

Title: PSI 2015/2016 Quantum Information - Lecture 3

Date: Feb 24, 2016 11:30 AM

URL: <http://pirsa.org/16020080>

Abstract:

Last Lecture

Adeva film

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

1 bit

1) Superdense coding

2) 4 Teilpunkte

$\frac{1}{\sqrt{2}}$
 $(\frac{1}{\sqrt{2}})$

if double
info



→ Not gut
3^{er} Teil

$$\begin{aligned} |x\rangle &= \sqrt{\frac{1}{2}} e^{i\frac{\pi}{2}x} \\ &= e^{i\frac{\pi}{2}x} \end{aligned}$$

Last Lecture

Adversary film.

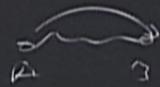
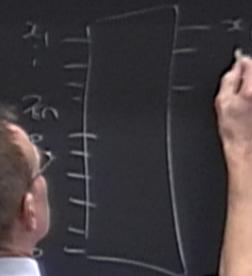
$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

1 bit of info

1) Superdense coding



→ NOT get 3rd bit

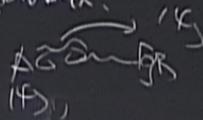


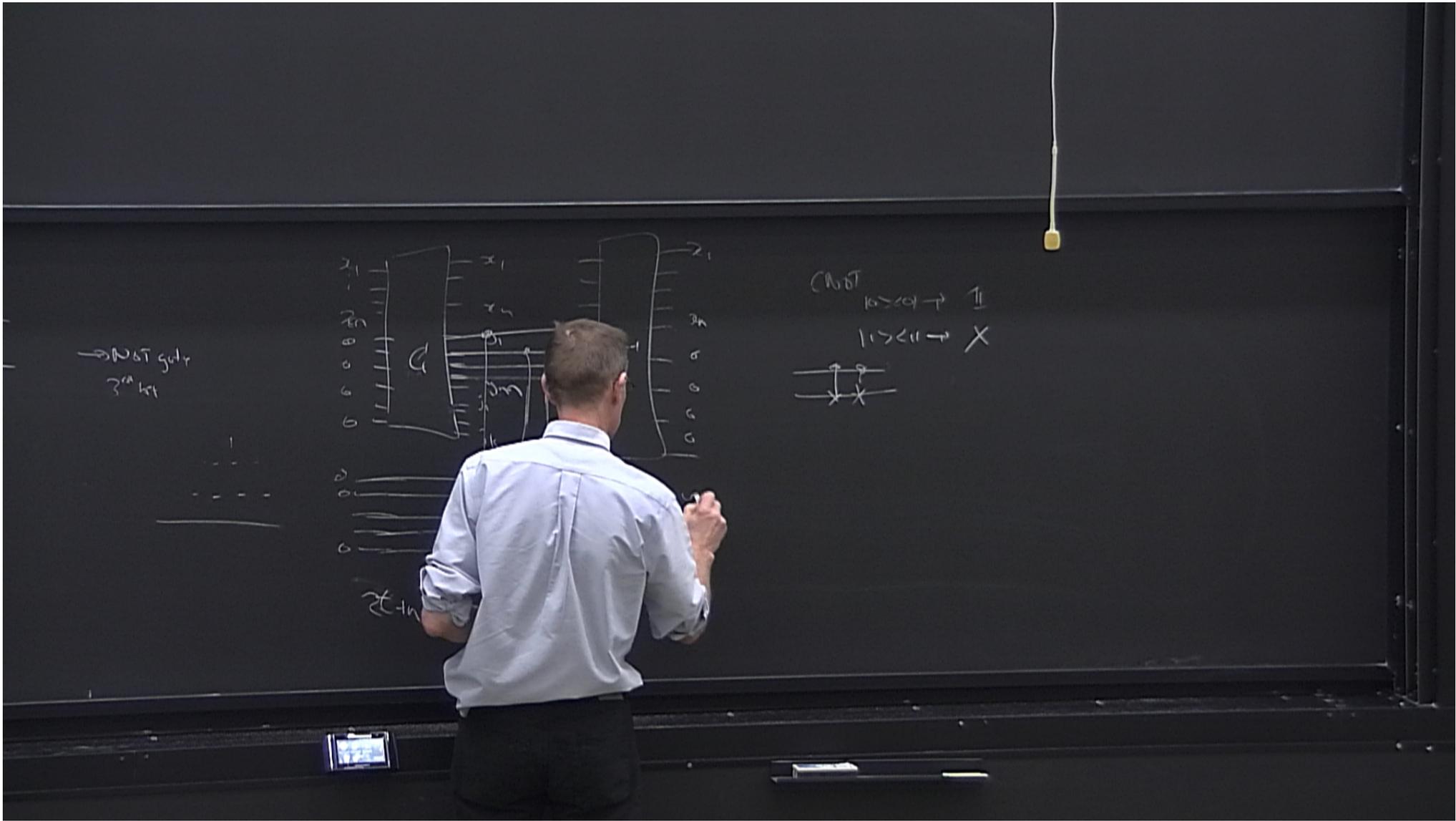
2 bits describe info

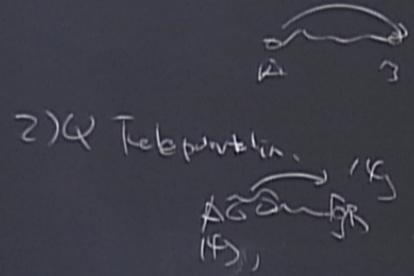
$$\sqrt{x} = \sqrt{e^{i\frac{\pi}{2}x}}$$

$$= e^{i\frac{\pi}{4}x}$$

2) Q Teleportation



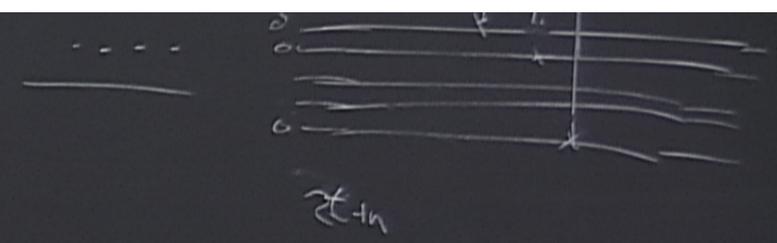




2 bird class into info

$$\sqrt{|x\rangle} = \sqrt{e^{i\frac{\pi}{2}x}}$$

$$= e^{i\frac{\pi}{4}x}$$



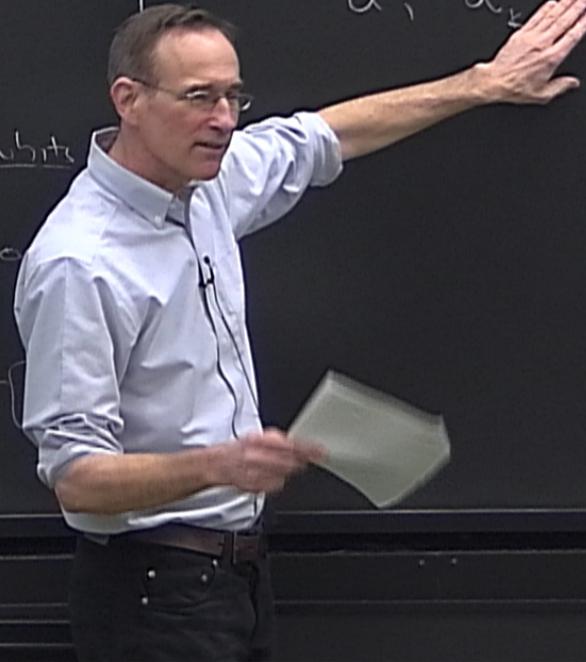
Implementations

Divincenzo criteria

1. Scalable system with 1000 defined qubits
2. Initial state $e^{-\beta H}$, 100
3. Control.
4. Measurement 10000 115000 tr
5. Noise is low

