Preparing Schrödinger cat states using a neural network

Presenter:

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Purpose of this work:

Development and experimental demonstration of a fast neural-network-based method for preparation of families of quantum states

Main idea:

- consider not a single state but the whole continuous family (here Schrödinger cat states)
- teach neural network to control the system on a selection of states
- use the neural network to quickly generate control for ANY state

First proposal of the idea: F. Sauvage and F. Mintert, PRL 129 (2022)

Physical system

(qubit + cavity)

Jaynes-Cummings Model in the dispersive regime:

$$H(t) = H^{\mathrm{drift}} + H^{\mathrm{ctrl}}_{\mathrm{qub}}(t) + H^{\mathrm{ctrl}}_{\mathrm{cav}}(t) \quad (1)$$

where:

$$H^{\mathrm{drift}} = -\chi n_{\mathrm{phot}} \sigma_z \quad (2)$$

$$H^{\mathrm{ctrl}}_{\mathrm{qub}}(t) = \mu_{\mathrm{qub}}\, \varepsilon_{\mathrm{qub}}(t)\, \sigma_+ + \mathrm{h.c.} \quad (3)$$

$$H^{\mathrm{ctrl}}_{\mathrm{cav}}(t) = \mu_{\mathrm{cav}}\, \varepsilon_{\mathrm{cav}}(t)\, a^\dagger + \mathrm{h.c.} \quad (4)$$

$\chi = 238.5$ MHz, $T_1^{\mathrm{qub}} = 35$ us, $T_2^{\mathrm{qub}} = 42$ us, $T_1^{\mathrm{cav}} = 225$ us

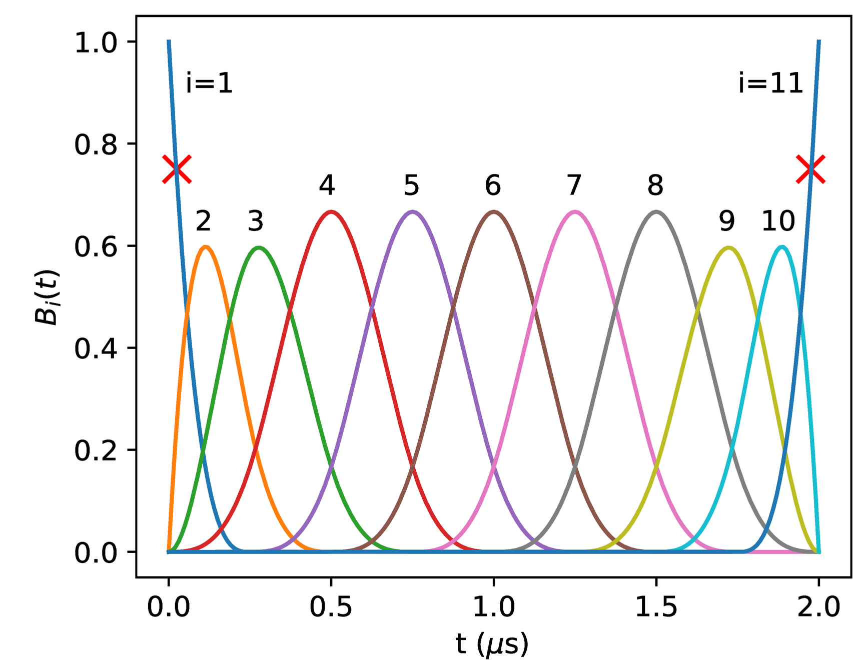
Control task and pulse representation

=> The system is driven during a fixed time-interval
=> We target the family of Schrödinger cat states:
$|\alpha\rangle + e^{-i\varphi}|-\alpha\rangle$ with $\alpha < 4$

