Temporal mode-matching effects in Linear Optical Quantum Computing

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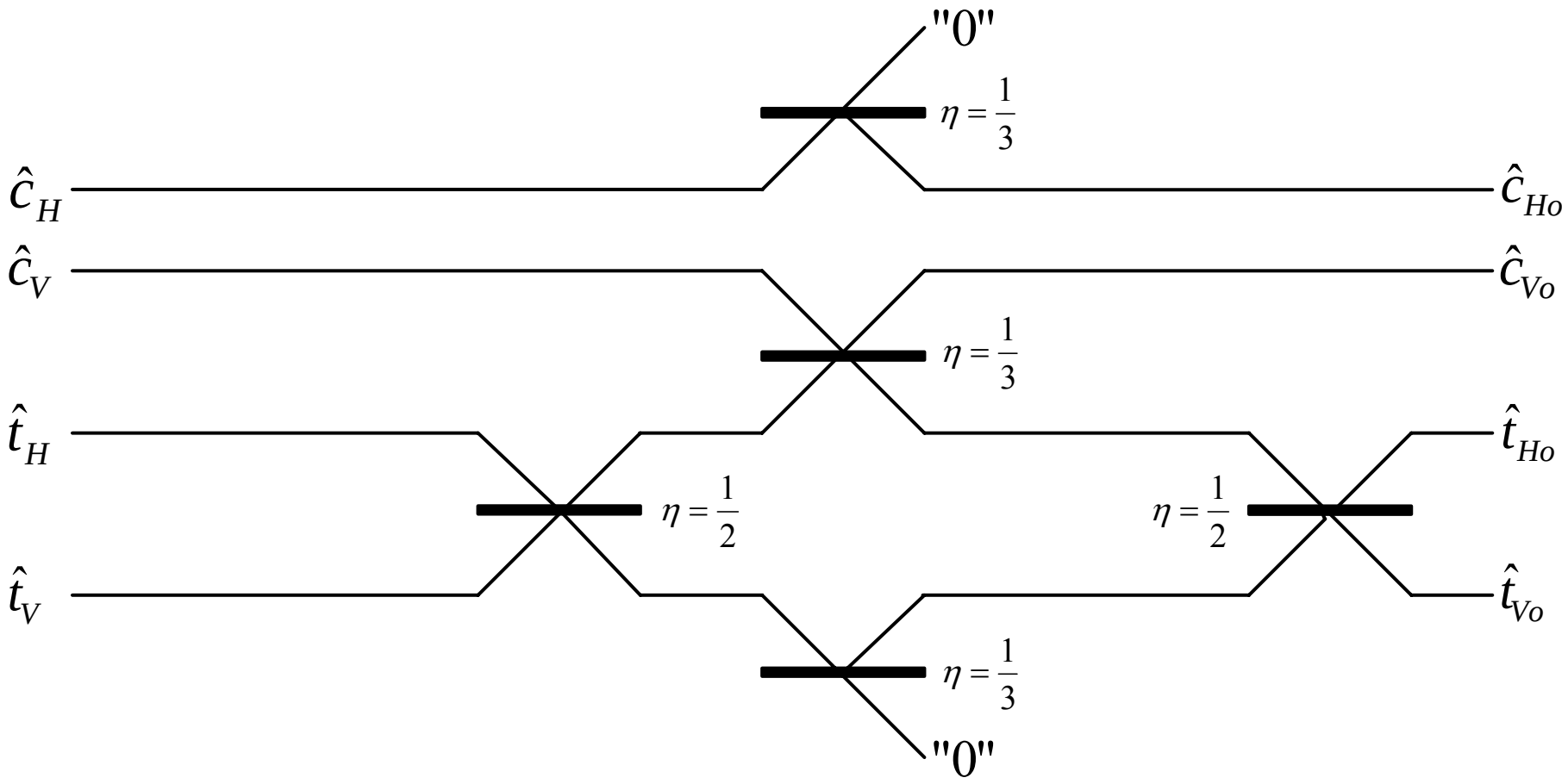
Motivation

