Alternativní strategie pro SH tomografii

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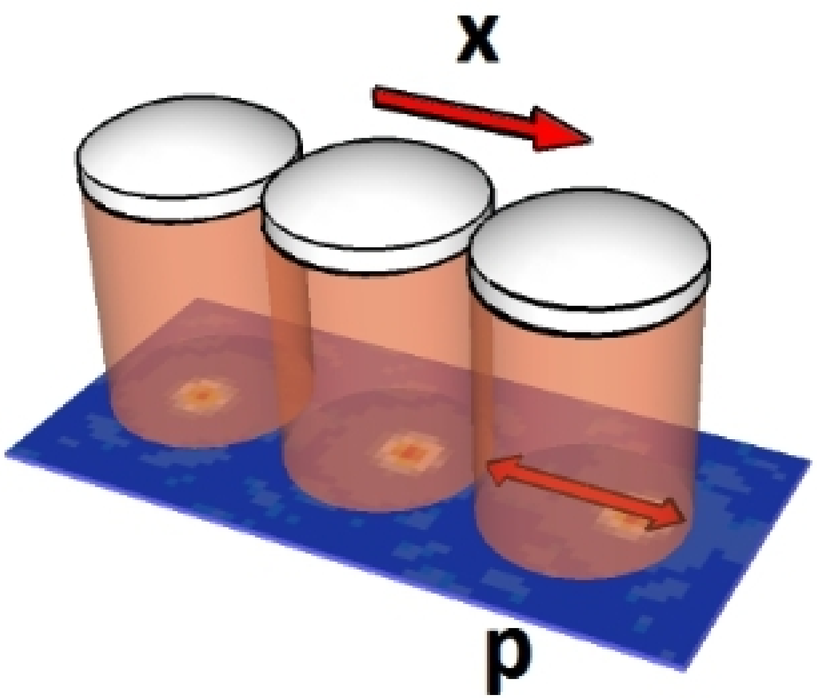
Shack-Hartmann detection

standard S-H detection

- local wavefront tilts are measured
- wavefront is reconstructed
- what if there is no well-defined wavefront?



SH-detection: detailed picture

system

- external degrees of freedom of light
- described by coherence matrix ρ
- notice that $\rho \geq 0$