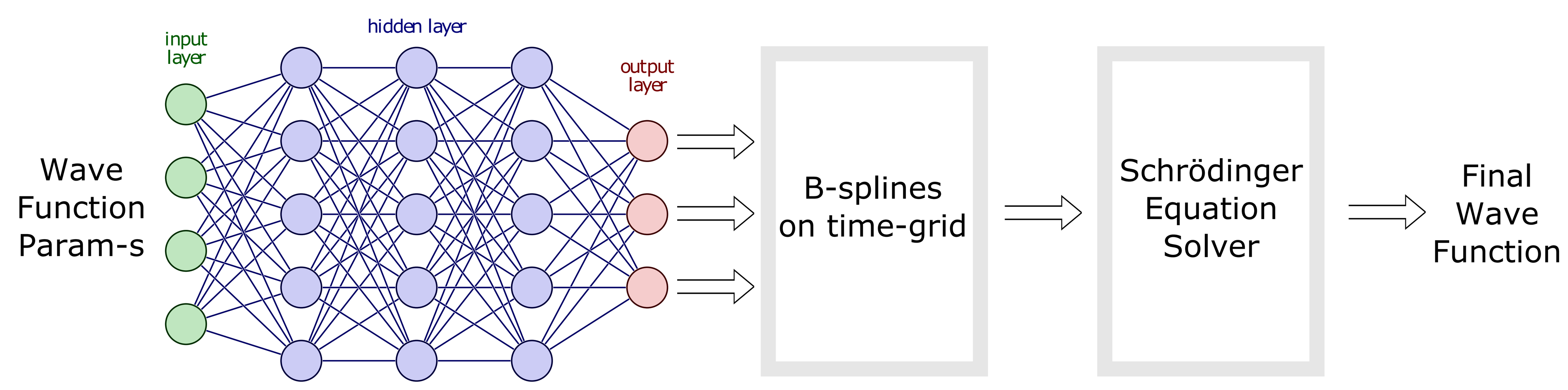
? For all states at once, find the optimal control, that is the 4 fields $\mathrm{Re}\,\varepsilon_{\mathrm{qub}}$, $\mathrm{Im}\,\varepsilon_{\mathrm{qub}}$, $\mathrm{Re}\,\varepsilon_{\mathrm{cav}}$, $\mathrm{Im}\,\varepsilon_{\mathrm{cav}}$

We search for the control pulses in the B-spline basis often applied in computational atomic physics ➡