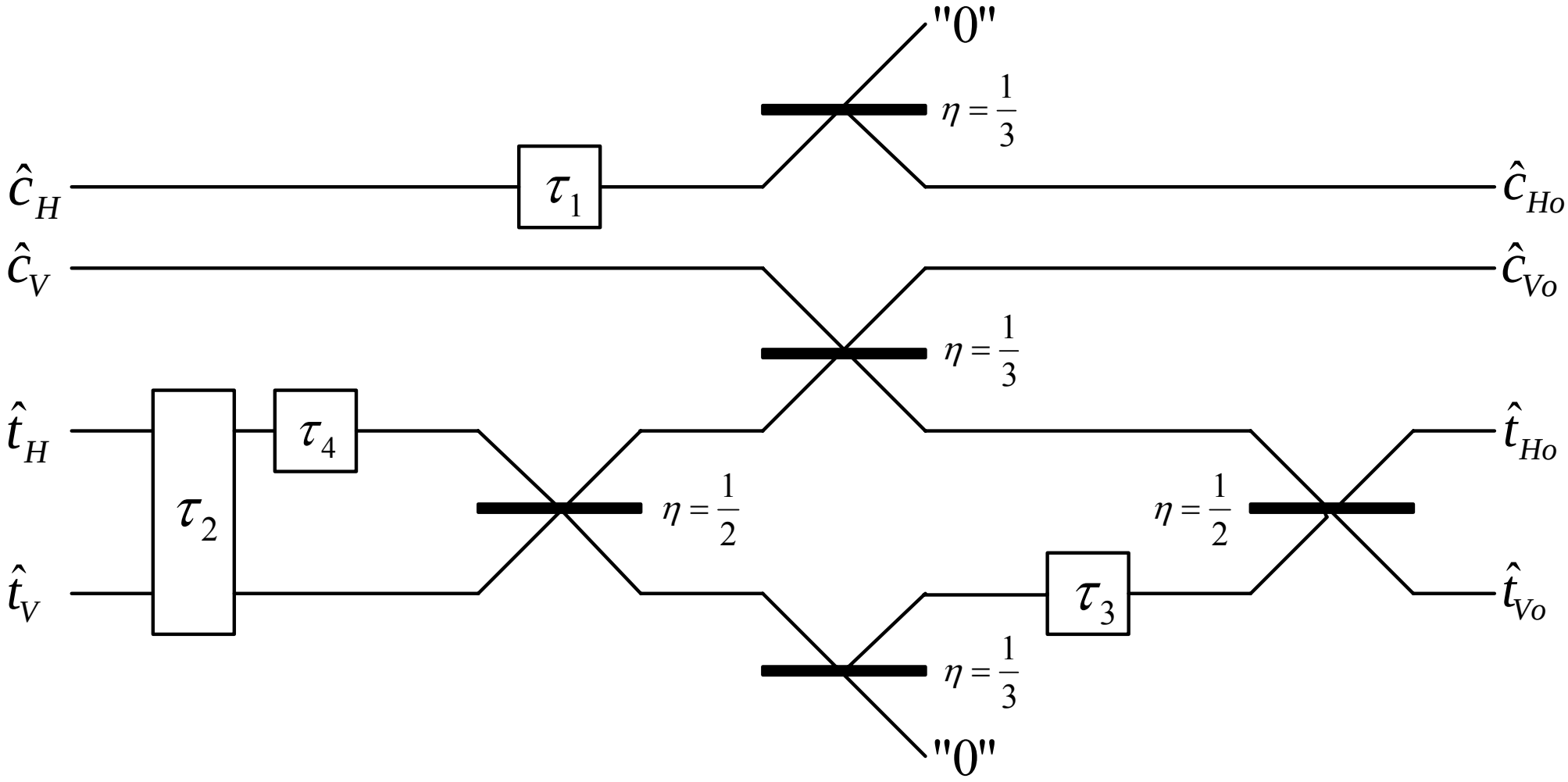
- Present LOQC models are highly idealized
- Develop model for ‘realistic’ LOQC circuit behavior
  - Imperfect photon generation
  - Mode-matching problems

Ideal CNOT-gate



- Coincidence basis CNOT-gate
  - Dual-rail logic
  - Operates in the coincidence basis
  - Non-deterministic, $P_{success}$ = 1/9
  - Equivalent to UQ's experimental implementation (O'Brien et. al., Nature, 2003)

