Протоколы преобразования трисжатого состояния в кубическое фазовое состояние

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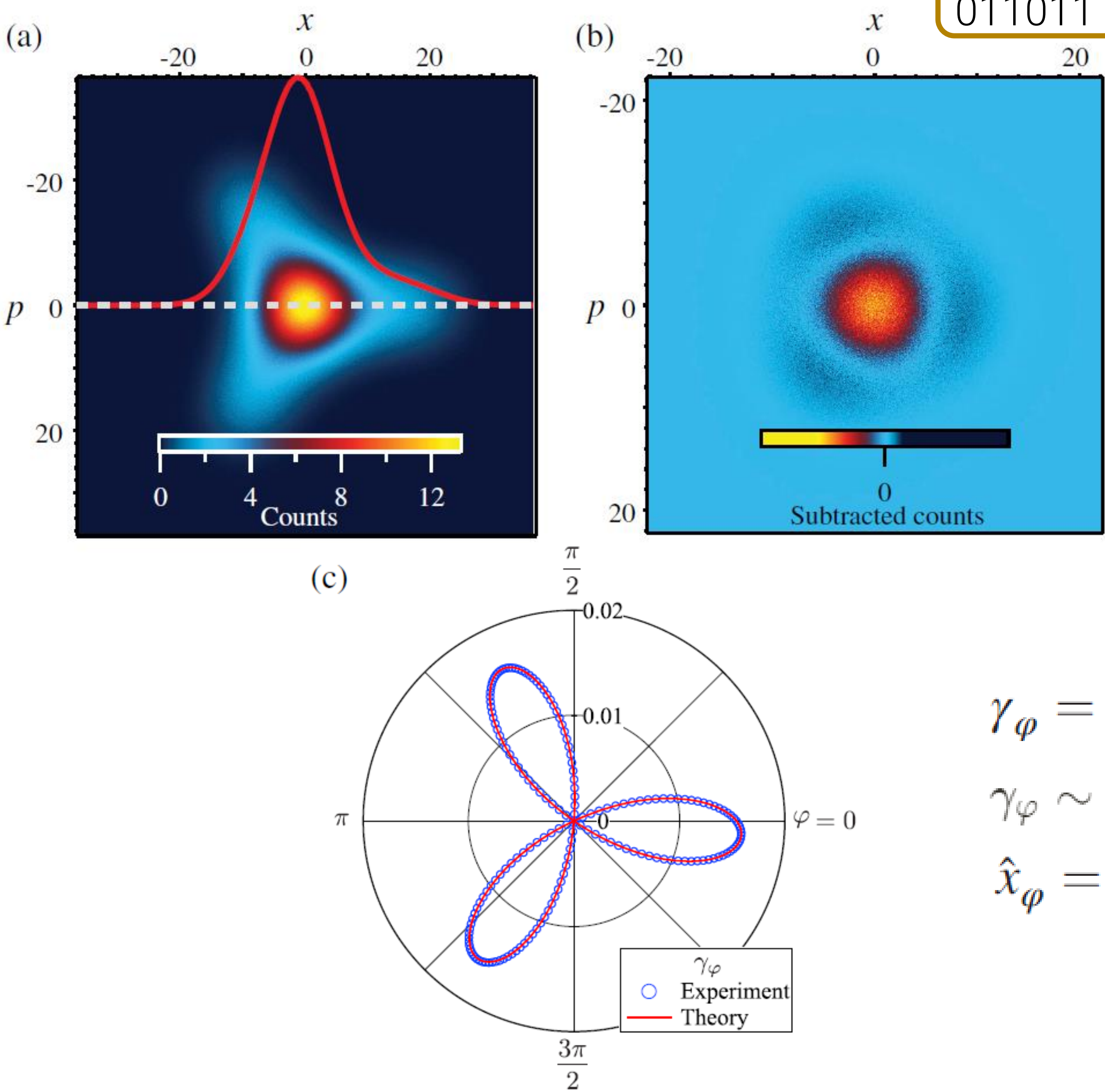
Sandbo Chang et al., Phys. Rev. X 10, 011011 (2020)