W. R. Johnson, *Atomic Structure Theory; Lectures on Atomic Physics*, Springer, New York (2007)

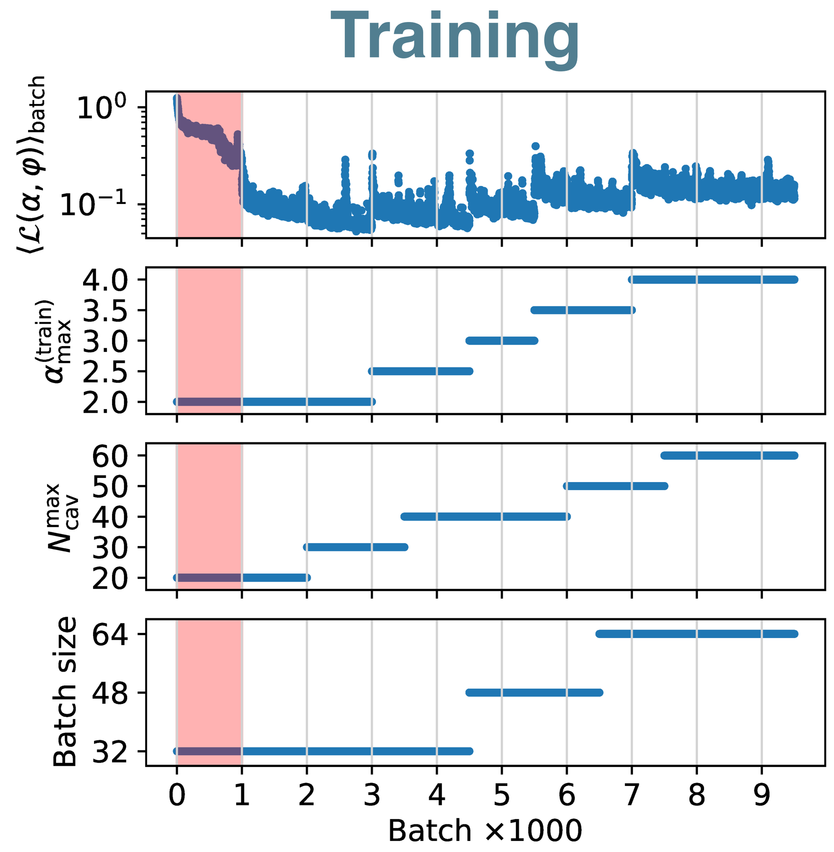


Data processing pipeline



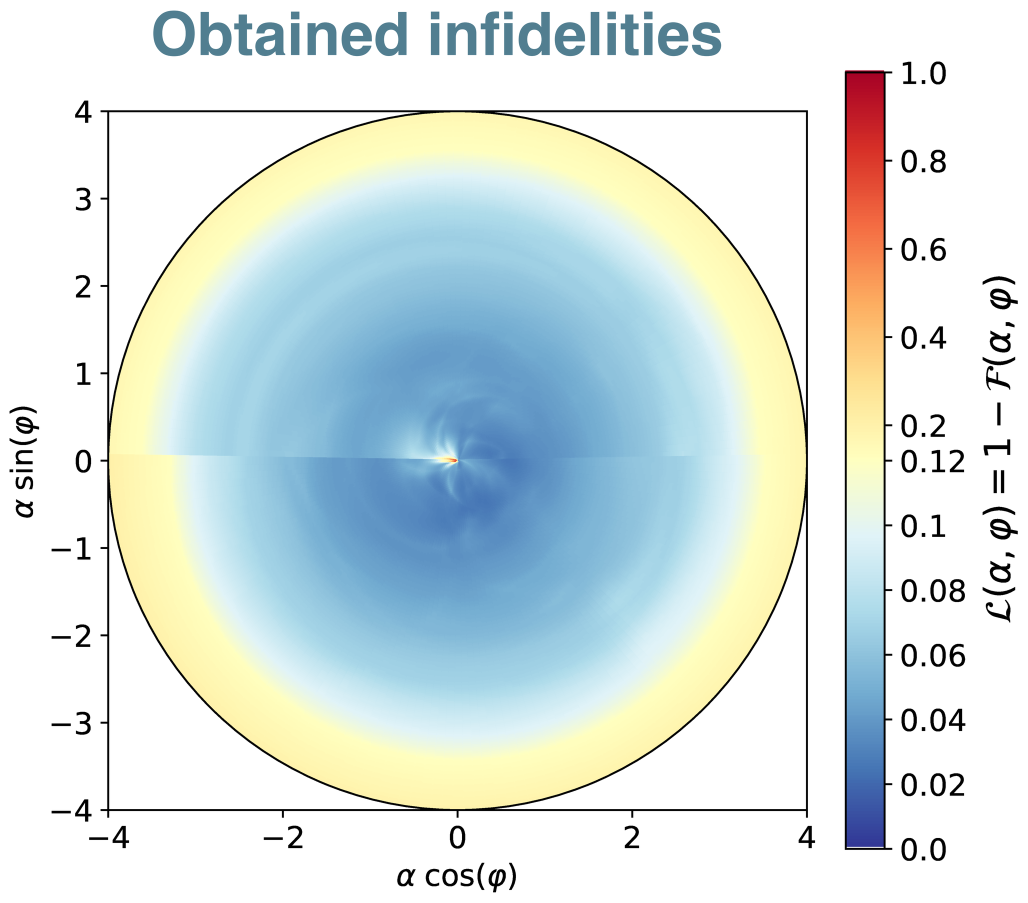
Loss (α, ϕ) = Infidelity $(\alpha, \phi) = 1 - \left|\langle \text{target cat} \,|\, \text{prepared state}\rangle\right|^2$

