

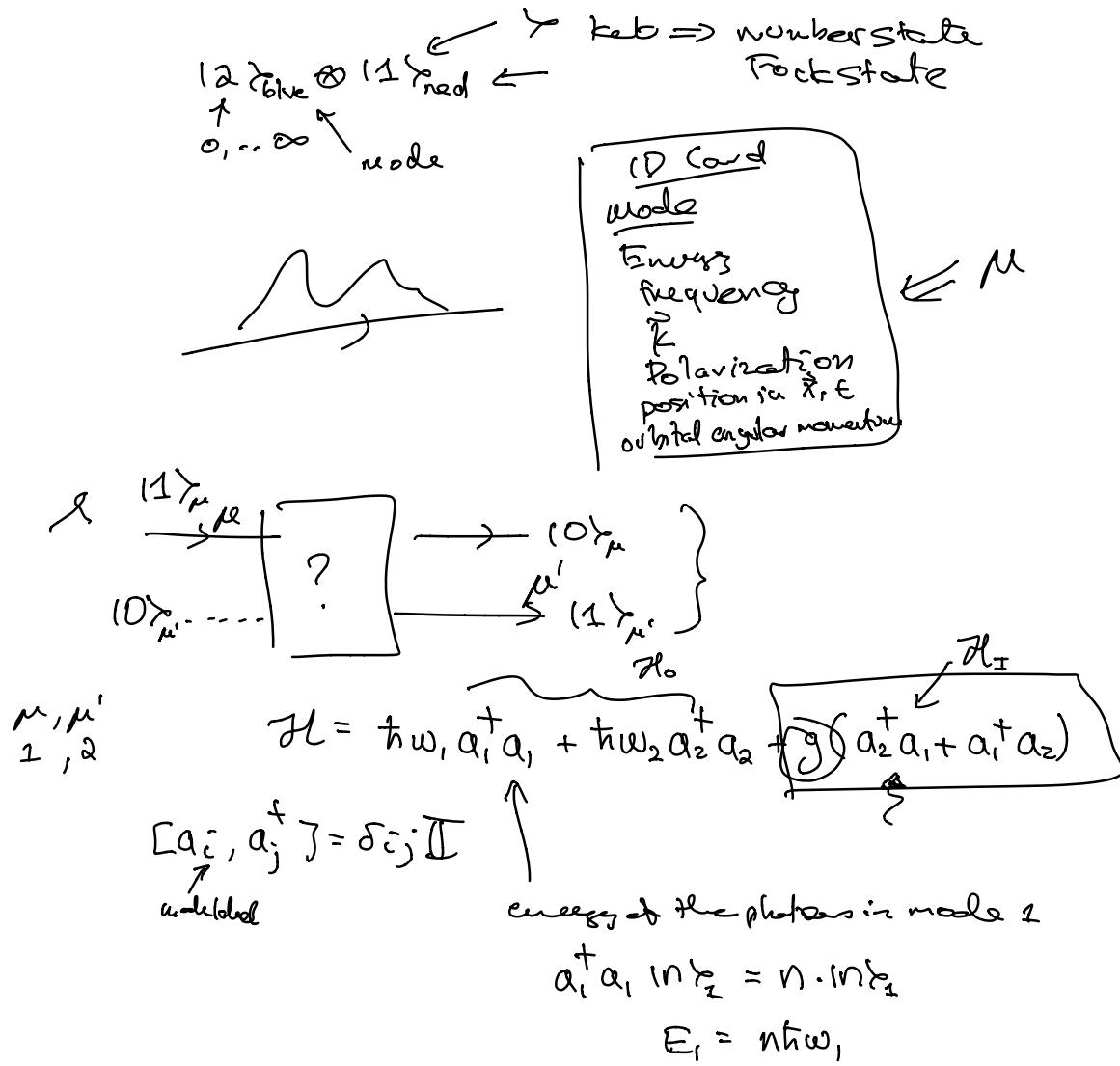
PHOTONIC QUANTUM COMPUTING

Terry Rudolph, Imperial College & PsiQuantum

Lecture 1: Photons as carriers of Quantum Info

Lecture 2: Measurement based Quantum Computing
2 photons as qubits

Lecture 3: Hardware & the photonic route to large scale
Fault tolerant Q-computing



Exercise $[\chi_0, \mathcal{H}_I] = ?$

$$[a_i^+ a_i, a_j^+] = \delta_{ij} \cdot a_j^+$$

$$[a_i^+ a_i, a_j^-] = -\delta_{ij} a_j^+$$

$$\chi_0 \cdot (a_1^+ a_2 - a_2^+ a_1)$$

$$\text{aus } \left[\frac{\hbar \omega_1 + \hbar \omega_2}{2} \right] \cdot g$$

If $\omega_1 = \omega_2$, $[\chi_I, \chi_0] = 0$

Knill
Caffman
& Milburn

$$(|1\rangle_1 \otimes |1\rangle_2 \otimes |1\rangle_3) \rightarrow |\Psi_{\text{out}}\rangle$$

$$\text{if } \omega_1 = \omega_2 = \omega_3$$

$$g(a_1^+ a_2 + a_2^+ a_1)$$

$|\Psi_{\text{out}}\rangle = e^{-i(\chi_0 + \chi_I) \cdot t}$

operator $\propto \text{dim}$

a_i

$|\Psi(0)\rangle$

fixed # of photons

$$|1\rangle_1 \otimes |2\rangle_2$$

$$e^{i\chi t} \frac{(a_1^+)^7}{\sqrt{7!}} \otimes \frac{(a_2^+)^2}{\sqrt{2!}} e^{i\chi t} |\Psi(0)\rangle$$

$$e^{i\chi t} \underbrace{(a_1^+ a_1^+ a_1^+ \dots \otimes \mathbb{I})}_{7 \text{ copies}} e^{i\chi t} \cdot e^{-i\chi t} (a_2^+ a_2^+ \dots \otimes a_2^+)^2 e^{i\chi t}$$