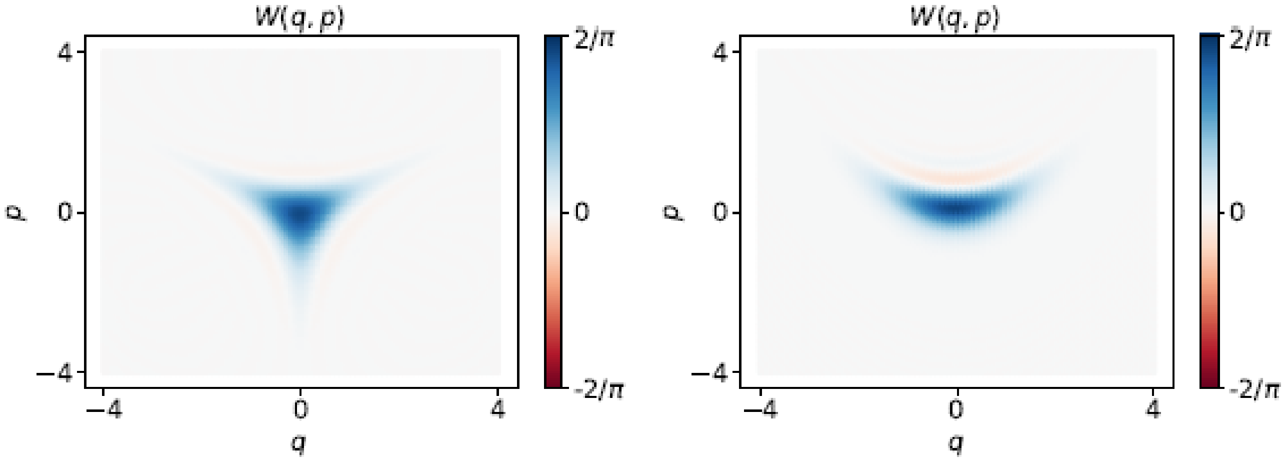


$$\gamma_\varphi = \gamma(x_\varphi)$$

$$\gamma_\varphi \sim \langle \hat{x}_\varphi^3 \rangle$$

$$\hat{x}_\varphi = \hat{x}\cos\varphi - \hat{p}\sin\varphi$$

Цель протоколов преобразования



(a) Trisqueezed state $|\Psi_{\text{in}}\rangle$. (b) Cubic phase state $|\Psi_{\text{target}}\rangle$.

$$|\Psi_{\text{in}}\rangle = e^{i(t^*\hat{a}^3 + t\hat{a}^{\dagger 3})}\,|0\rangle \qquad |\Psi_{\text{target}}\rangle = e^{ir\hat{q}^3}\,\hat{S}(\xi_{\text{target}})\,|0\rangle$$

$$\hat{S}(\xi) = e^{\frac{\xi^*}{2}\hat{a}^2 - \frac{\xi}{2}\hat{a}^{\dagger 2}}$$

$$\hat{D}(\beta) = e^{\beta\hat{a}^\dagger - \beta^*\hat{a}}$$

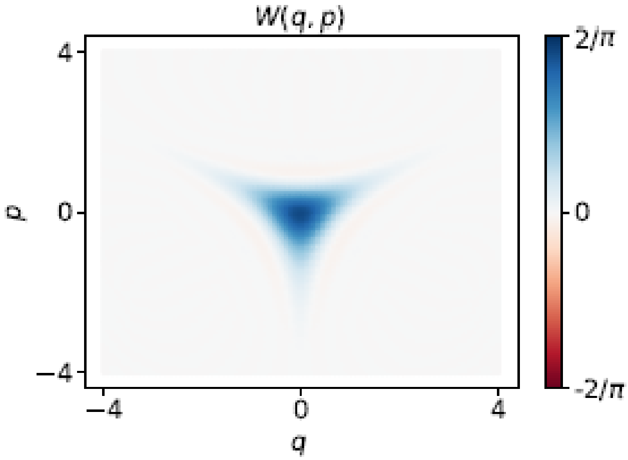
$$\hat{U}_p(\gamma) = e^{-i\gamma\hat{n}}$$