Photons

$$a, a^\dagger (H\nu)$$

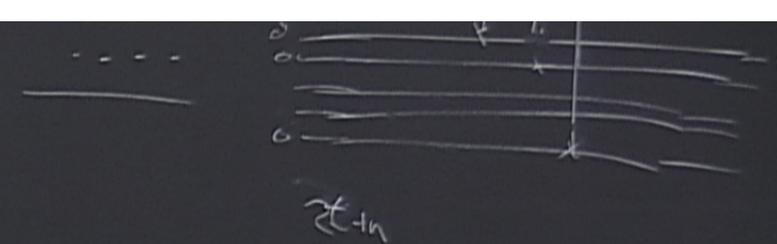


2) Teleportation

2 birdclassmate info

$\sqrt{x} = \sqrt{e^{i\frac{\pi}{2}x}}$
 $= e^{i\frac{\pi}{4}x}$

1g
 1g



Implementations

Divincenzo criteria

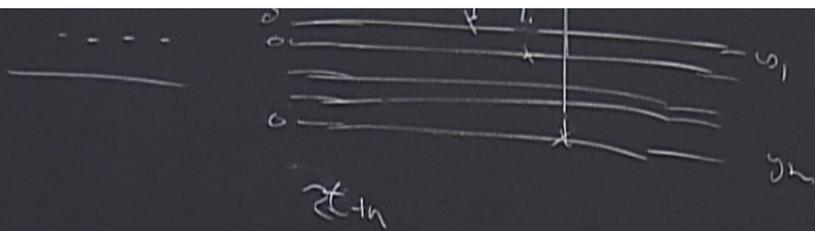
1. Scalable system with 1000 defined qubits
2. Initial state $e^{-\beta H}$, $|000\rangle$
3. Control.
4. Measurement 10001
 11011 $\text{tr}(X\rho)$
5. Noise is low

Photons

a, a^\dagger

$$\frac{10\Phi}{dt} = 4\Phi$$

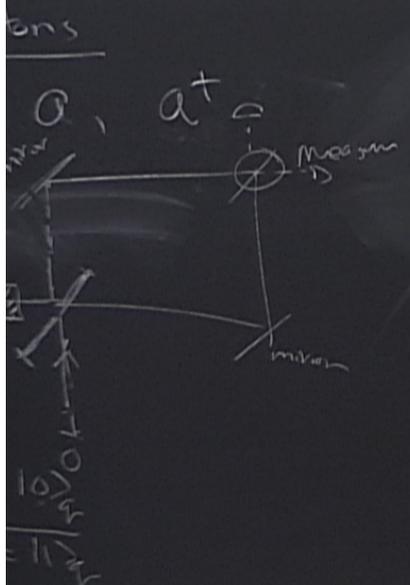
ψ_1 $\psi_1 + \psi_2$



we can effriate de $(x, y, z) \rightarrow (x, y, z + l, z)$
 quantity $k \rightarrow | \rightarrow | \rightarrow$

phase shifter -

$$a^{\dagger} \rightarrow e^{i\phi} a^{\dagger}$$



$$\alpha |10\rangle_z + \beta |11\rangle_z = \alpha |01\rangle + \beta |10\rangle = (\alpha a_2^{\dagger} + \beta a_1^{\dagger}) |vacuum\rangle$$

$$\rightarrow (\alpha a_2^{\dagger} + \beta a_1^{\dagger} e^{i\phi}) |V\rangle$$

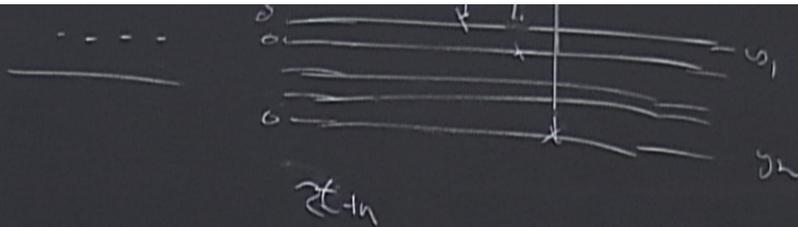
$$Z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$e^{-i\phi/2} e^{i\phi Z} (\alpha |10\rangle_z + \beta |11\rangle_z)$$

$$\underbrace{\left(\cos \frac{\phi}{2} I + i \sin \frac{\phi}{2} Z \right)}_{e^{i\phi/2}}$$

$$e^{i\frac{\pi}{2}x}$$

$$e^{i\pi x}$$

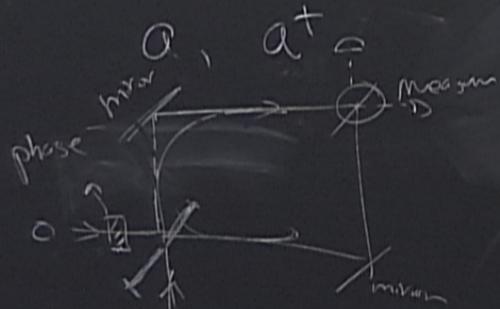


We can eff. rotate $a_1 \rightarrow (x, y, z) \rightarrow (x, y, z)$
 quantity $k \rightarrow 1$