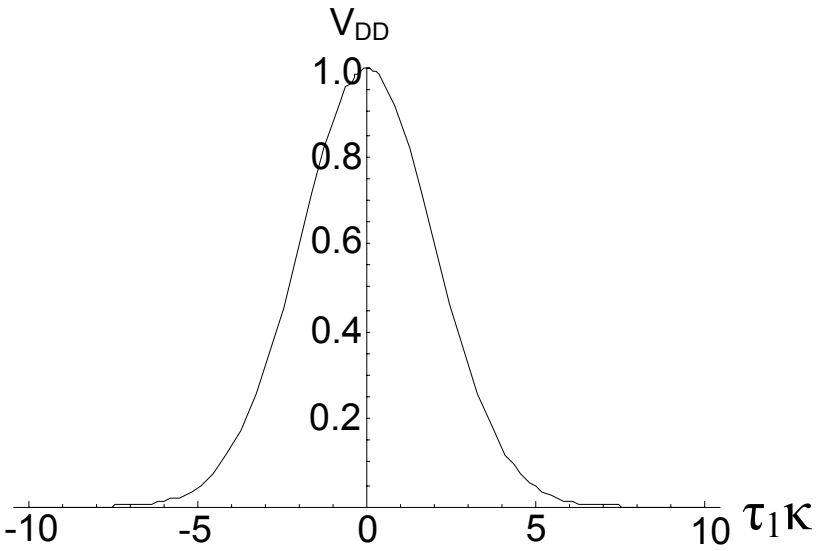
CNOT-gate with mode-matching

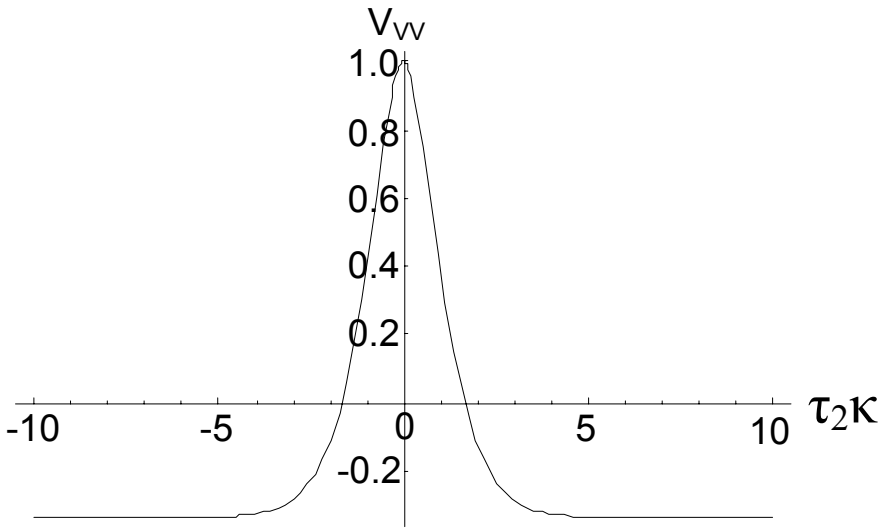


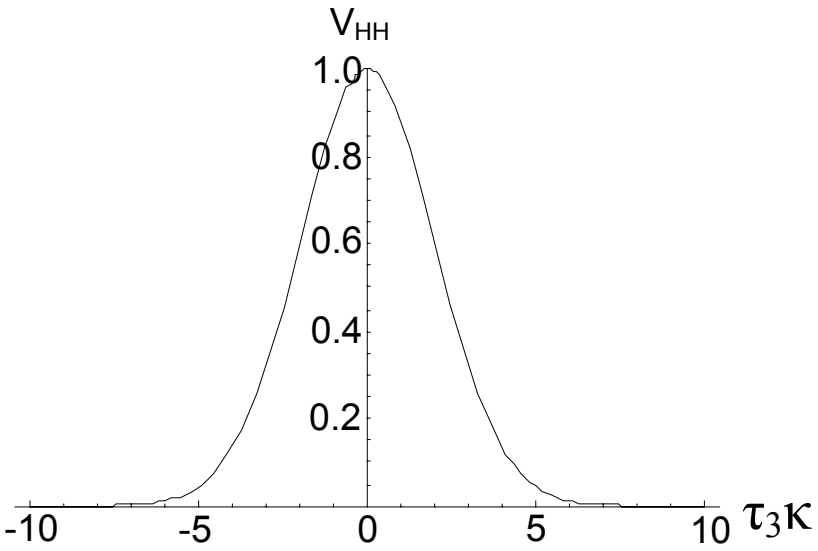
- τ_1-τ_4 are mode-matching parameters

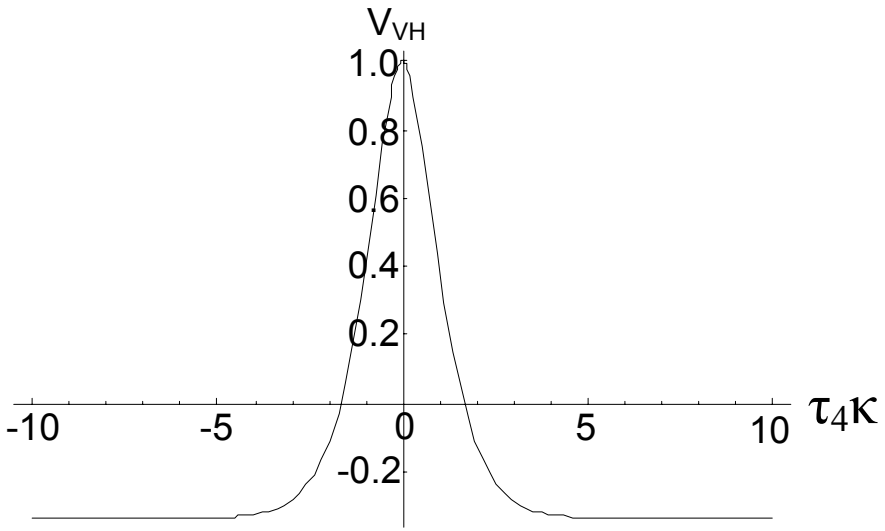
$$|\psi_{in}\rangle = \left(\alpha \int \kappa_\omega |1\rangle_{\omega,H} d\omega + \beta \int \kappa_\omega |1\rangle_{\omega,V} d\omega\right)_c \otimes \left(\gamma \int \kappa_\omega |1\rangle_{\omega,H} d\omega + \delta \int \kappa_\omega |1\rangle_{\omega,V} d\omega\right)_t$$

Mode-matching effects









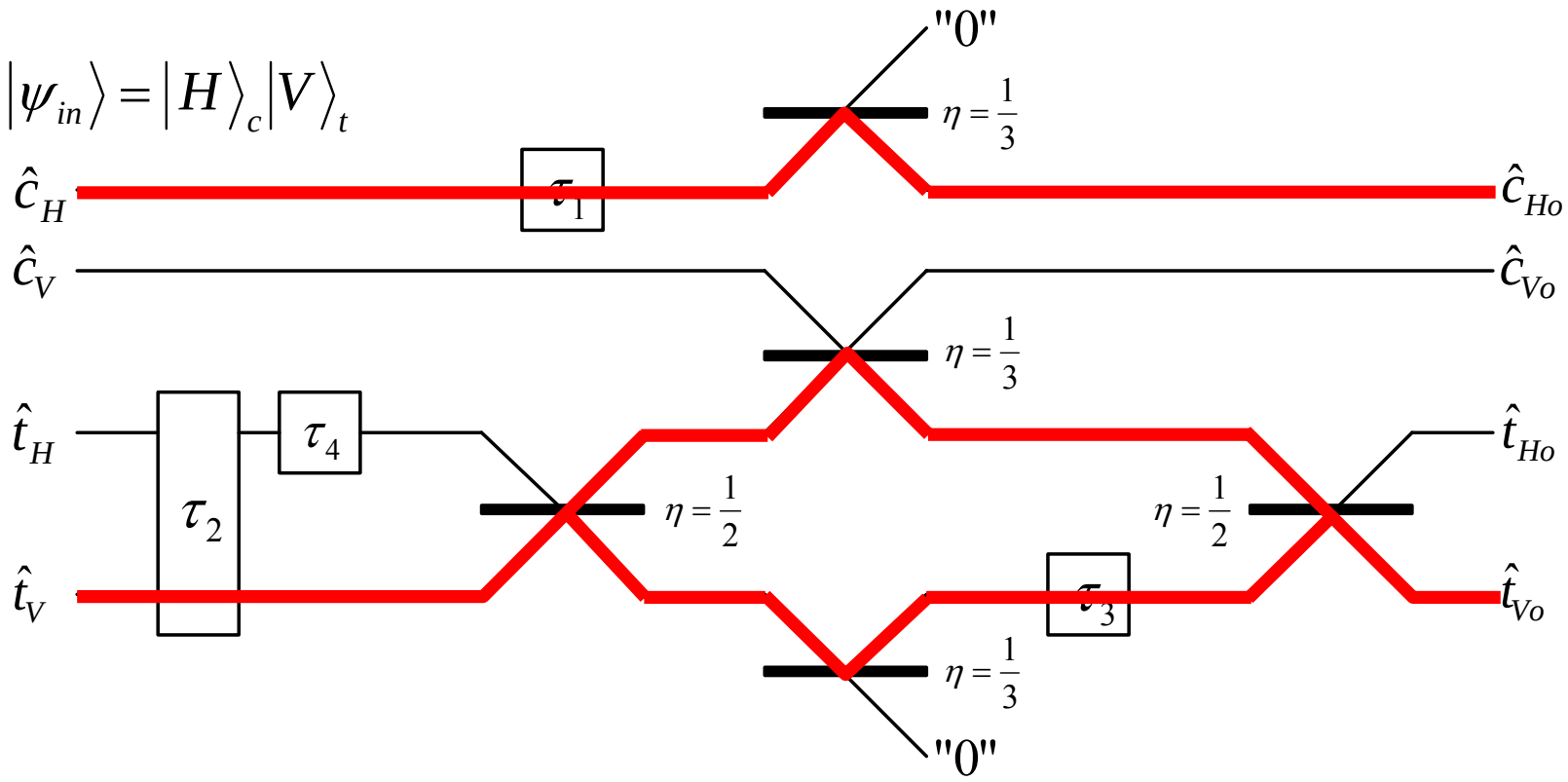
- Where photons have Gaussian distributed packets with bandwidth κ

