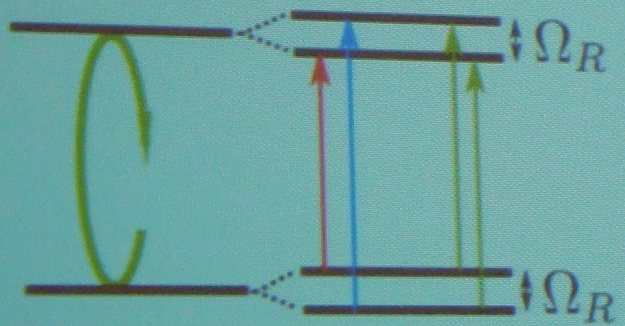
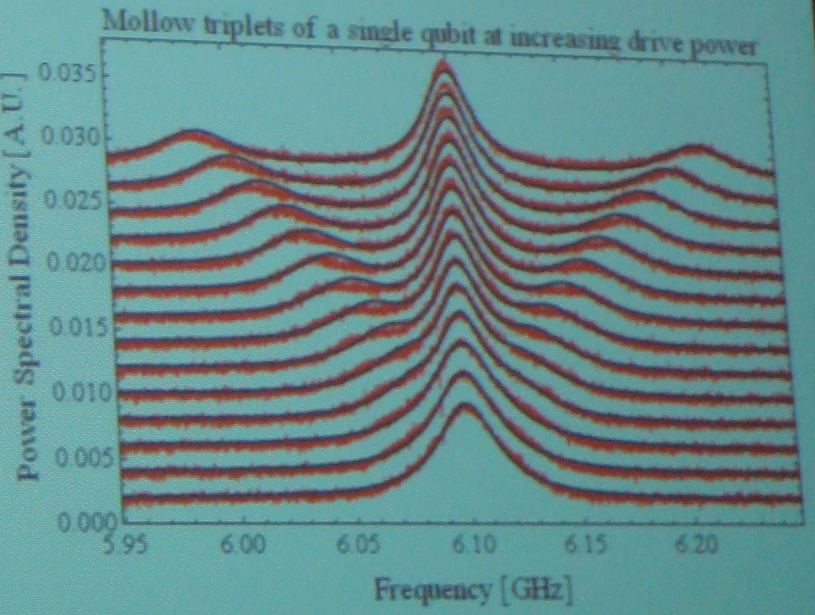
Resonance fluorescence measurements on a single qubit

- Resonance Fluorescence Measurements:
  - Measure a voltage V(t)
  - V(t) is down-converted, Fourier transformed, multiplied with its conjugate and averaged
- Mollow triplet: A strong drive resonant with a 2-level system splits those levels