Photons

phase shifter -

$$a^{\dagger} \rightarrow e^{i\phi} a^{\dagger}$$



$$\alpha |0\rangle_1 + \beta |1\rangle_2 = \alpha |0\rangle + \beta |1\rangle = (\alpha a_2^{\dagger} + \beta a_1^{\dagger}) |vacuum\rangle$$

$$\rightarrow (\alpha a_2^{\dagger} + \beta a_1^{\dagger} e^{i\phi}) |V\rangle$$

$$Z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$e^{-i\phi/2} e^{i\frac{\phi Z}{2}} (\alpha |0\rangle_1 + \beta |1\rangle_2)$$

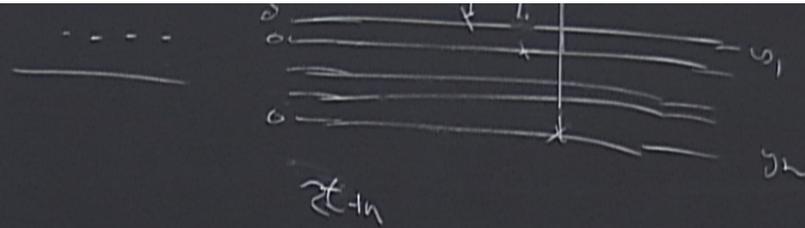
$$\underbrace{\left(\cos\frac{\phi}{2} I + i \sin\frac{\phi}{2} Z \right)}_{e^{i\phi/2}}$$

$$a_2^{\dagger} |0\rangle = |0\rangle_1$$

$$a_1^{\dagger} |0\rangle = |1\rangle_2$$

$$e^{i\frac{\pi}{2}x}$$

$$e^{i\pi x}$$

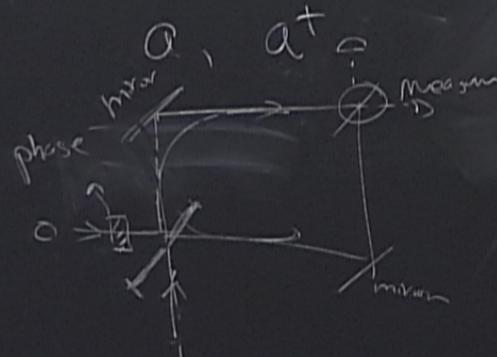


We can effinate $d_c(x, y, \omega) \rightarrow (x, y, \omega)$
 quantity $k \rightarrow 1$

Photons

phase shifter

$$a^\dagger \rightarrow e^{i\phi} a^\dagger$$



$$\alpha |0\rangle_1 + \beta |1\rangle_2 = \alpha |01\rangle + \beta |10\rangle = (\alpha a_2^\dagger + \beta a_1^\dagger) |vacuum\rangle$$

$$\rightarrow (\alpha a_2^\dagger + \beta a_1^\dagger e^{i\phi}) |vacuum\rangle$$

$$Z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$e^{-i\phi/2} e^{i\frac{\phi Z}{2}} (\alpha |0\rangle_1 + \beta |1\rangle_2)$$

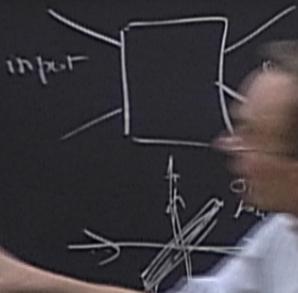
$$\left(\cos\frac{\phi}{2} I + i \sin\frac{\phi}{2} Z \right)$$

$$e^{i\phi/2}$$

$$a_2^\dagger |0\rangle = |01\rangle$$

$$a_1^\dagger |0\rangle = |10\rangle$$

Beam splitter



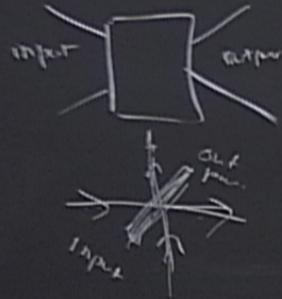
$$\begin{pmatrix} a_1^+ \\ a_2^+ \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta e^{i\phi} \\ \sin\theta e^{-i\phi} & \cos\theta \end{pmatrix} \begin{pmatrix} a_1^+ \\ a_2^+ \end{pmatrix}$$

$$\approx \frac{1}{\sqrt{2}} (|0\rangle_y + |1\rangle_y)$$

Hadamard
Yrotation

$$\frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix} e^{i\phi}$$

$$\begin{matrix} -1 & -1 \\ -\frac{2}{2} & = \textcircled{-1} \end{matrix}$$



$$|d_2^+\rangle = \frac{1}{\sqrt{2}}(|0\rangle_2 + |1\rangle_2)$$

$$\sin^2 \theta e^{-i\phi}$$

cos θ

$$|d_2^\perp\rangle$$

Hadamard
Yrotation

$$\frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix} e^{i\phi} \begin{pmatrix} -1 & -1 \\ -\frac{2}{i} & -1 \end{pmatrix}$$