$$\gamma \in \mathbb{R},\ \beta \in \mathbb{C},\ \xi \in \mathbb{C}$$

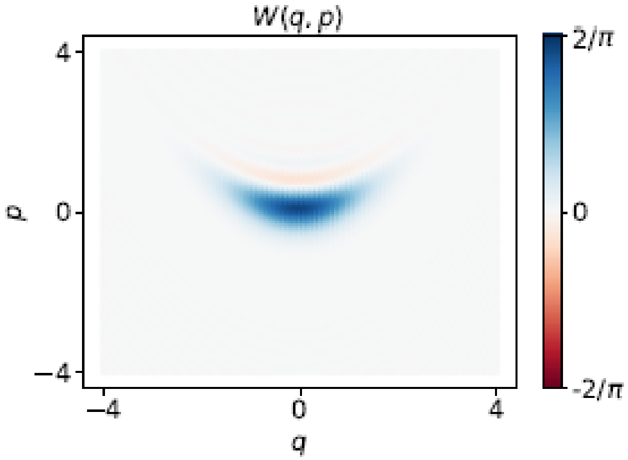
$$\hat{n} = \hat{a}^\dagger\hat{a}$$

Zheng, Yu, et al. "Gaussian conversion protocols for cubic phase state generation." *PRX Quantum* 2.1 (2021): 010327.

Цель протоколов преобразования



(a) Trisqueezed state $|\Psi_{\text{in}}\rangle$.



(b) Cubic phase state $|\Psi_{\text{target}}\rangle$.

$$|\Psi_{\text{in}}\rangle = e^{i(t^*\hat{a}^3 + t\hat{a}^{\dagger 3})}\,|0\rangle$$

$$|\Psi_{\text{target}}\rangle = e^{ir\hat{q}^3}\,\hat{S}(\xi_{\text{target}})\,|0\rangle$$

$$\hat{S}(\xi) = e^{\frac{\xi^*}{2}\hat{a}^2 - \frac{\xi}{2}\hat{a}^{\dagger 2}}$$

$$\hat{D}(\beta) = e^{\beta\hat{a}^\dagger - \beta^*\hat{a}}$$

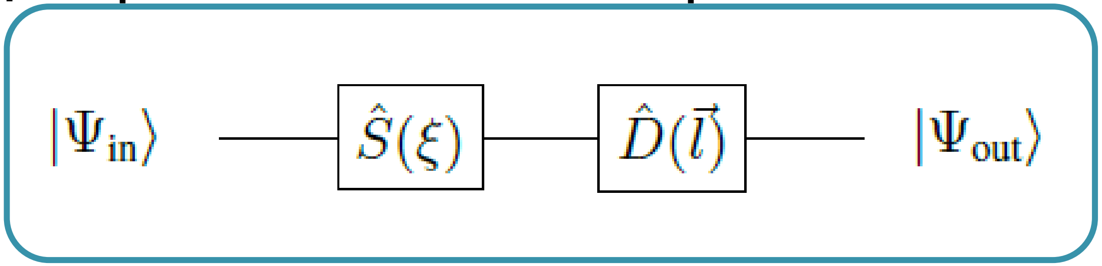
$$\hat{U}_p(\gamma) = e^{-i\gamma\hat{n}}$$

Протоколы преобразования

- Детерминистический
- Вероятностный

Zheng, Yu, et al. "Gaussian conversion protocols for cubic phase state generation." *PRX Quantum* 2.1 (2021): 010327.

