Accurate and Precise Characterization of Linear Optical Interferometers

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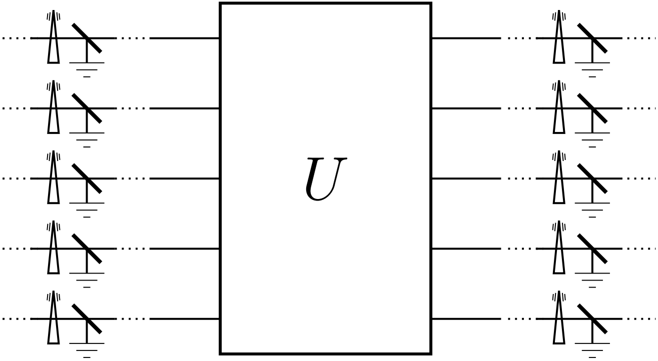
Characterization of Linear Optics

Why Characterization of Linear Optical Interferometers?

Linear Optical Interferometer



Why Linear Optical Interferometers?

Theory

- Linear optical quantum computation
- BosonSampling
- Optical quantum walk

Experiments

- Better single-photon sources
- Better detectors
- Tunable photonic integrated circuits

Problem

The current procedures for characterizing multi-channel interferometers are inaccurate and imprecise.

Background: Current Characterization Procedures

Characterization using Coherent States

Complete Characterization of Quantum-Optical Processes

Mirko Lobino, Dmitry Korystov, Connor Kupchak, Eden Figueroa,
Barry C. Sanders, A. I. Lvovsky*

The technologies of quantum information and quantum control are rapidly improving, but full exploitation of their capabilities requires complete characterization and assessment of processes that occur within quantum devices. We present a method for characterizing, with arbitrarily high accuracy, any quantum optical process. Our protocol recovers complete knowledge of the process by studying, via homodyne tomography, its effect on a set of coherent states, that is, classical fields produced by common laser sources. We demonstrate the capability of our protocol by evaluating and experimentally verifying the effect of a test process on squeezed vacuum.

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Suitable for general CPTP channel.

Phase stability requirement.

m-channel process $\implies$ m^4 measurements on m homodyne detectors, m-product coherent states.

Characterization using One and Two Photons

Super-stable tomography of any linear optical device

Anthony Laing* and Jeremy L. O'Brien
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Linear optical circuits of growing complexity are playing an increasing role in emerging photonic quantum technologies. Individual photonic devices are typically described by a unitary matrix containing amplitude and phase information, the characterisation of which is a key task. We present a constructive scheme to retrieve the unitary matrix describing an arbitrary linear optical device using data obtained from one-photon and two-photon ensembles. The scheme is stable on the arbitrarily increasable length scale of the photon packet and independent of photon loss at input and output ports of the device. We find a one-to-one correspondence between ideal data and unitary

arXiv:1208.2868v1 [quant-ph] 14 Aug 2012

Stable to photon-packet length scale

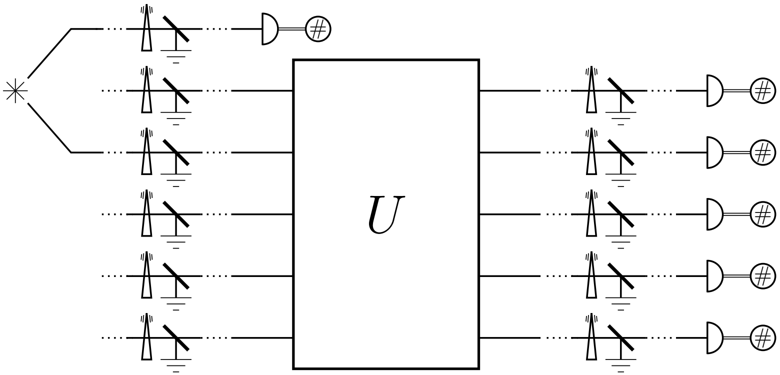
Inaccurate. No good estimator of precision.