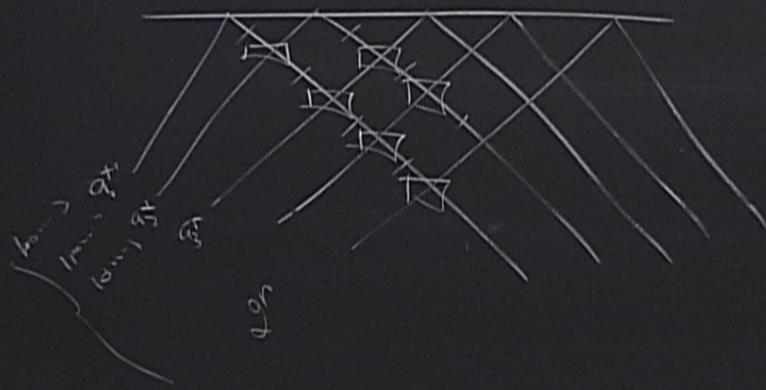
$$e^{i\theta \vec{n} \cdot \vec{\sigma}}$$

$n_x = 1$
 $n_y = 0$
 $n_z = 0$

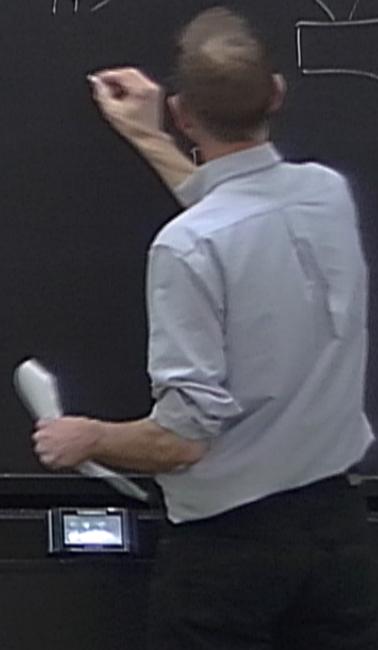
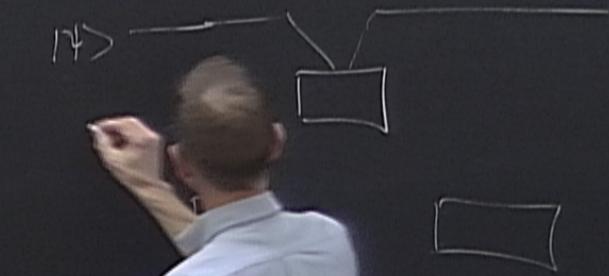
det

Theorem (Beck et al PRL 73, 58, 1998)

$$U(2^n)$$



$|1\rangle$



$(a_2^\dagger)^2 = \sin \theta e^{-i\phi} \cos \theta$

$a_2^\dagger \sim \frac{1}{\sqrt{2}}(|0\rangle_4 + |1\rangle_4)$

(The classmate of) $\frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix} e^{i\theta}$

$\det 1$

$\begin{matrix} \theta_1 = 1 \\ \theta_2 = 2 \\ \theta_3 = 3 \end{matrix}$

$-1-1$
 $-\frac{2}{2} = -1$

Yrotator

$U(2^n)$

$\alpha + \beta a_1^\dagger + \gamma (a_1^\dagger)^2$

$|1\rangle \xrightarrow{U} |4\rangle$

$|1\rangle$

$|0\rangle$

θ_1, ϕ_1

θ_2, ϕ_2

θ_3, ϕ_3

$|1\rangle$

$|0\rangle$

$\langle 1 | a_2^\dagger$

$\langle 0 | \text{root}$

$\theta_1, \theta_2, \theta_3 = 0$
 $\theta_1 = \theta_2 = 27.5^\circ$
 $\theta_3 = 65.5^\circ$

$(\alpha + \beta a_1^\dagger + \gamma (a_1^\dagger)^2) a_2^\dagger$