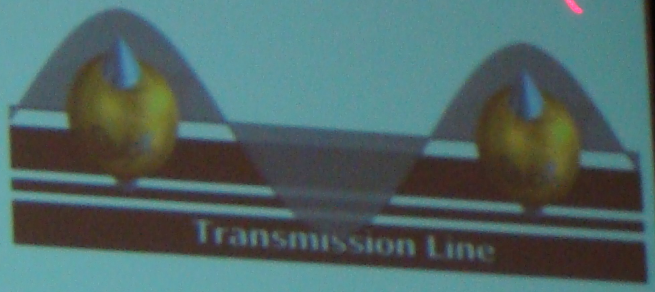


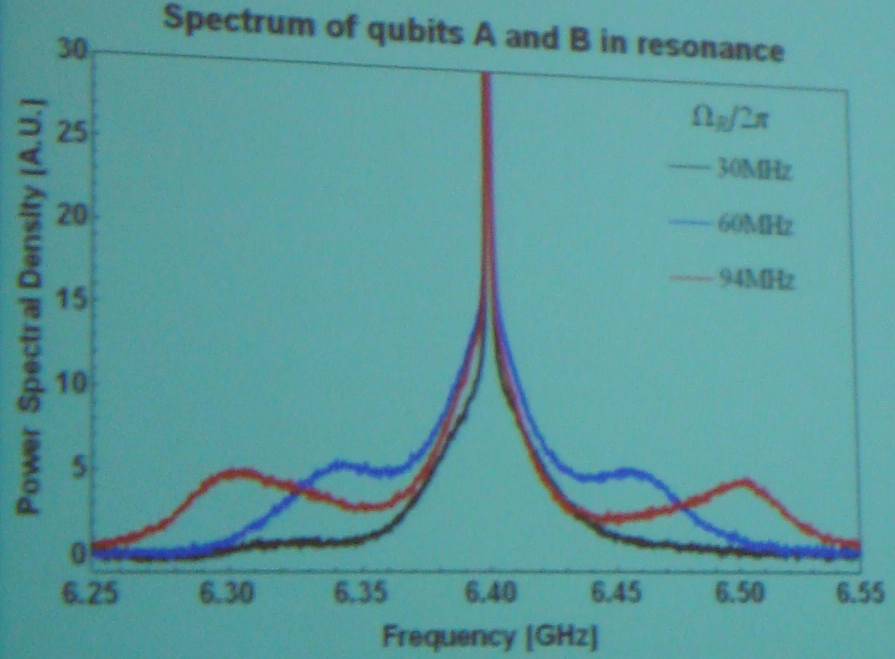
O. Astafiev *et al.*, Science **327**, 840 (2010)

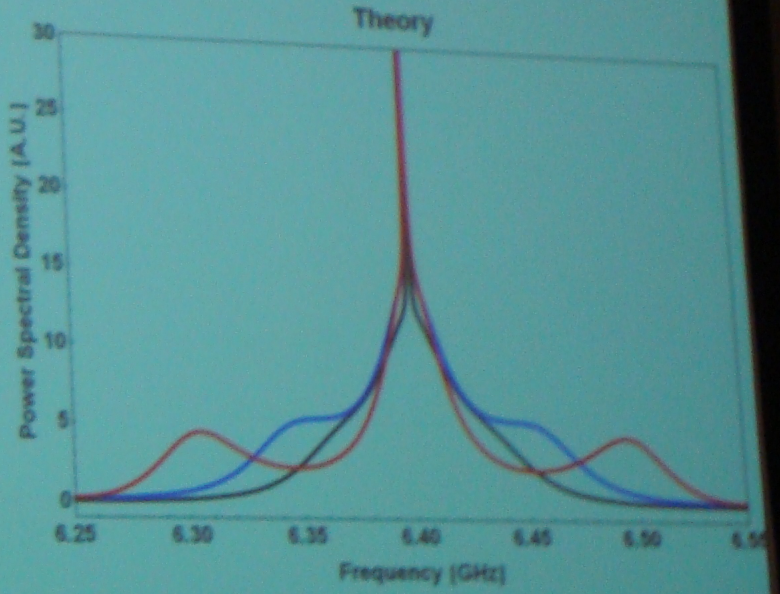
C. Lang *et al.*, Phys Rev Lett **106**, 243601 (2011)

Resonance fluorescence for 2 qubits: 2π

- Coherent interaction via standing mode
- Measurement shows mollow triplet shape plus sharp peak