Peter's question of the day

Can we infer the mode-matching parameters?

Non-intrusive determination of mode-matching parameters

- Assumptions:
  - Detectors are ideal → no filtering
  - Only one degree of freedom in mode-matching



Measure in

$|H\rangle_c |V\rangle_t$

basis

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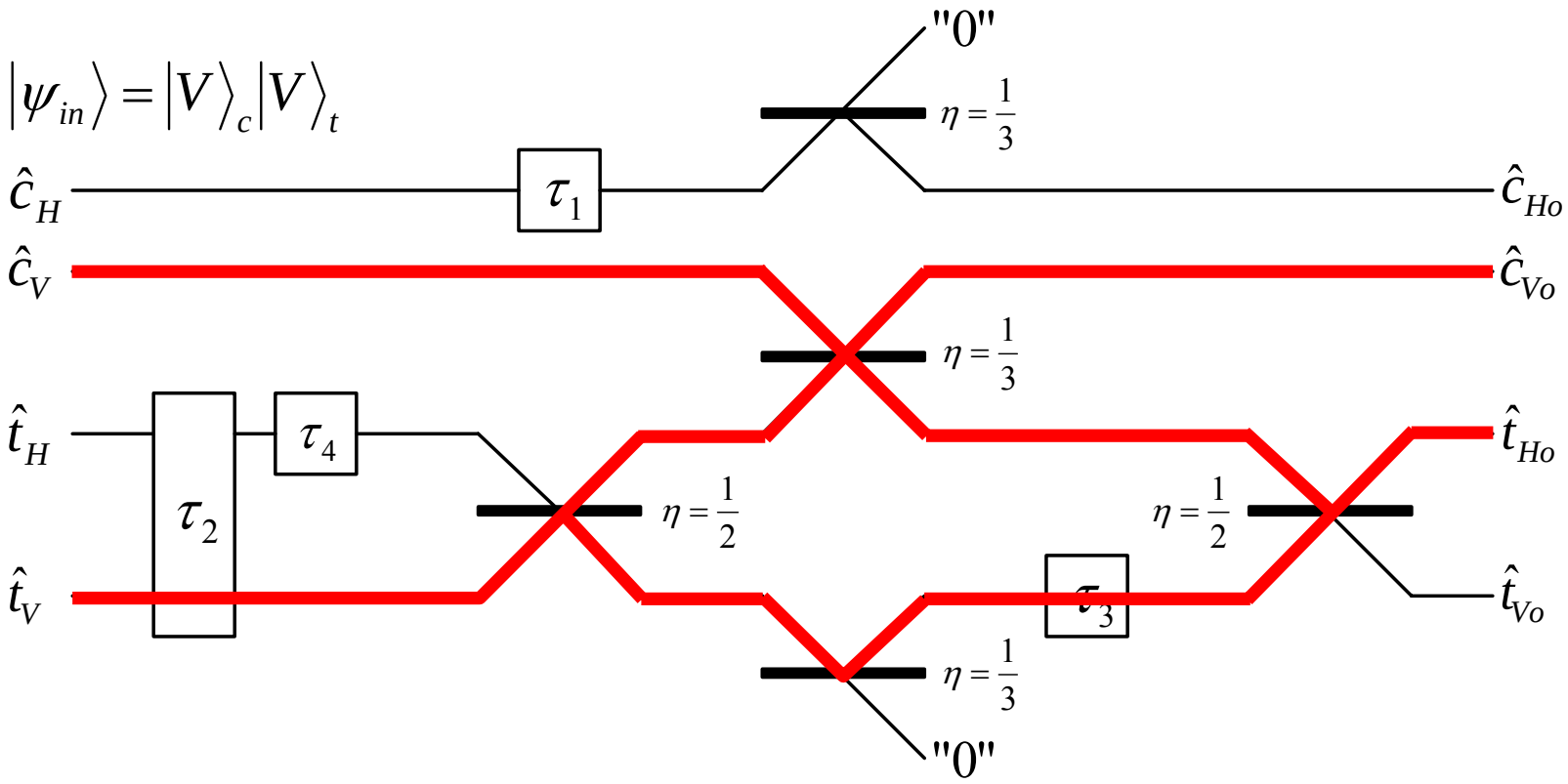