measurement

- simultaneous position and momentum measurement

Z.Hradil, J.R., L.L.Sanchez-Soto, Phys. Rev. Lett. ***105****, 010401 (2010)*

Standard QSE

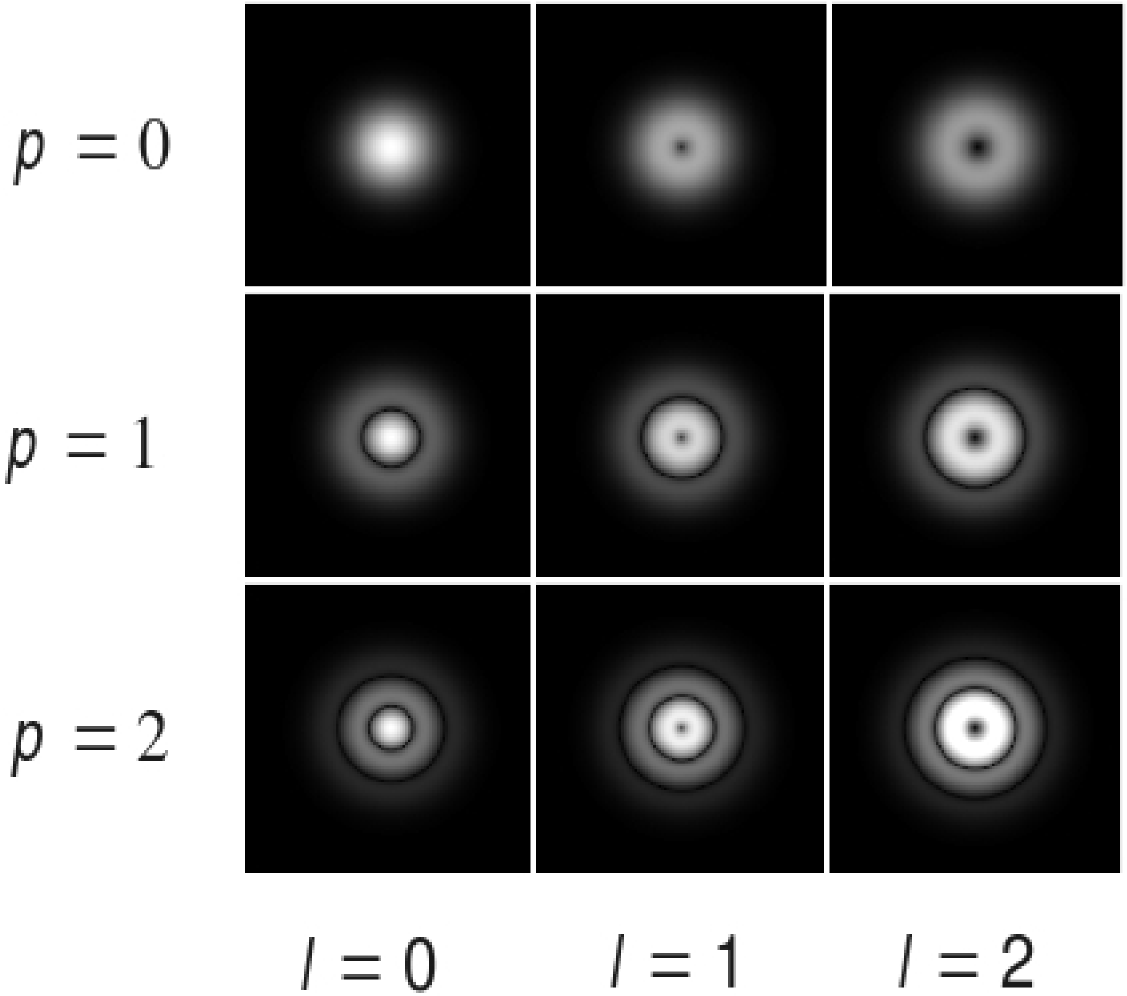
some known issues

- knowledge of the measurement required
- result may strongly depend on the reconstruction space
- imperfect knowledge of the apparatus
  - bias
  - reconstruction artifacts
  - reconstruction breaks down

Characterization of vortex beams

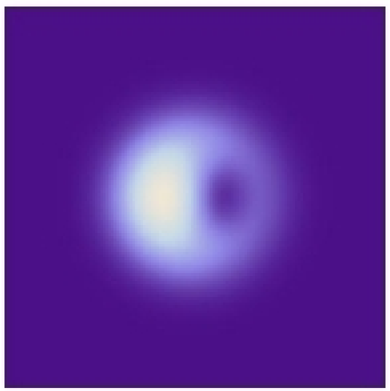
- Laguerre-Gaussian beams

$$LG_p^l(x,y) = \langle x\, y | l\, p \rangle \propto r^{|l|} L_p^{|l|}(2r^2) e^{-r^2} e^{il\varphi}$$

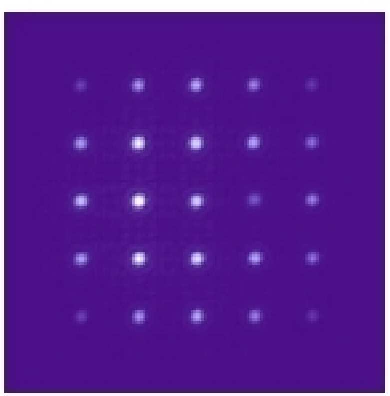


Characterization ...