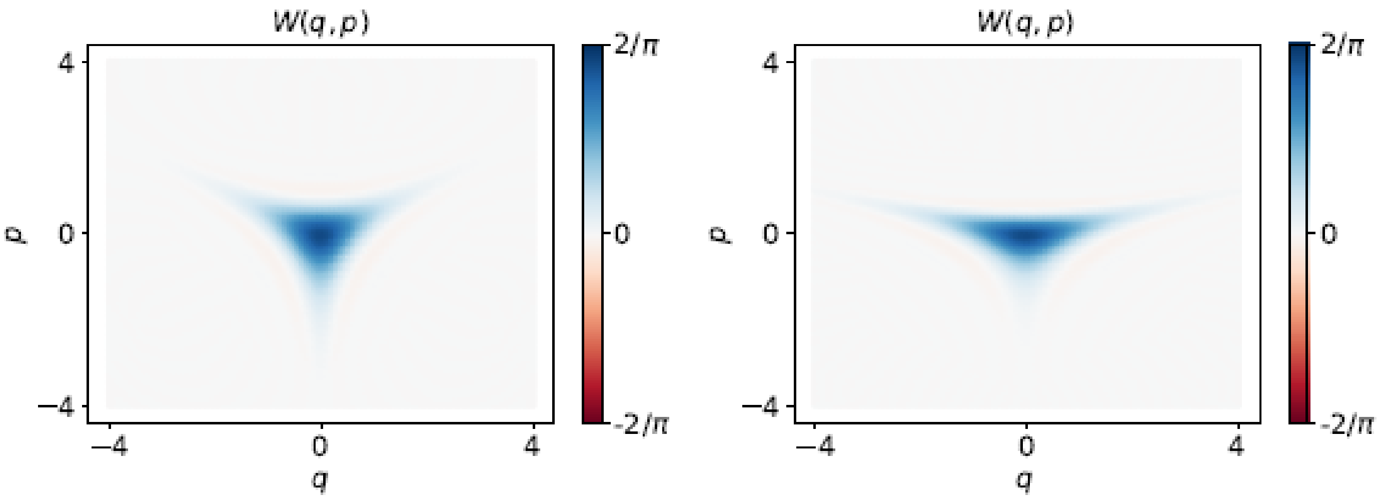
Детерминистический протокол



$$|\Psi_{\text{in}}\rangle = e^{i(t^*\hat{a}^3 + t\hat{a}^{\dagger 3})}\,|0\rangle$$

$$|\Psi_{\text{target}}\rangle = e^{ir\hat{q}^3}\,\hat{S}(\xi_{\text{target}})\,|0\rangle$$

$$\hat{S}(\xi)e^{it(\hat{a}^3+\hat{a}^{\dagger 3})}\,\hat{S}^\dagger(\xi) \to e^{ir\hat{q}^3}$$



(a) Trisqueezed state $|\Psi_{\text{in}}\rangle$.   (b) Output state $|\Psi_{\text{out}}\rangle$.

$$\hat{S}(\xi) = e^{\frac{\xi^*}{2}\hat{a}^2 - \frac{\xi}{2}\hat{a}^{\dagger 2}}$$

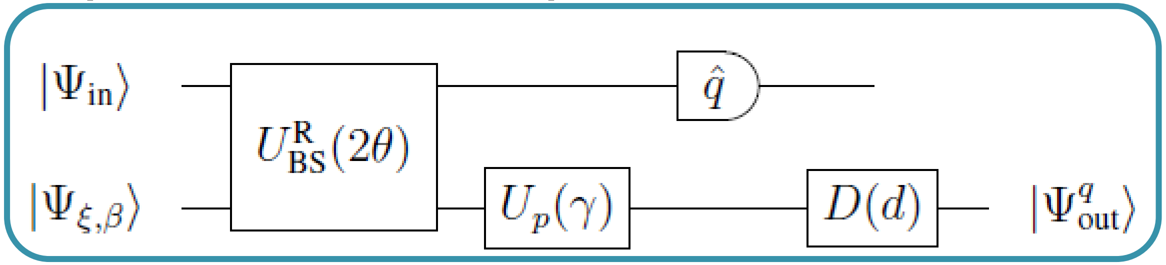
$$\hat{D}(\beta) = e^{\beta\hat{a}^\dagger - \beta^*\hat{a}}$$

$$\beta \in \mathbb{C},\ \ \xi \in \mathbb{C}$$

Triplicity	Cubicity	Fidelity	Squeezing	Displacement l_p	Displacement l_q
0.1	0.1558	0.9708	0.6741 (3.4 dB)	0.1547	$2 \cdot 10^{-9}$
0.125	0.2757	0.9273	0.7816 (2.1 dB)	0.2268	-10^{-8}
0.15	0.4946	0.8557	0.9463 (0.5 dB)	0.3029	$-5 \cdot 10^{-8}$

$$\mathcal{F}(\rho, \Psi_{\text{target}}) = \langle \Psi_{\text{target}}|\rho|\Psi_{\text{target}}\rangle.$$