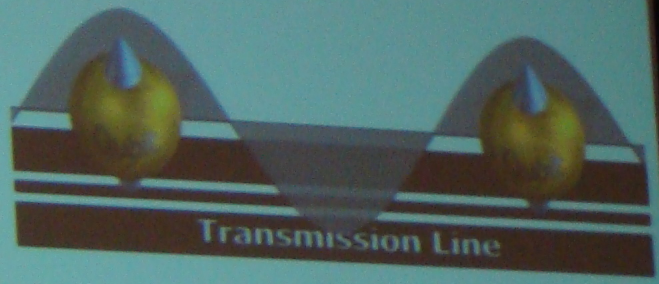


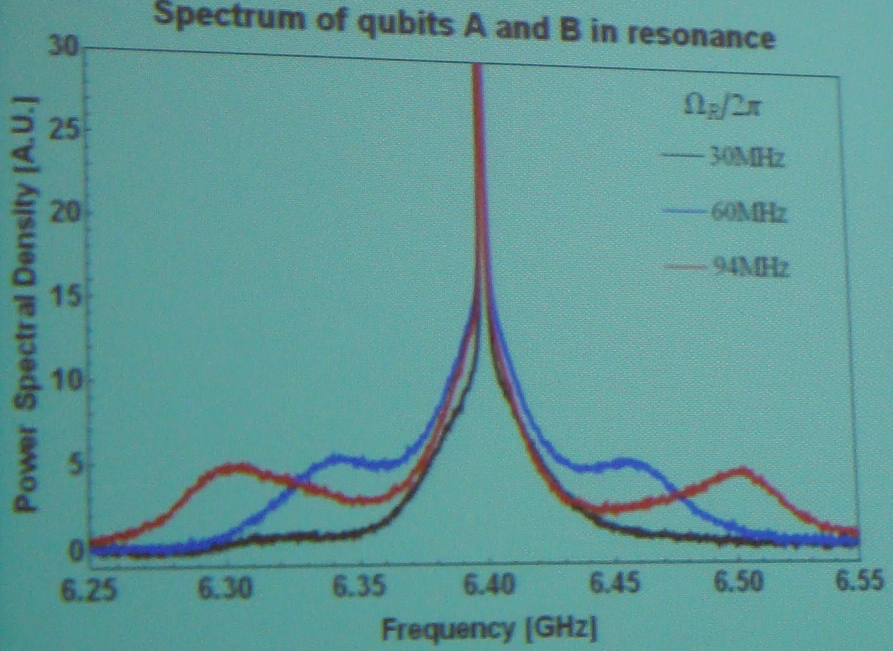


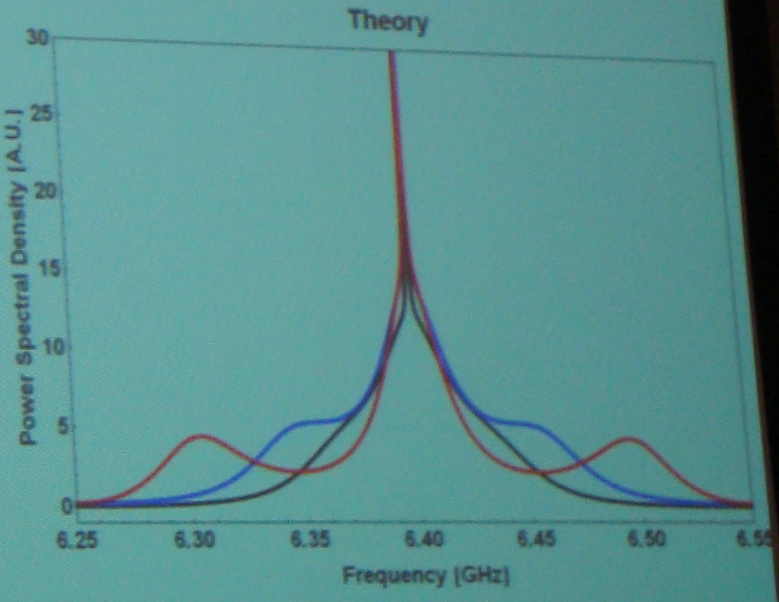


Resonance fluorescence for 2 qubits: 2π

- Coherent interaction via standing mode
- Measurement shows mollow triplet shape plus sharp peak