Accurate and Precise Characterization

Characterization using One and Two Photons

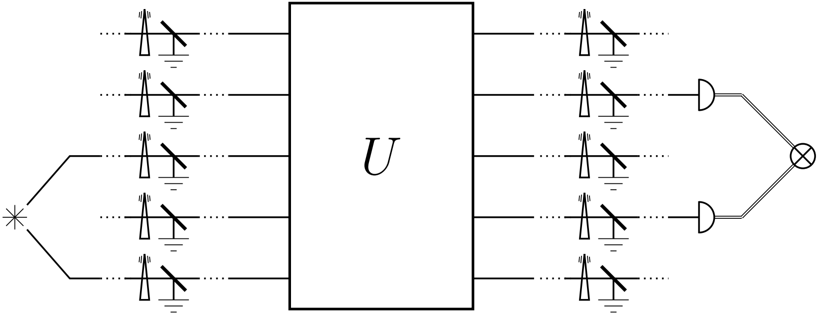
$$U = \begin{pmatrix} \tau_{1,1} & \tau_{1,2} & \cdots & \tau_{1,m} \\ \tau_{2,1} & \tau_{2,2}e^{i\alpha_{2,2}} & \cdots & \tau_{2,m}e^{i\alpha_{2,m}} \\ \vdots & \vdots & \ddots & \vdots \\ \tau_{m,1} & \tau_{m,2}e^{i\alpha_{m,2}} & \cdots & \tau_{m,m}e^{i\alpha_{m,m}} \end{pmatrix}$$

Accurate and Precise Characterization



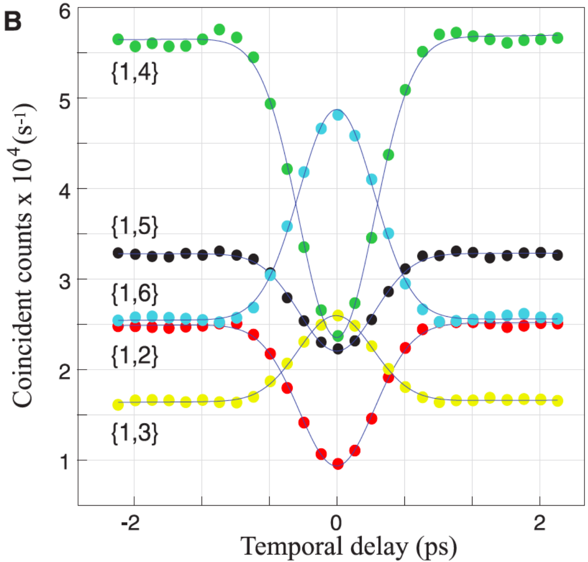
Single-photon transmission rates $\rightarrow \tau_{i,j}$