Вероятностный протокол



$$|\Psi_{\text{in}}\rangle = e^{i(t^*\hat{a}^3 + t\hat{a}^{\dagger 3})}|0\rangle$$

$$|\Psi_{\xi,\beta}\rangle = \hat{D}(\beta)\hat{S}(\xi)|0\rangle$$

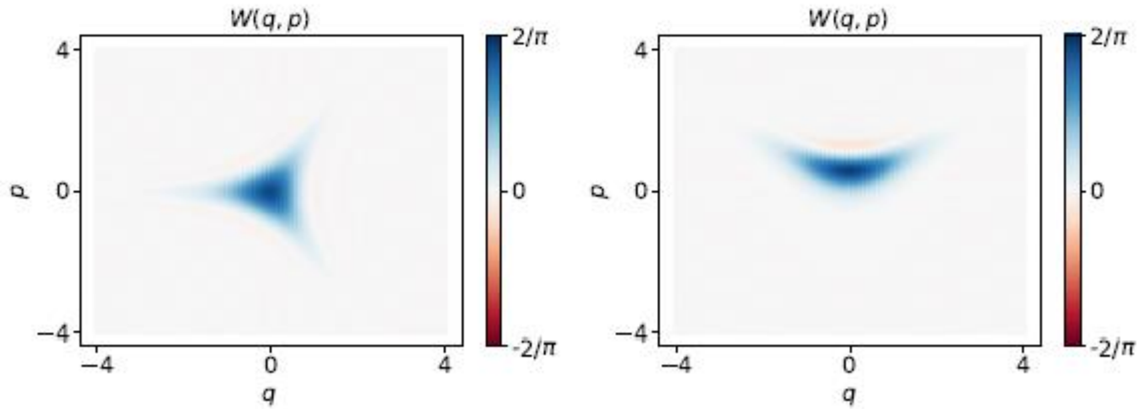
$$U^{\text{R}}_{\text{BS}}(2\theta) = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix}$$

$$\hat{D}(\beta) = e^{\beta\hat{a}^\dagger - \beta^*\hat{a}}$$

$$\hat{U}_p(\gamma) = e^{-i\gamma\hat{n}}$$

$$\gamma \in \mathbb{R},\ \beta \in \mathbb{C},\ \xi \in \mathbb{C}$$

$$t = 0.1\exp(i\pi/2))$$

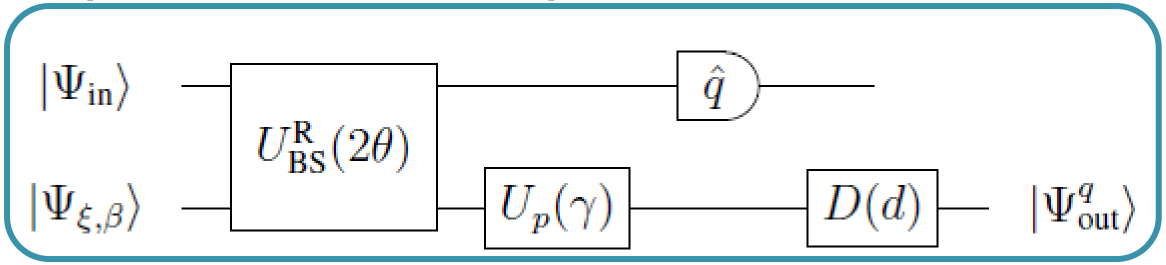


(a) Rotated trisqueezed state.

(b) Output state.

Triplicity	Fidelity	Probability	θ	q_β	ξ	d
0.1	0.9971	0.0513	1.0133	0.8304	0.3257 (2.83 dB)	-0.9525
0.125	0.9866	0.0434	0.7992	1.2153	0.001 (0.01dB)	-1.1104
0.15	0.9284	0.0508	0.6378	0.001	1.4184 (12.3dB)	-1.3639

