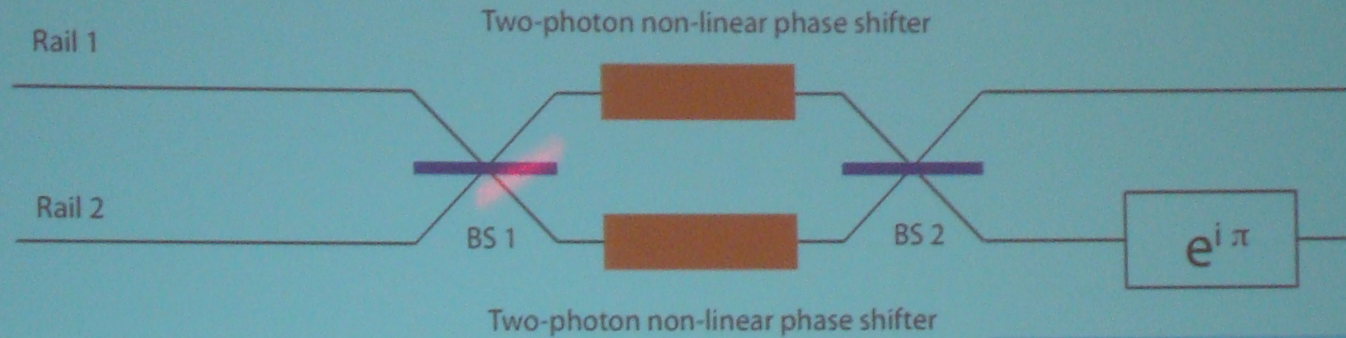
A Controlled Phase Gate with Dual Rail Photons



Apply a π phase on the second mode to get a controlled-phase gate

$$|00\rangle \rightarrow |00\rangle$$

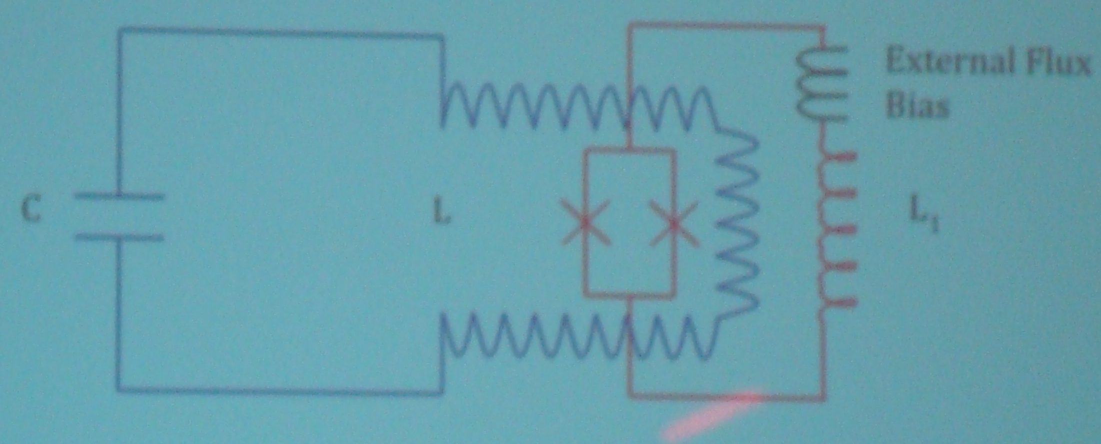
$$|01\rangle \rightarrow \sqrt{\frac{1}{2}}(|01\rangle + |10\rangle) \rightarrow \sqrt{\frac{1}{2}}(|01\rangle + |10\rangle) \rightarrow |10\rangle \rightarrow |10\rangle$$

$$\sqrt{\frac{1}{2}}(|10\rangle - |01\rangle) \rightarrow \sqrt{\frac{1}{2}}(|10\rangle - |01\rangle) \rightarrow -|01\rangle \rightarrow |01\rangle$$

$$\sqrt{\frac{1}{2}}(|20\rangle + |02\rangle) \rightarrow -\sqrt{\frac{1}{2}}(|20\rangle + |02\rangle) \rightarrow \quad 11\rangle$$

Model for a Two-Photon Phase Shifter

- Couple photons in a microwave cavity to a superconducting phase qubit.



The flux of the resonator inductance mostly threads the squid loop.

The spectrum of the qubit is controlled by tuning the external flux and can be tuned in and out of resonance with the resonato

System Hamiltonian

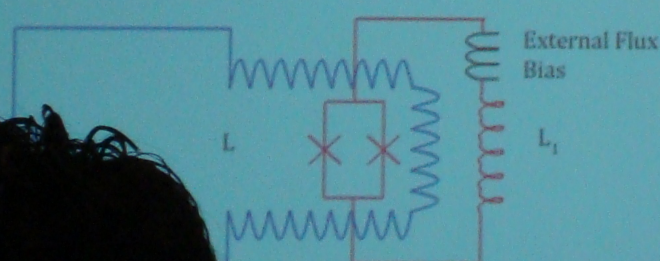
$$H_r = \frac{q_L^2}{2C_e} + \frac{\Phi_L^2}{2L} \qquad H_q = \frac{q^2}{2\tilde{C}_J} - 2E_J\cos\phi + \frac{1}{2}E_L(\phi + \phi_x)^2$$

$$V = -\frac{\chi}{2C_e} q q_L + \chi E_J \phi_L \sin\phi + \frac{\chi^2}{2} E_J \phi_L^2 \cos\phi$$

$$\phi_L = 2\pi\frac{\Phi_L}{\Phi_0}$$

$$V_2 = \eta_2(\hat{a} + \hat{a}^\dagger)^2 \cos\phi$$

$$\Phi_0 = 2.07 \times 10^{-15}\ Wb$$



This non-linear coefficient is determined by the choice of system parameters. We can expect it to be a few tens of MHz.

This term couples two photons with a si[...] qubit excitation.