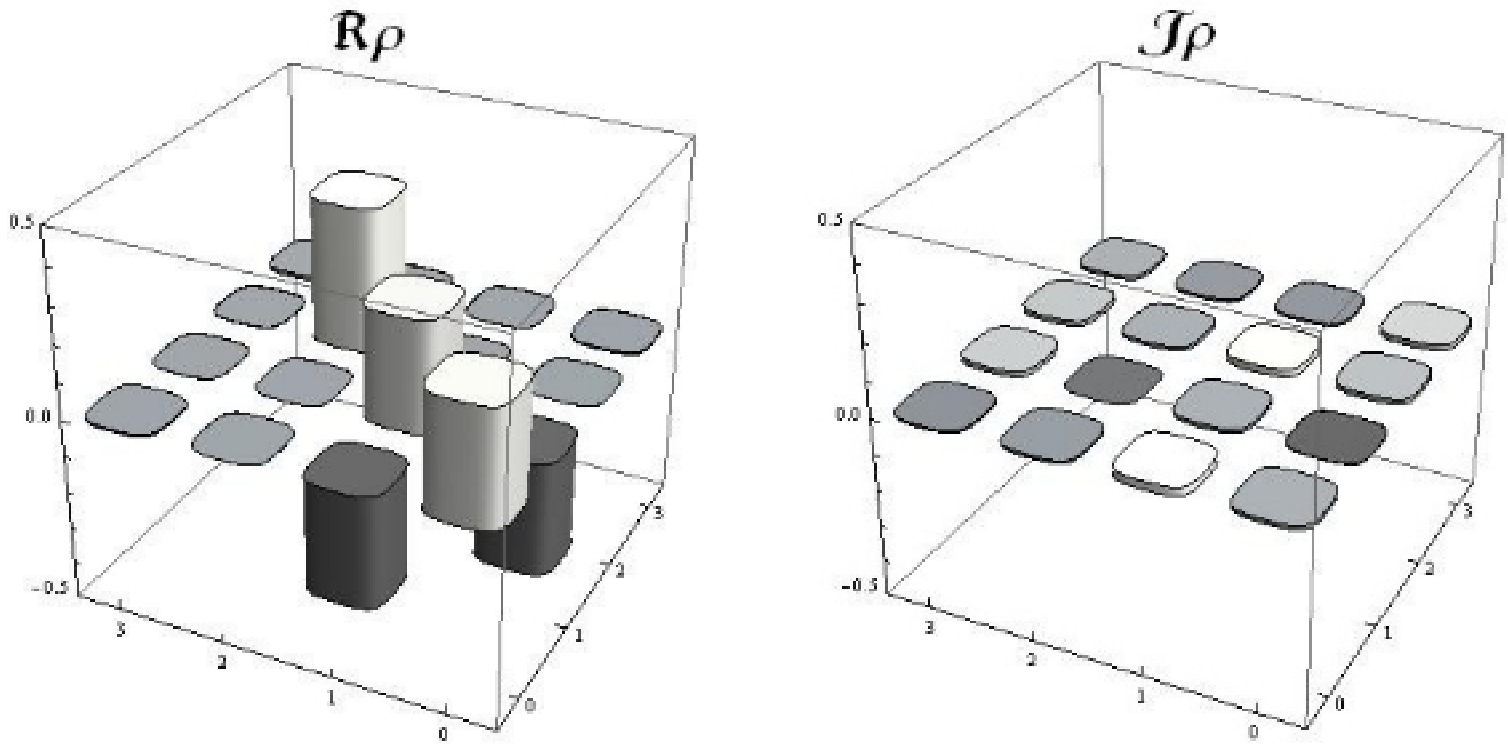
$$\rho_{\text{true}} = \frac{3}{5}\left|LG_0^0 - LG_0^1\right\rangle\left\langle LG_0^0 - LG_0^1\right| + \frac{2}{5}\left|LG_0^2\right\rangle\left\langle LG_0^2\right|$$