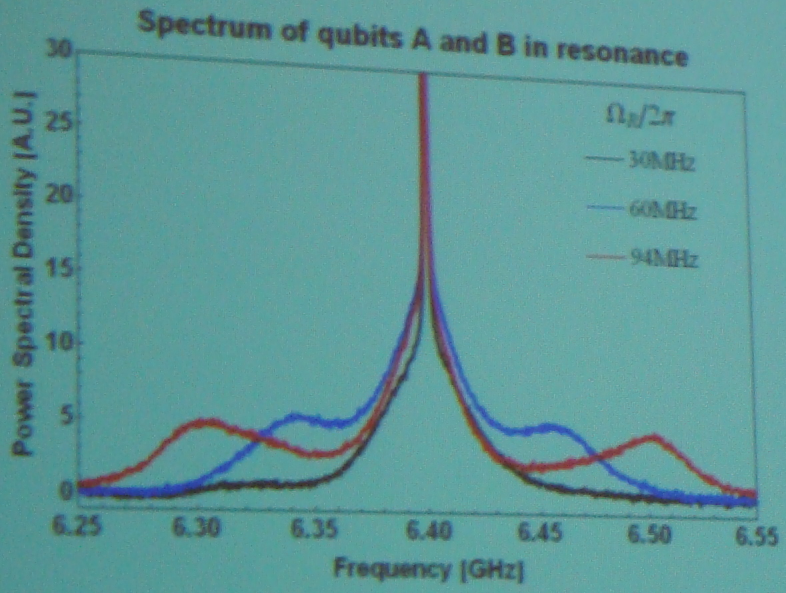




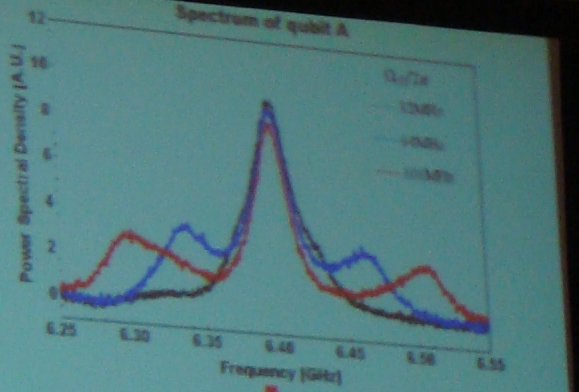


Looking at the peak

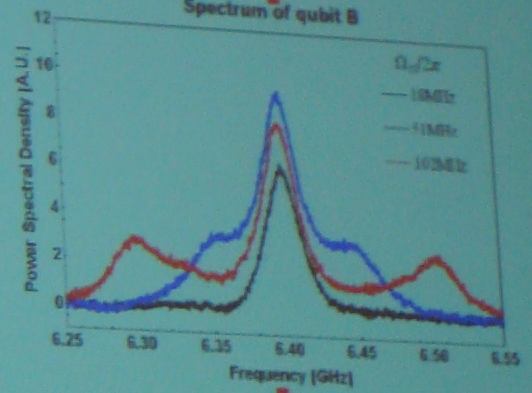
- Result has 3 parts:
  - Mollow triplet of qubit 1
  - Mollow triplet of qubit 2
  - Extra peak
- Coherent peak is artificially removed



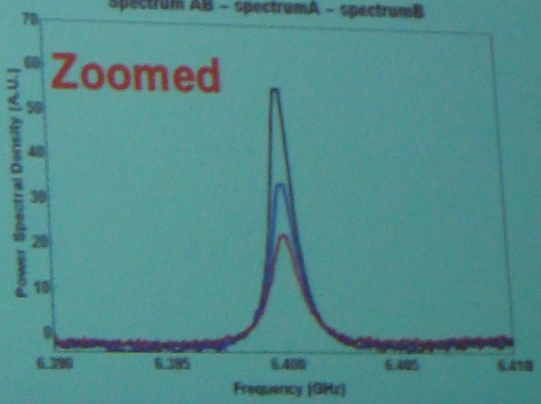
=



+



+



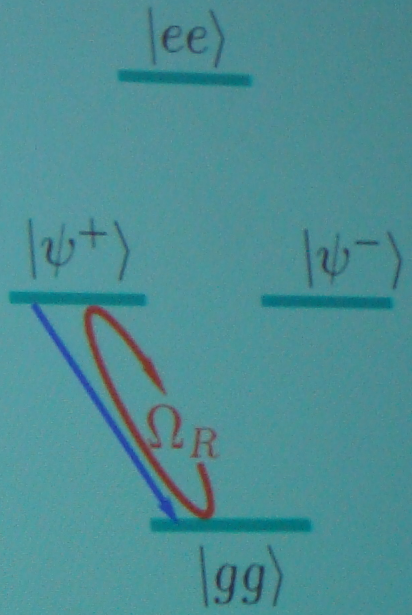
Symmetric and Antisymmetric state

$$\psi^+ = |eg\rangle + |ge\rangle$$

- Same symmetry as resonant mode
  - Driven directly
  - Mollow triplet shape
  - Decays quickly