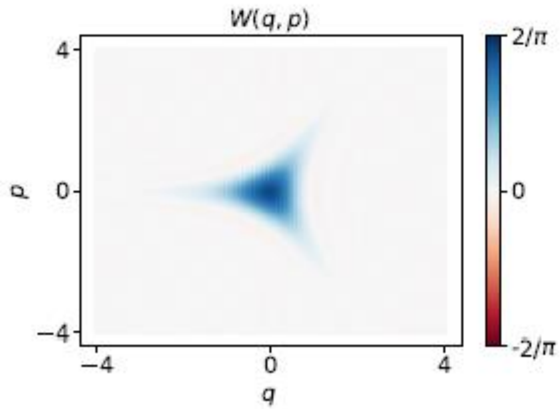
Вероятностный протокол



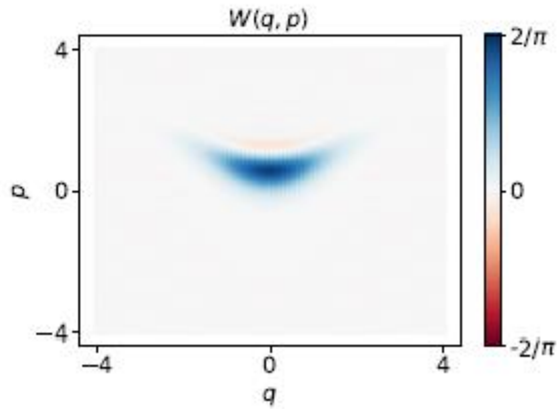
$$|\Psi_{\rm in}\rangle = e^{i(t^*\hat{a}^3 + t\hat{a}^{\dagger 3})}|0\rangle$$

$$|\Psi_{\xi,\beta}\rangle = \hat{D}(\beta)\hat{S}(\xi)|0\rangle$$

$$U^{\rm R}_{\rm BS}(2\theta) = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix}$$



(a) Rotated trisqueezed state.



(b) Output state.