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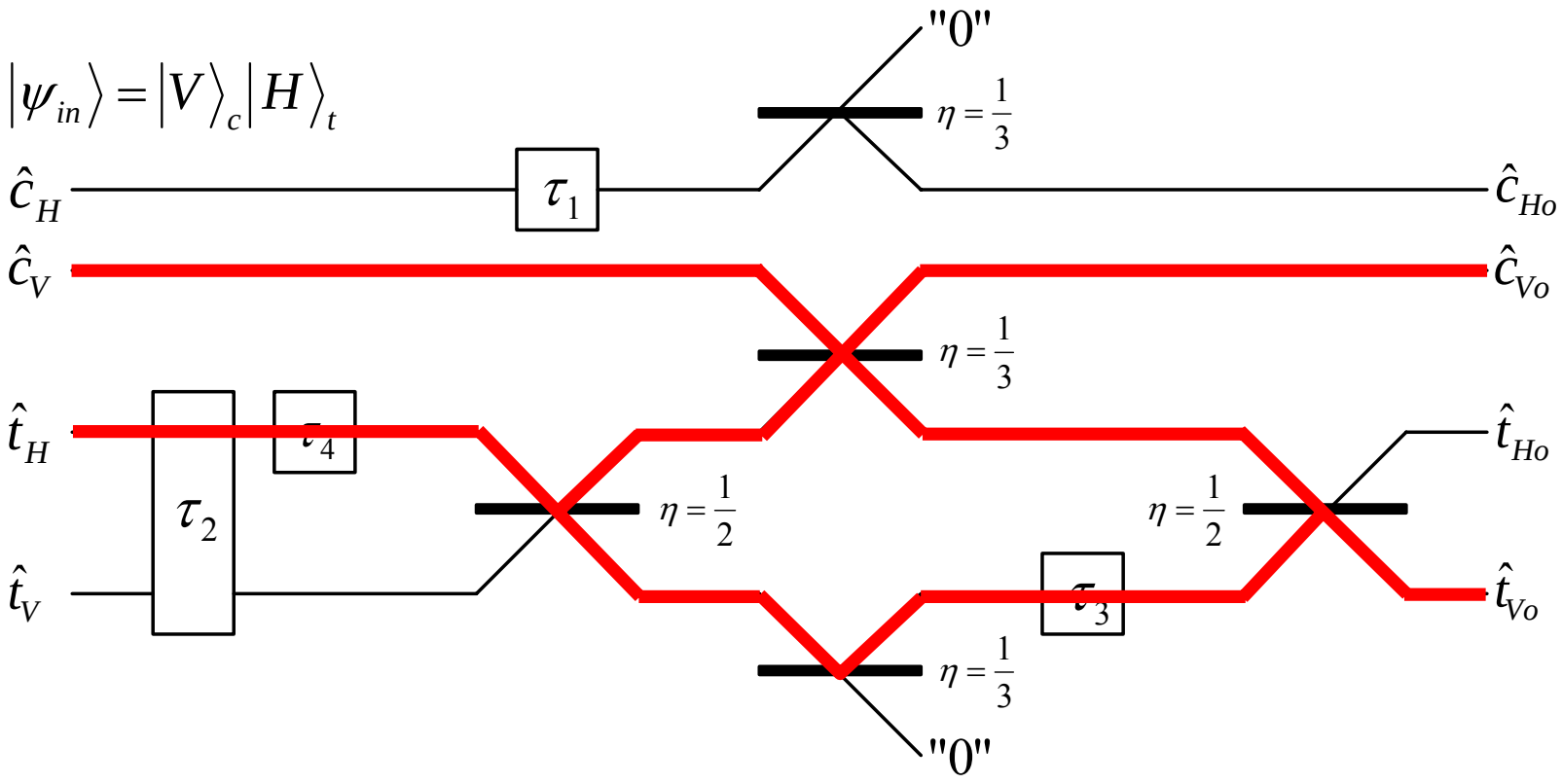

