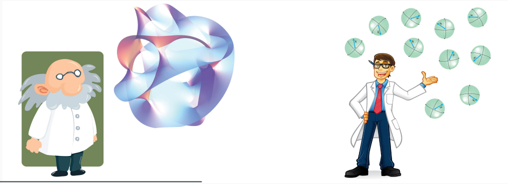
Motivation

Dimension witnesses



- Dimension witness: $\sum_{b,x,y} \alpha_{b,x,y} P(b|x,y) \leq C_d \leq Q_d$ [1]
  - Witnessing minimal classical/quantum dimension
  - If $C_d < Q_d$, certifying quantum behaviour (assuming d)

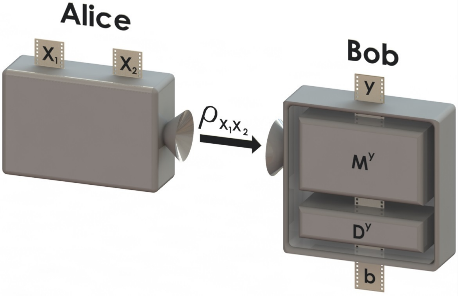
But "how quantum"?



[1] R. Gallego, N. Brunner, C. Hadley, A. Acín, PRL 105, 230501 (2010)

Setup

Quantum random access code (QRAC)



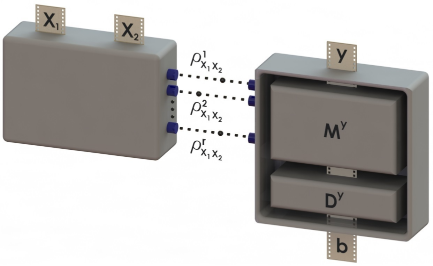
- $x_1, x_2 \in \{1, \ldots, d\}$, ρ_{x_1,x_2}: d-dim quantum state, $y \in \{1, 2\}$, M^y: measurement on $\mathbb{C}^d$, D^y: decoding function, $b \in \{1, \ldots, d\}$
- Average success probability: $\bar{p} = \frac{1}{2d^2} \sum_{x_1,x_2,y} P(b = x_y | x_1, x_2, y)$
- Known: $\bar{p}_{C_d} = \frac{1}{2}\left(1 + \frac{1}{d}\right) < \frac{1}{2}\left(1 + \frac{1}{\sqrt{d}}\right) = \bar{p}_{Q_d}$ [2] [3]

What is between the two (separable states)?

[2] A. Ambainis, D. Kravchenko, A. Rai, arXiv:1510.03045 (2015)

[3] MF, J. Kaniewski, arXiv:1803.00363 (2018)

Separable QRAC



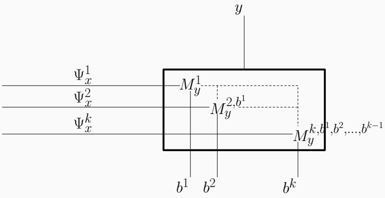
- Product structure: $d = d_1 \cdot d_2 \cdot \ldots \cdot d_r$
- Assumptions: projective and separable measurements
- Goal: for a given d, derive bounds for all product structures

d = 4	
Q_4	$\bar{p}_{Q_4}$
$Q_2 Q_2$	$\bar{p}_{Q_2 Q_2}$
$C_2 Q_2$	$\bar{p}_{C_2 Q_2}$
C_4	$\bar{p}_{C_4}$

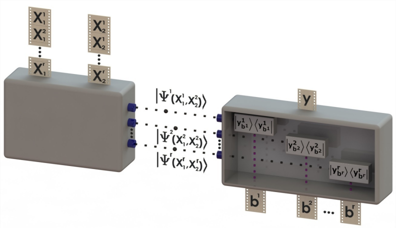
Technical results

Parallel QRACs

- Idendity decoding
- Non-adaptiveness

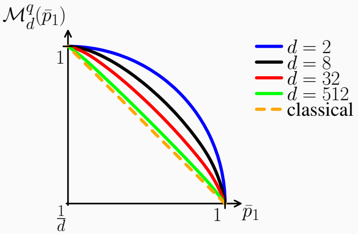


  - No need for adaptive strategies
- Pure state encoding



Trade-off function

- $\bar{p} = \frac{1}{2}\left[P(b = x_1|y = 1) + P(b = x_2|y = 2)\right] =: \frac{1}{2}(\bar{p}_1 + \bar{p}_2)$
  - Given $\bar{p}_1$, what is the best $\bar{p}_2$ achievable?



- $\bar{p}_{Q_{d_1} Q_{d_2} \dots Q_{d_r}} = \frac{1}{2}\left[\bar{p}_1^1 \bar{p}_1^2 \cdots \bar{p}_1^r + M_{d_1}^q(\bar{p}_1^1) \cdot M_{d_2}^q(\bar{p}_1^2) \cdot \ldots \cdot M_{d_r}^q(\bar{p}_1^r)\right]$
  - Maximisation over r parameters

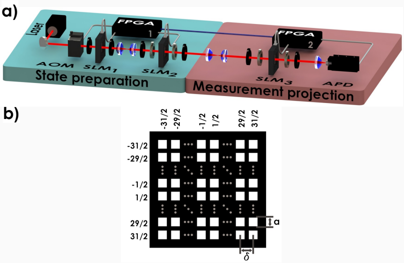
Results

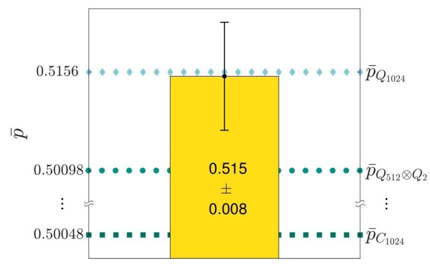
Numerical results

d = 4	
Q_4	0.75
$Q_2 Q_2$	0.728553
$C_2 Q_2$	0.654508
C_4	0.625

d = 6	
Q_6	0.704124
$Q_3 Q_2$	0.673176
$C_2 Q_3$	0.614357
$C_3 Q_2$	0.596856
C_6	0.583333

d = 8	
Q_8	0.676777
$Q_4 Q_2$	0.640165
$Q_2 Q_2 Q_2$	0.621859
$C_2 Q_4$	0.591506
$C_2 Q_2 Q_2$	0.582955
$C_4 Q_2$	0.570164
C_8	0.5625


a)
Laser
FPGA
1
AOM
SLM1
SLM2
State preparation
FPGA
2
SLM3
APD
Measurement projection
b)
-31/2
-29/2
-1/2
1/2
29/2
31/2
a
δ


0.5156
0.50098
0.50048
$\bar{p}$
0.515
±
0.008
$\bar{p}_{Q_{1024}}$
$\bar{p}_{Q_{512} \otimes Q_2}$
$\bar{p}_{C_{1024}}$

Thank you for your attention! Questions?

Lots of open positions in Gdansk!

(just check Quantiki...)