Schrödinger Picture

$$\left[\frac{[a_1^{(+)}(-t)]^7}{\sqrt{7!}} \cdot \frac{[a_2^{(+)}(-t)]^2}{\sqrt{2!}} \right] |\Psi(0)\rangle$$

"easy to compute"

$$\omega_1 = \omega_2 = \omega$$

$$\frac{\partial \alpha_i^{(H)\dagger}}{\partial t} = i [\mathcal{H}, \alpha_i^{(H)\dagger}]$$

$$\frac{\partial \alpha_i^{(H)}}{\partial t} = i\omega \alpha_i^+ + ig \alpha_2^+$$

$$\frac{\partial \alpha_2^{(H)}}{\partial t} = i\omega \alpha_2^+ + ig \alpha_1^+$$

$$\frac{\partial \begin{bmatrix} \alpha_1^{(H)} \\ \alpha_2^{(H)} \end{bmatrix}}{\partial t} = i \begin{bmatrix} \omega & g \\ g & \omega \end{bmatrix} \begin{bmatrix} \alpha_1^{(H)} \\ \alpha_2^{(H)} \end{bmatrix}$$

$$\begin{bmatrix} \alpha_1^{(H)}(t) \\ \alpha_2^{(H)}(t) \end{bmatrix} = \begin{pmatrix} e^{i(\omega - g)t} & 0 \\ 0 & e^{i(\omega + g)t} \end{pmatrix} \begin{bmatrix} \alpha_1^{(H)}(0) \\ \alpha_2^{(H)}(0) \end{bmatrix}$$

$U \leftarrow$ 2x2 unitary

"linear optics" $\alpha_1^+ \alpha_2^+$

$$U = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$$

"beamsplitter"



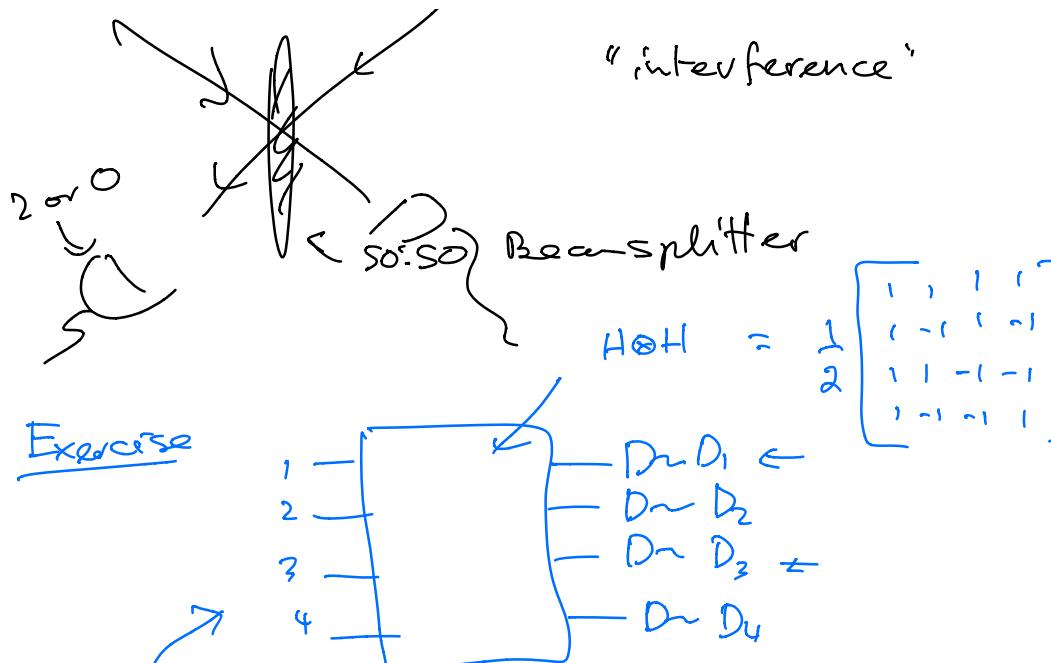
$|\Psi_{\text{out}}\rangle$

$$\alpha_1^+ \cdot \frac{\alpha_2^+}{\sqrt{2}}(0) \rightarrow \frac{(a_1^+ + a_2^+)(a_1^+ - a_2^+)}{\sqrt{2}}(0)$$

$$= \left[\frac{(a_1^+)^2 - (a_2^+)^2}{2} \right] 100\%$$

$$= \frac{1}{\sqrt{2}} \left(12 \gamma_2 10 \gamma_2 - 10 \gamma_2 12 \gamma_2 \right)$$

\uparrow bunch \uparrow



Of the 6 possible input states which have 2 photons in different modes, which ones can cause D₁ and D₃ to click.

$$11 \& 11 \& 10 \& 10 \longrightarrow$$