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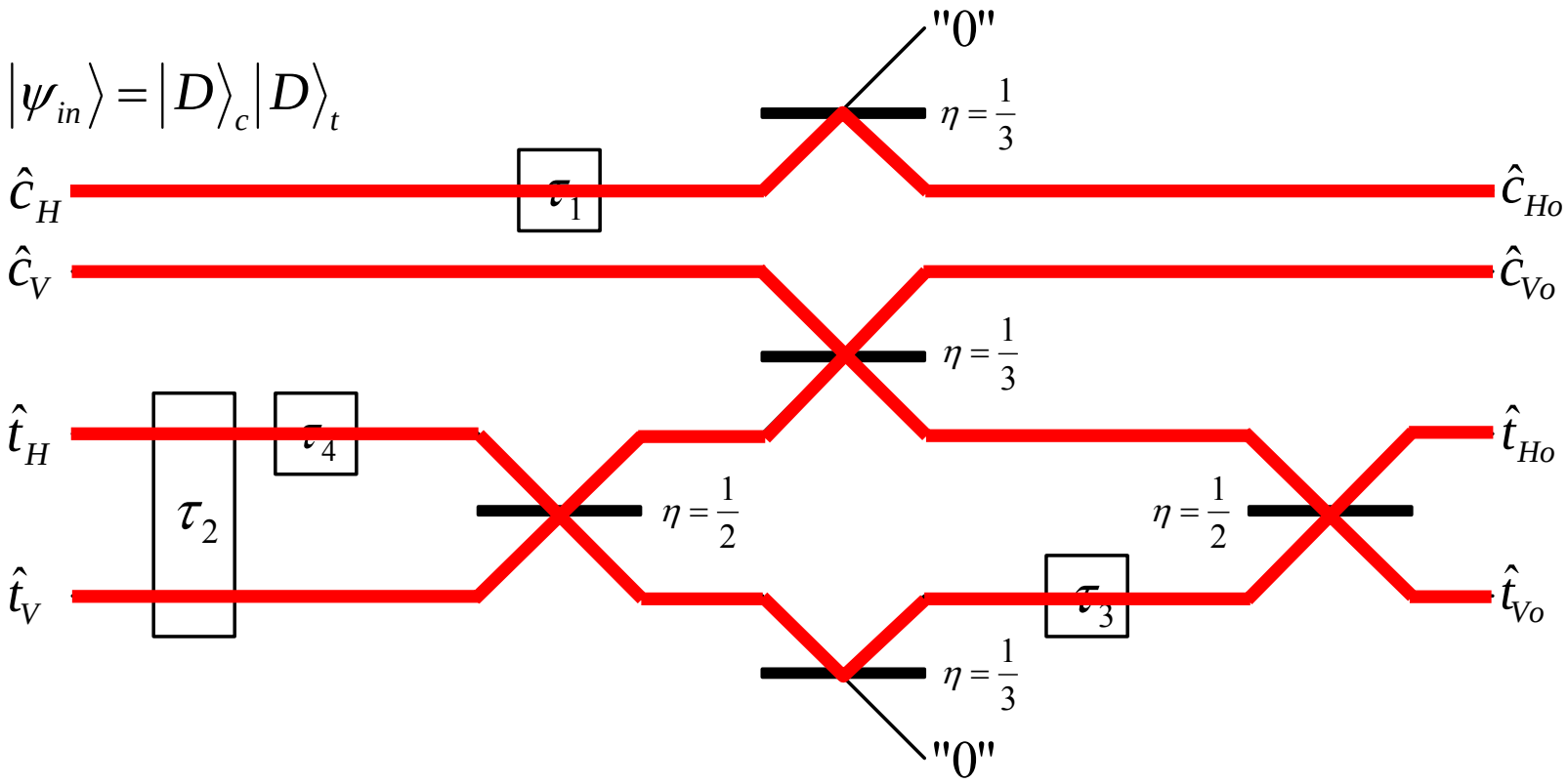