intensity

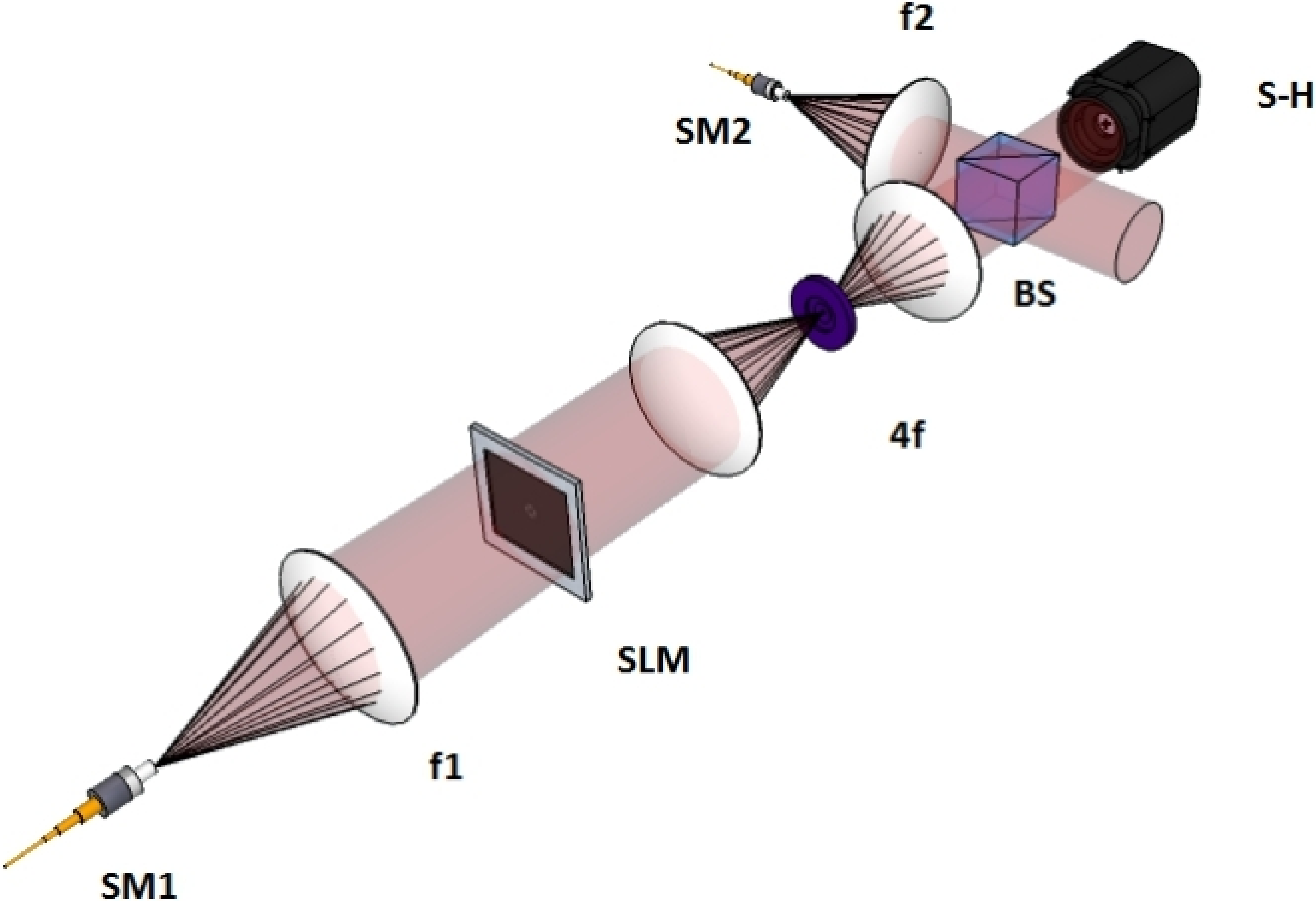


SH data