Training

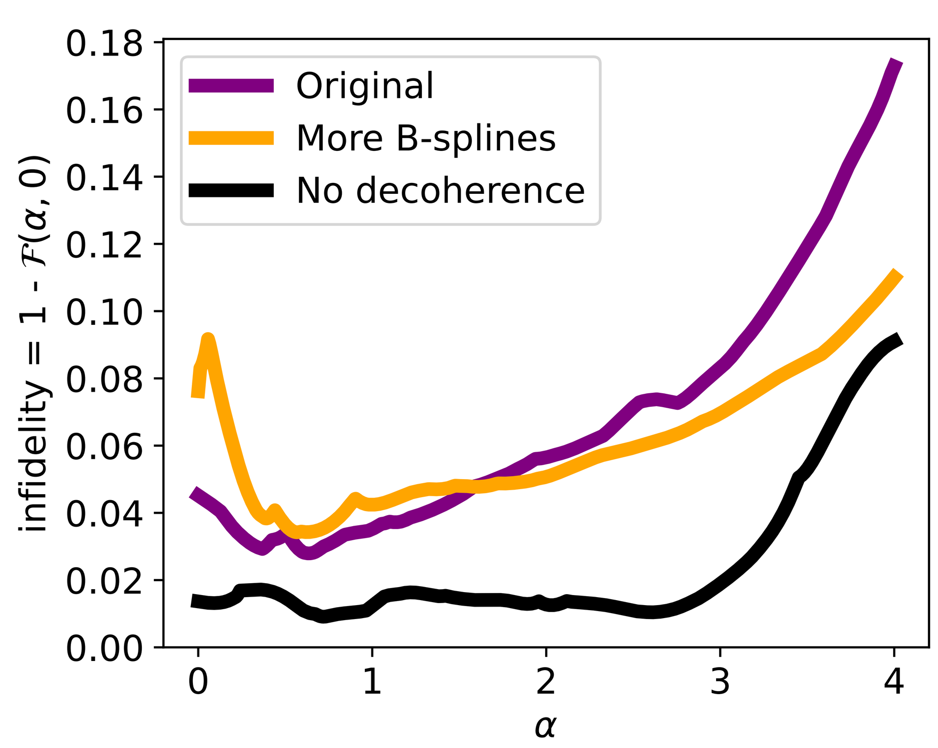


Theoretical results

Obtained infidelities



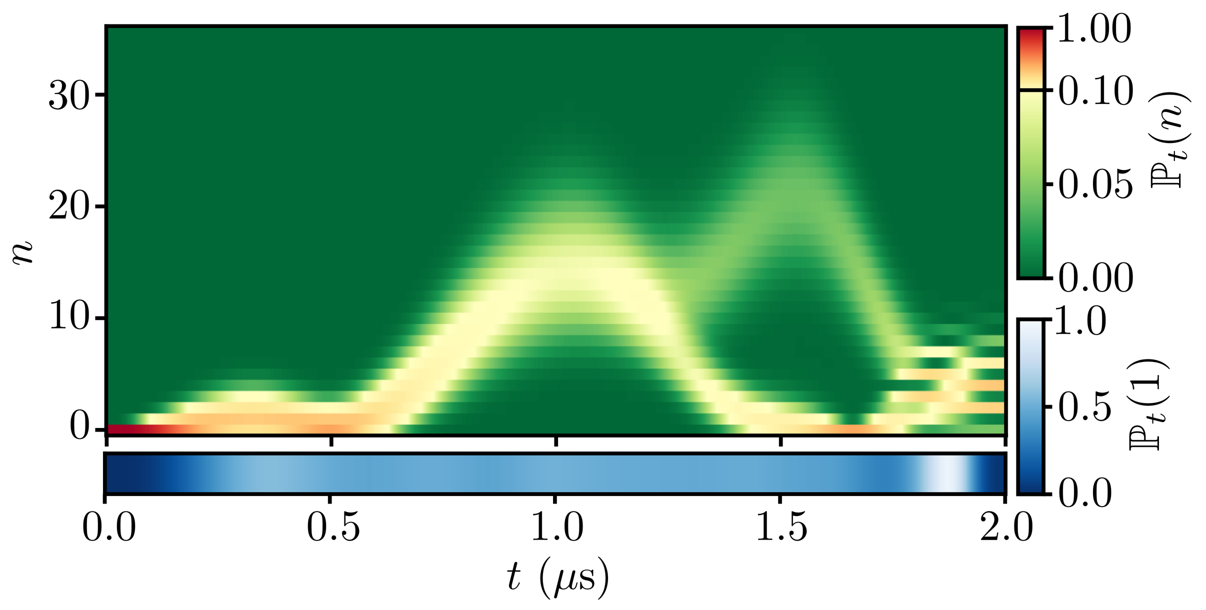
Infidelity sources



=> at small α due to linear sampling
=> at large α due to small B-spline set
=> decoherence is the main source