Accurate and Precise Characterization

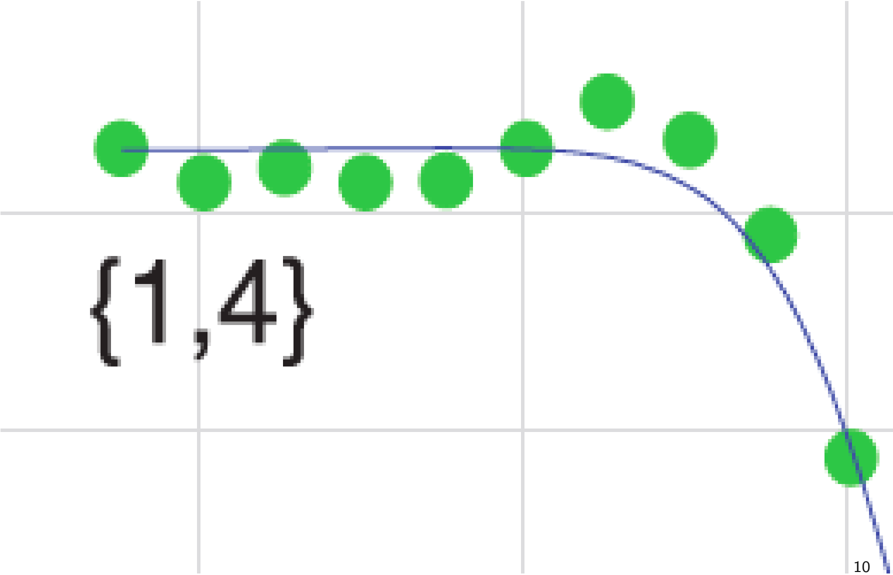


Two-photon coincidence rates $\rightarrow \alpha_{i,j}$

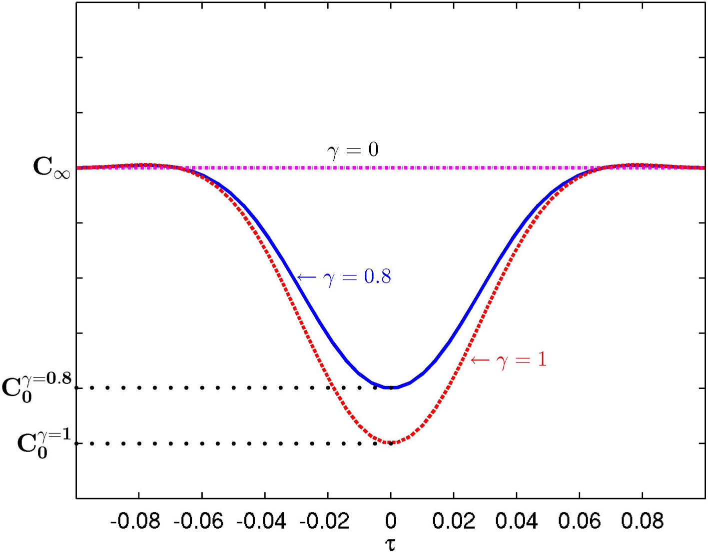
Curve Fitting for Enhanced Precision



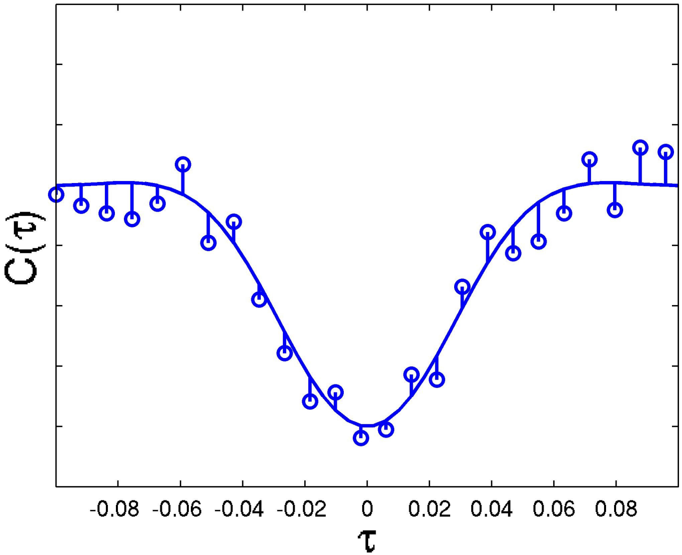
Curve Fitting for Enhanced Precision



Calibration against Mode Mismatch



Bootstrapping for Meaningful Error Bars



Experimental Verification

Measure beamsplitter reflectivity using single-photon data.

Calibrate for mode-mismatch using beamsplitter of known reflectivity.

Measure reflectivity value of three beamsplitters obtained using different methods.

Our procedure gives correct answer wrt single photon data within error bars. Other methods do not.

Conclusion

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Accurate, precise characterization of linear optics interferometers.

Experimental test of characterization procedure.