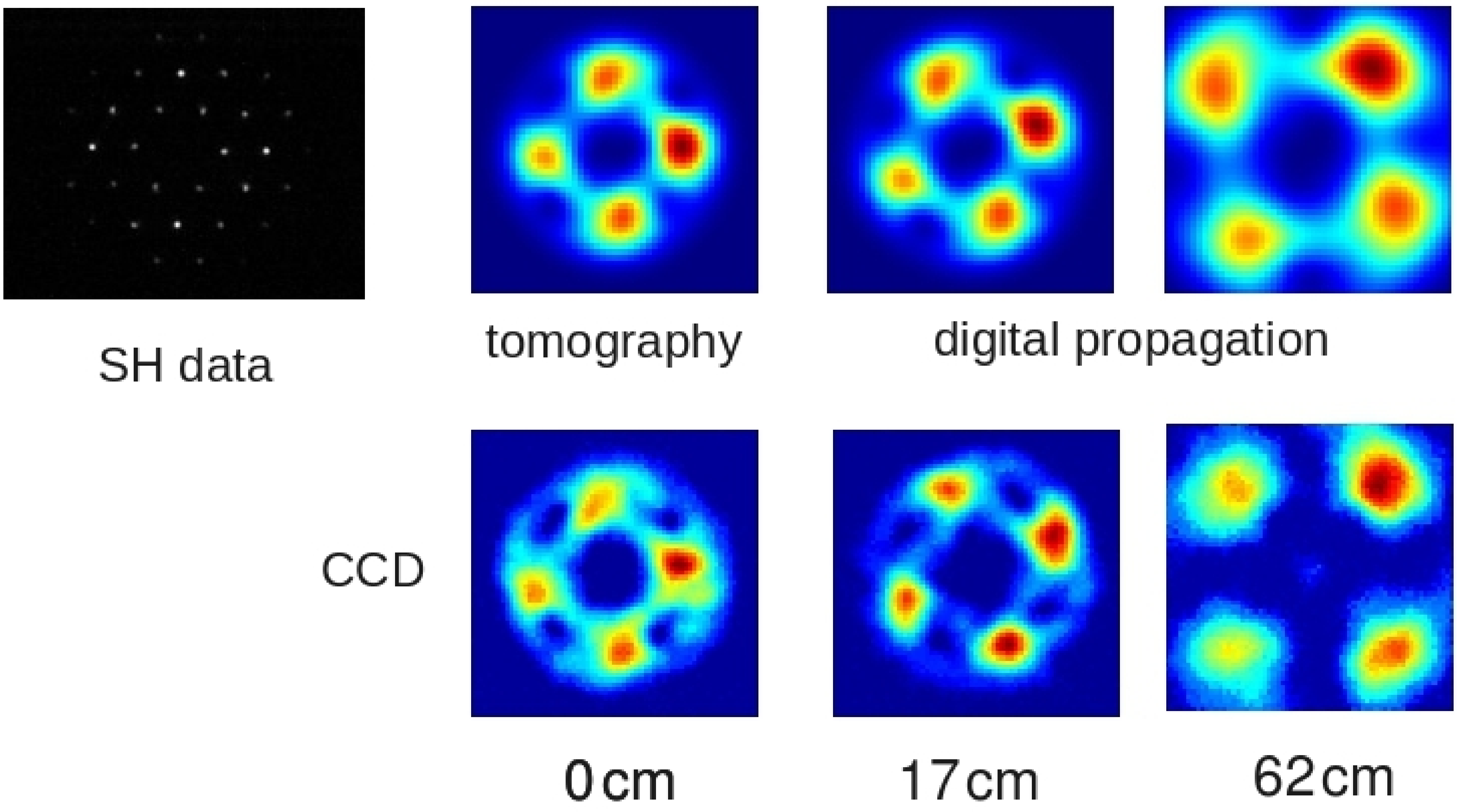
reconstruction from simulated data (5% noise)