$t = 0.1\exp(i\pi/2))$

$\beta = q_\beta + ip_\beta$

$\xi = |\xi|e^{i\varphi}$

$p_\beta = 0$

$\varphi = 0$

$\gamma = -\pi/2$

Triplicity	Fidelity	Probability	θ	q_β	ξ	d
0.1	0.9971	0.0513	1.0133	0.8304	0.3257 (2.83 dB)	-0.9525
0.125	0.9866	0.0434	0.7992	1.2153	0.001 (0.01dB)	-1.1104
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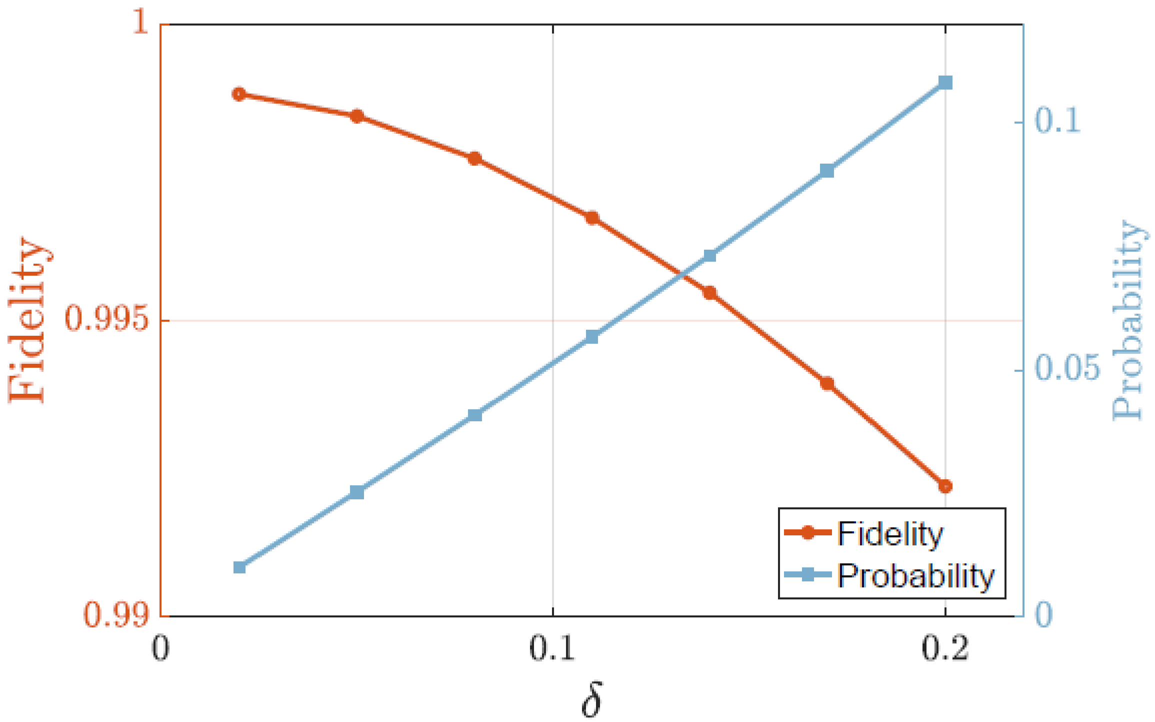
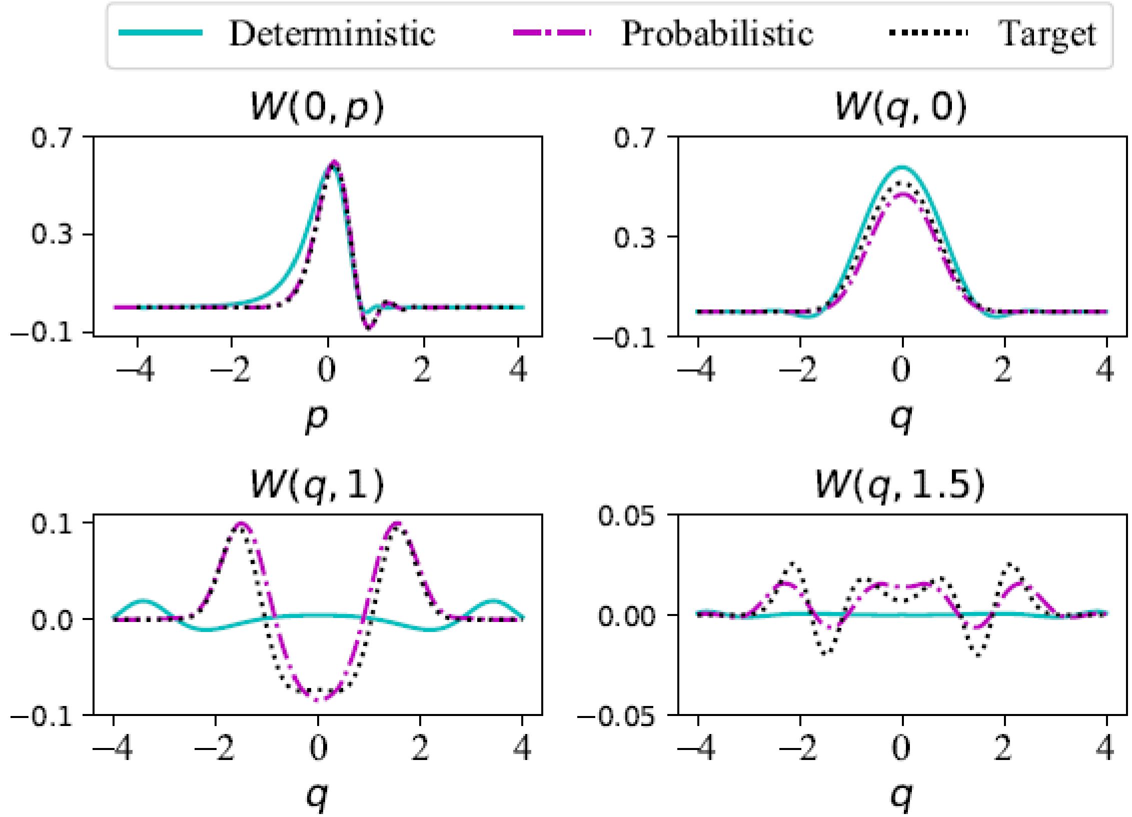


Fidelity and success probability as a function of the width of the acceptance region δ.

Сравнение результатов двух протоколов



Slices of Wigner functions to compare the output states of the deterministic and probabilistic protocols with the target cubic phase states for cubicity $r = 0.1558$. The value of the target squeezing is fixed at 5 dB.

Спасибо за внимание!