Cavity dynamics

$(\alpha = 2, \varphi = 0)$

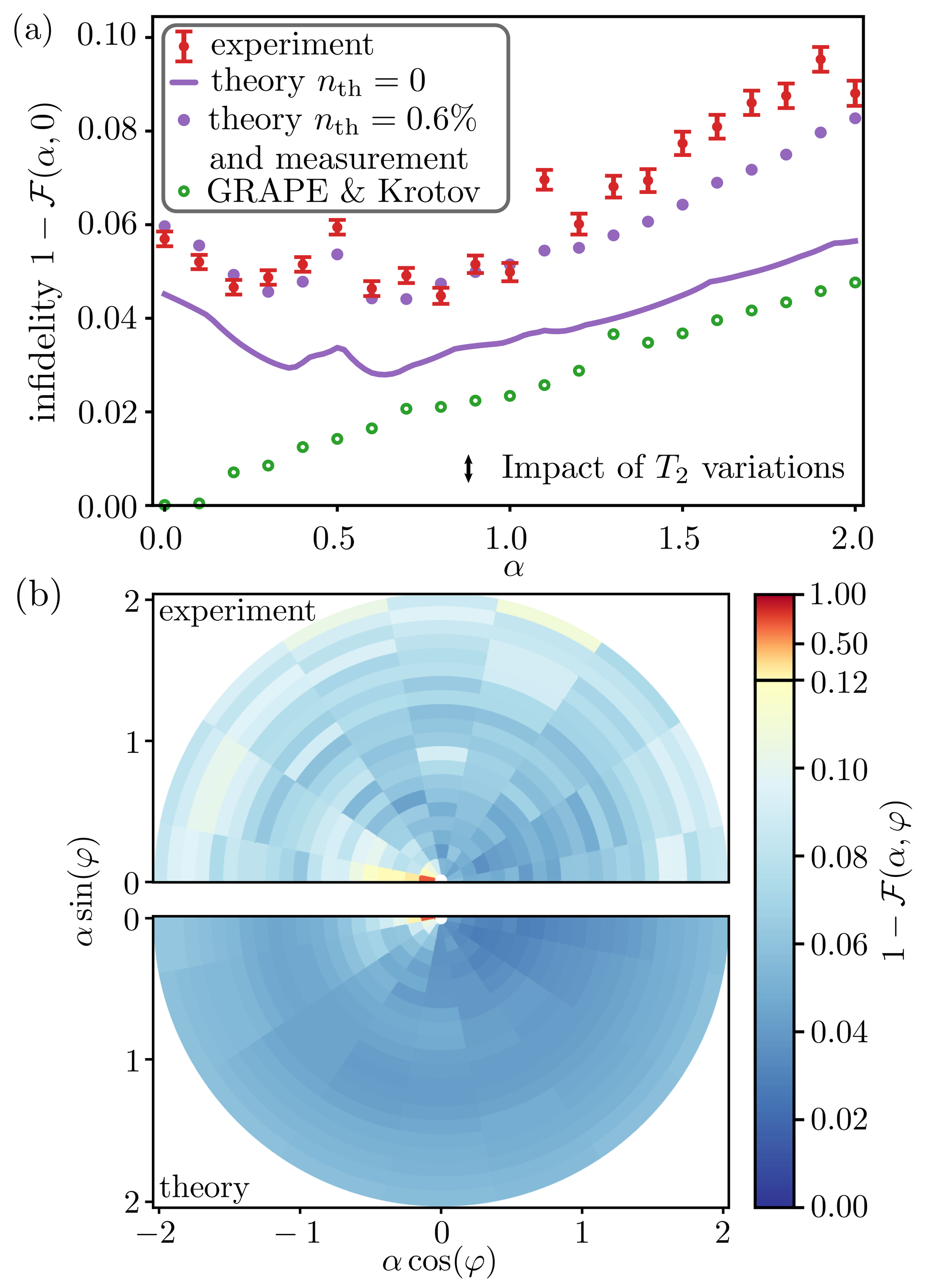


See our manuscript for more details:

H. Hutin, P. Bilous et al.
arXiv:2409.05557

Experiment vs theory

$(\alpha < 2)$



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