Experimental setup



Propagation of vortices

- target state $|LG_0^4\rangle + |LG_0^8\rangle$



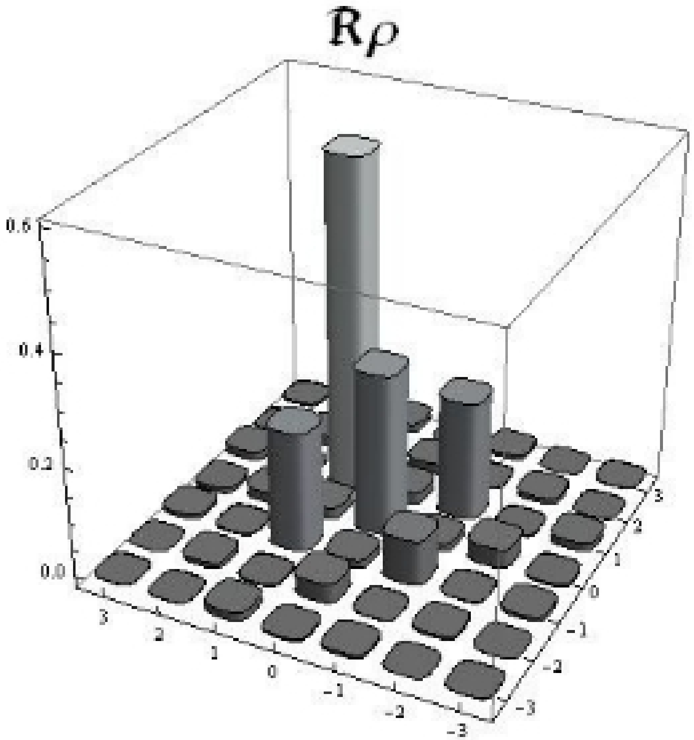
Plane waves

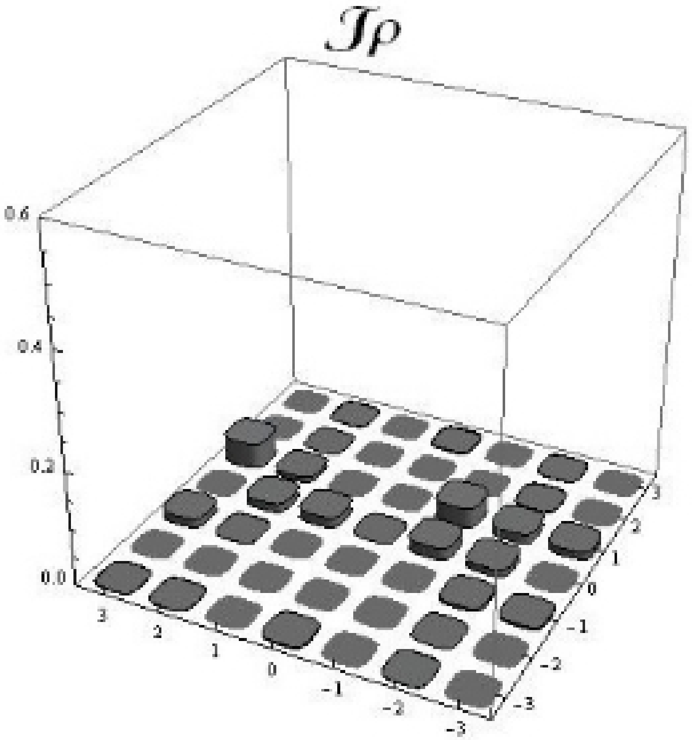
- target state

$$\rho = |\Psi\rangle\langle\Psi| + \alpha\,|0\rangle\langle 0|\ ,\quad |\Psi\rangle = |-1\rangle + \beta\,|1\rangle$$

angle w.r.t. optical axis

- reconstruction





Data pattern tomography

key features

- prior knowledge of the apparatus is not required
- estimator is a mixture of experimentally feasible probe states
- reconstruction space is spanned by the probe states
- *field of view* is determined by the quantum resources used in the experiment

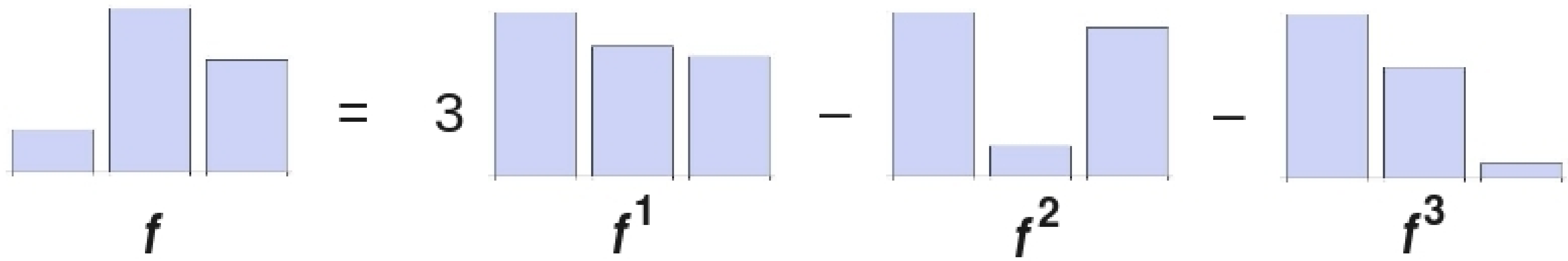
Procedure

- probe states σ_k measured
- data patterns f_j^k recorded
- unknown state ρ measured and data f_j recorded

- best fit of f_j in terms of f_j^k found: $f_{j,\text{est}} = \sum_k x_k f_j^k$
- estimator: $\rho_{\text{est}} = \sum_k x_k \sigma_k$