Measure in

$|D\rangle_c |D\rangle_t$

basis

Non-intrusive determination of mode-matching parameters

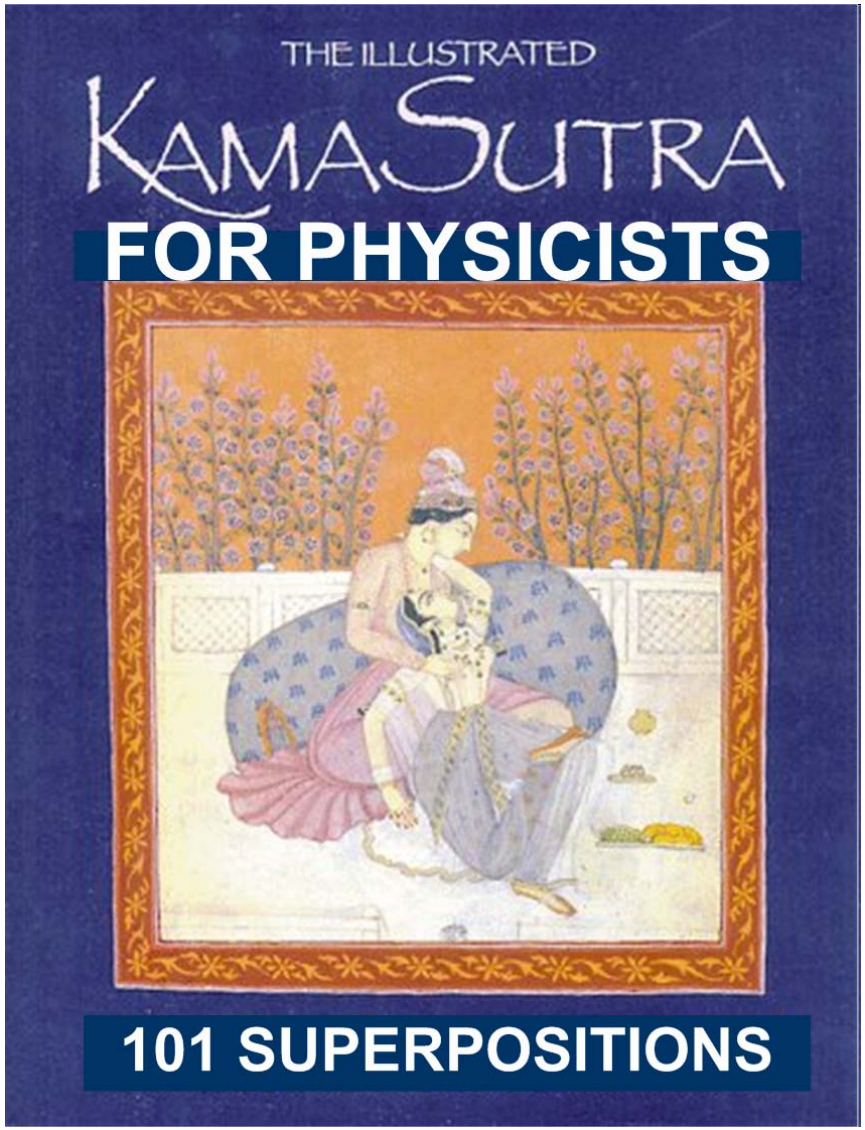
- In principle, 4 coincidence measurements can uniquely determine τ_1-τ_4 non-intrusively
- Problems
  - We assume there is only one degree of freedom in mode-matching
  - Experimental problems apart from mode-matching
- More general approach
  - Use more than 4 inputs and 4 coincidence measurements
- Accuracy
  - Ideal gate model: error ~ 3.4%
  - Model with mode matching: error ~ 1.2%

Final note

- Techniques described apply in general to any source of distinguishability
  - Temporal
  - Frequency
  - Spatial
  - Polarization

Peter's lame joke of the day…

My idea for a book



Questions?