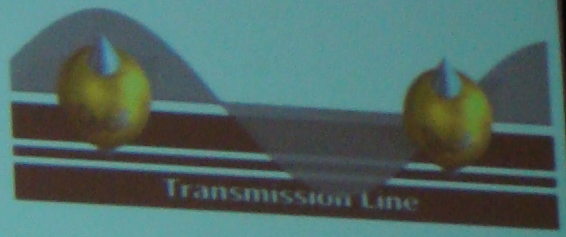
$$\psi^- = |eg\rangle - |ge\rangle$$

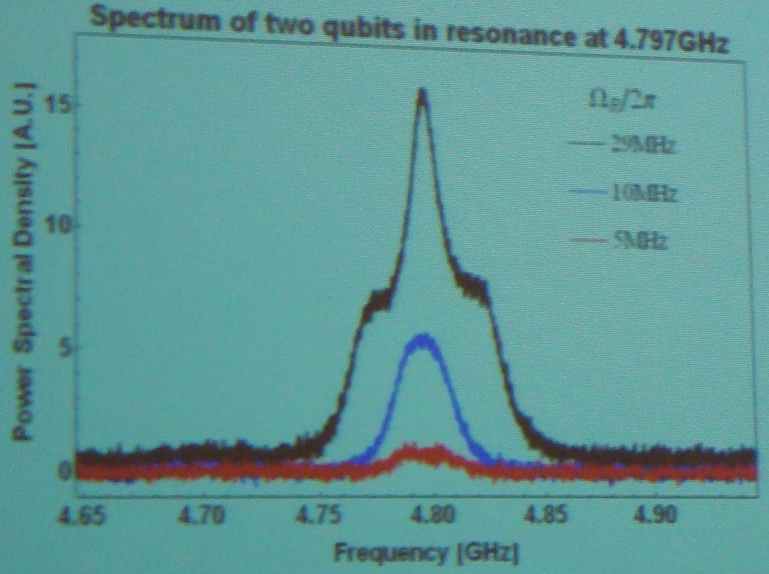
- Opposite symmetry to resonant mode
  - Does not couple to resonant field
  - Decoherence-free subspace
  - Does not get driven in first order
  - Decays slowly

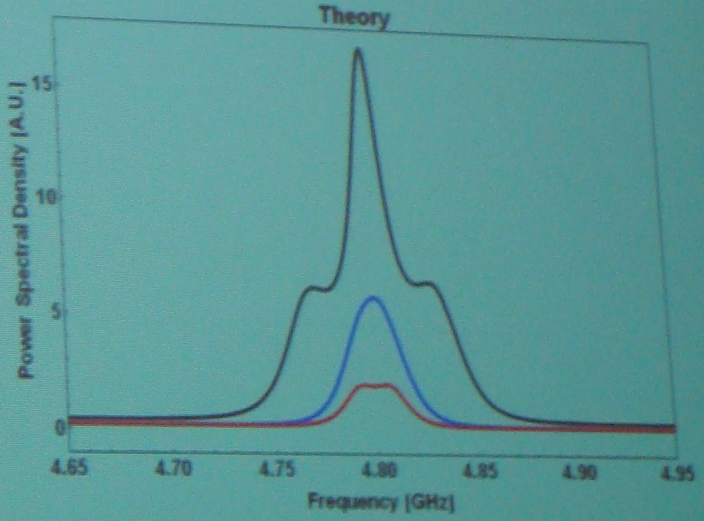


Resonance fluorescence for 2 qubits: 3/2 π

- Mediated by virtual photons
- Measurements presented are done at 3/2 π phase diff
  - Coherent tone is removed in the experimental results
- At normal Mollow triplet powers, no splitting







Conclusions

- Cooperative effects are observed in resonance fluorescence
  - At 3/2π phase difference: exchange splitting at low powers
  - At 2π phase difference : decoherence free subspace