- quantum theory enters the procedure through positivity constraints

Very simple example



reconstruction: $\rho = 3\sigma_1 - \sigma_2 - \sigma_3$

Procedure

data pattern tomography

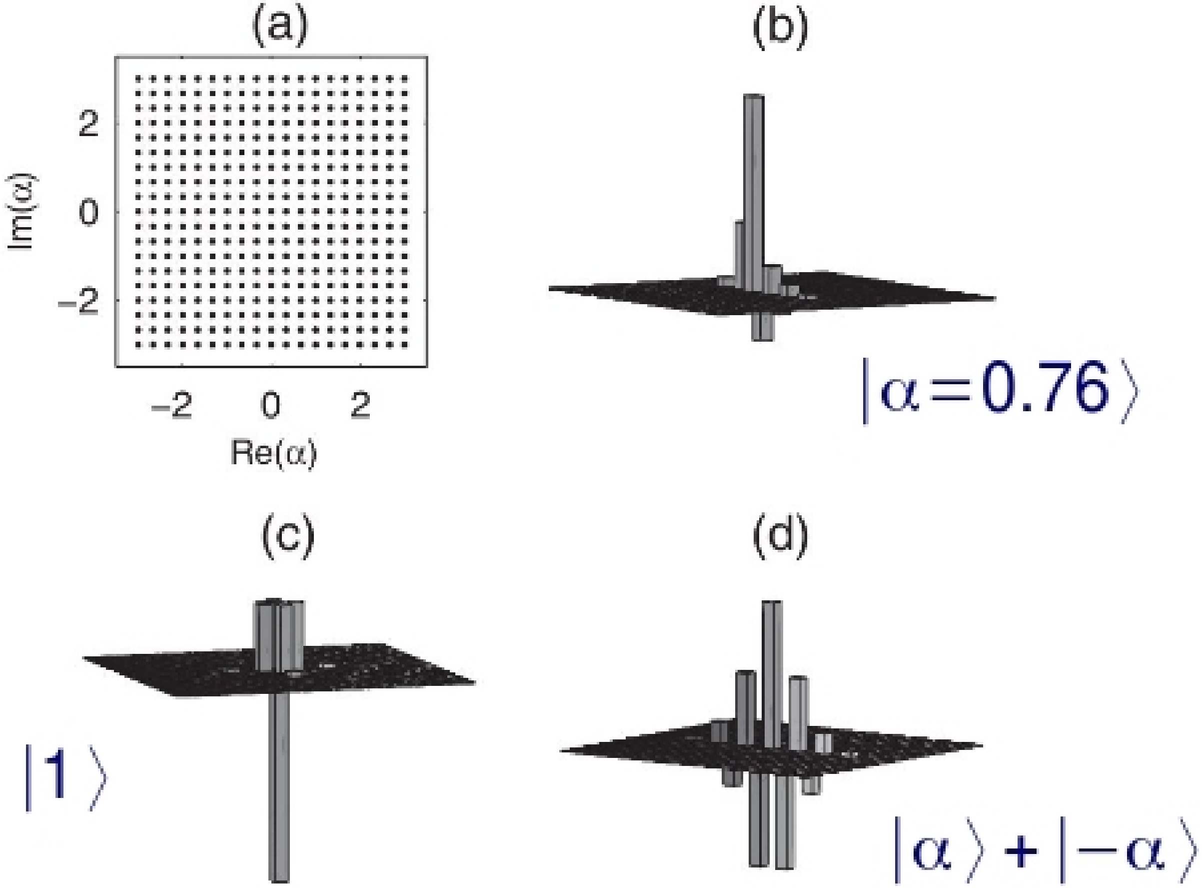
- find $\boldsymbol{x}$ minimizing $\mathrm{dist}\left(\boldsymbol{f}, \sum_k x_k \boldsymbol{f}^k\right)$
- subject to $\rho_{\mathrm{est}} = \sum_k x_k \sigma_k$ being non-negative $\rho_{\mathrm{est}} \geq 0$

numerical implementation

- primal-dual interior point method
  - barrier function
  - perturbed complementarity condition

State representation

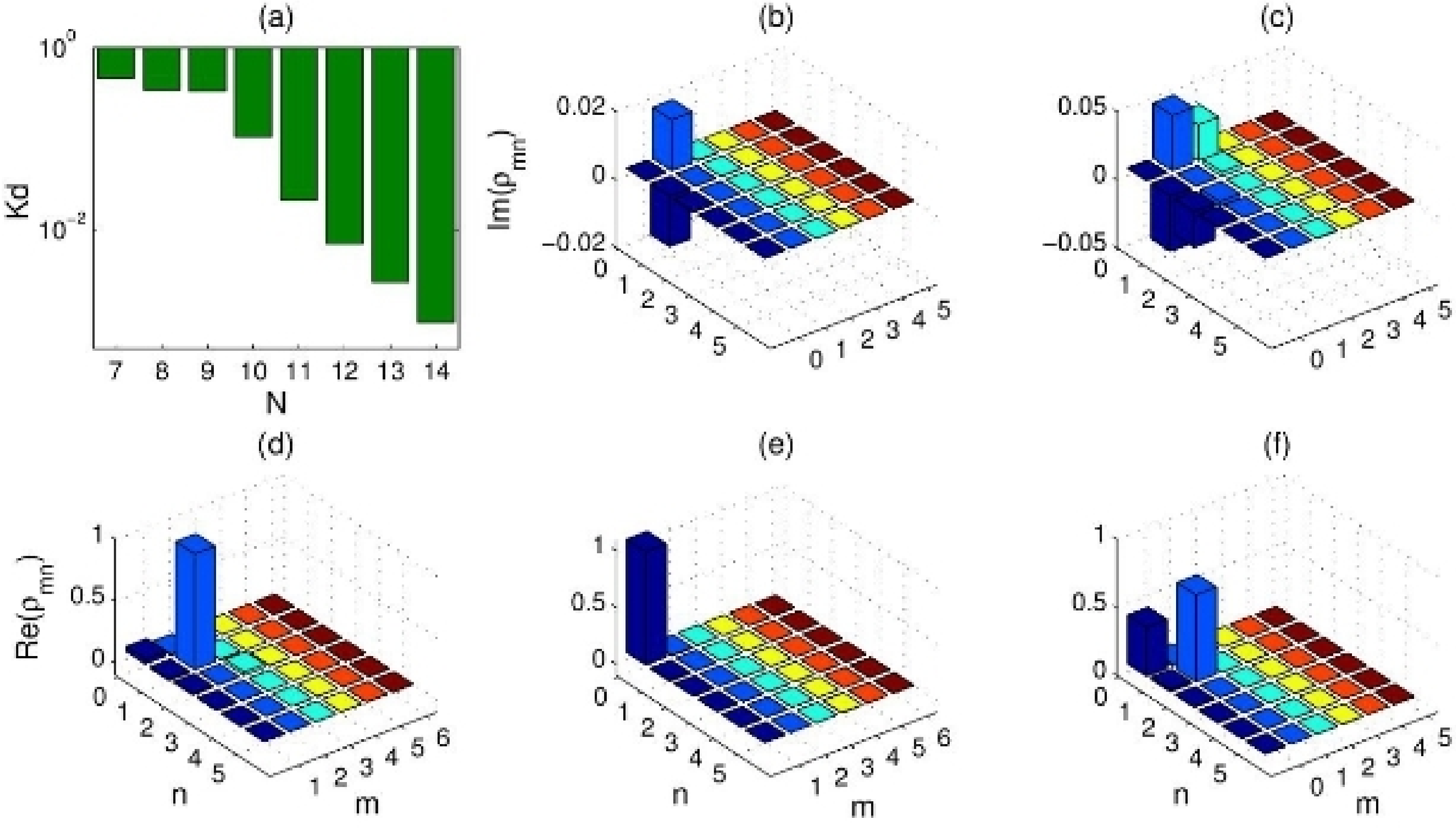
- coherent-state representation



Example: homodyne tomography

- phase-averaged coherent probe states

$p_j =$



Conclusions

- Data pattern tomography proposed for SH tomography.
- No prior calibration of the measurement apparatus is necessary.
- Tomography with unknown wavefront sensors is possible.
- *Field of view* is uniquely defined by the measurement.

J.R., D.Mogilevtsev, Z.Hradil, Phys. Rev. Lett. ***105****, 010402 (2010)*