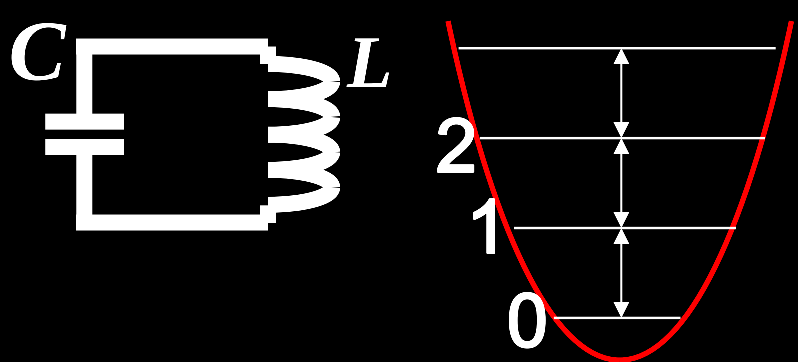
M. Weides and A. Ustinov

Quantum simulation with superconducting circuits

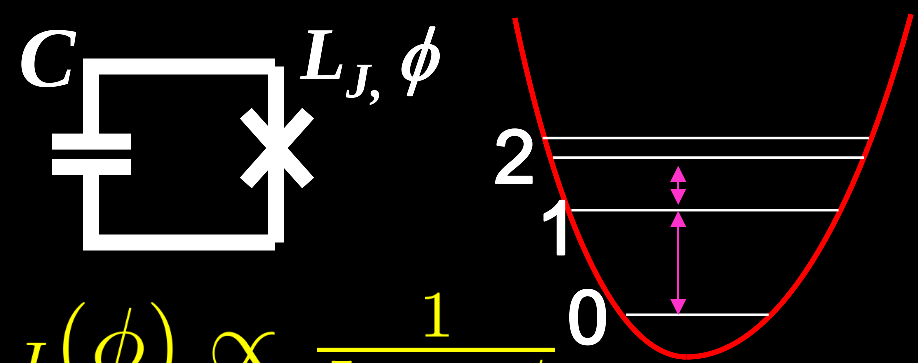
Karlsruhe Institute of Technology, Germany

FET information day 20th January 2014

linear LC oscillator



non-linear LC oscillator



$$L_J(\phi) \propto \frac{1}{I_c \cos\phi}$$

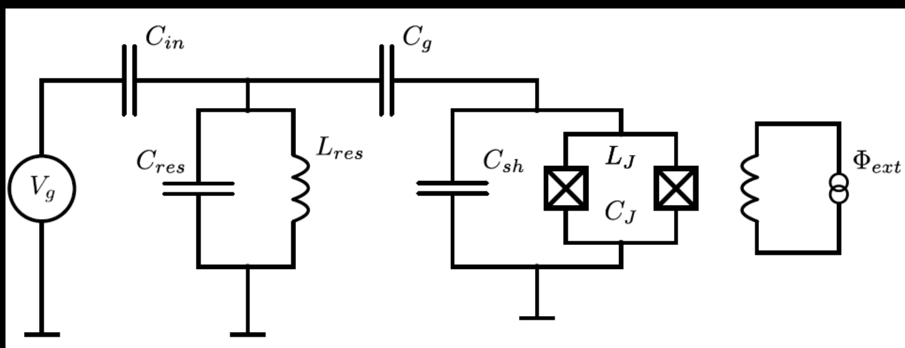
Superconducting quantum circuit provide

- Strong coupling w/ EM field, long coherence, fast& local detuning
- high density, integration w/ std. electronics
- simple resonant circuit design, straightforward scalability

Spectrometry and coherence setups

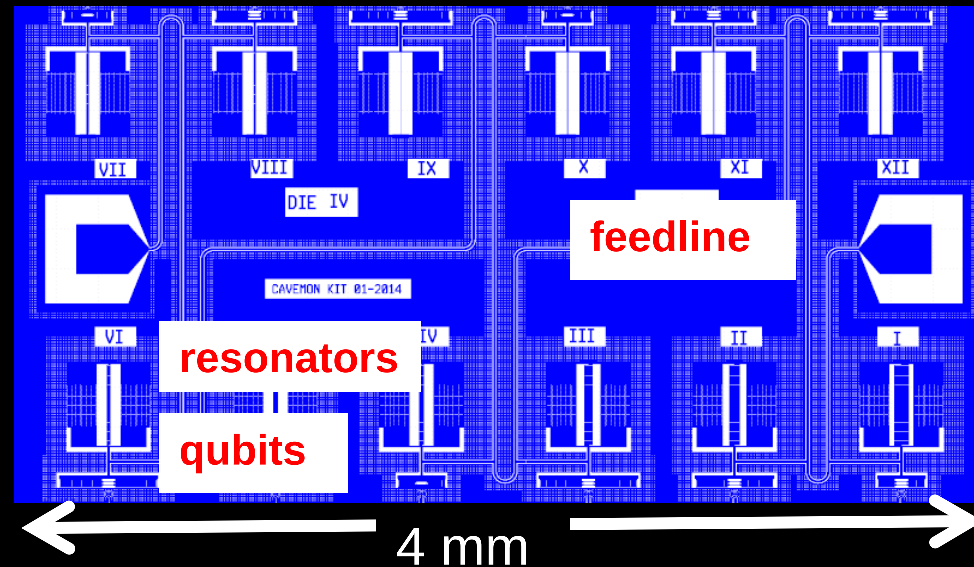
Jaynes-Cummings

$$\hat{H} = \hbar\omega_r \hat{a}^\dagger \hat{a} + \hbar\omega_q \frac{\hat{\sigma}_z}{2} + \frac{\hbar\Omega}{2}\hat{E}\hat{S}$$



$$\Delta = \omega_q - \omega_r, \gamma, \kappa, g$$

KIT: 12 qubit/resonator pairs w/ on-chip bias



^{3}He/^{4}He and ^{3}He setups

- Spectroscopy and coherence 1-20GHz range

Large volume ^{3}He/^{4}He dilution refrigerator (for 8 chips)

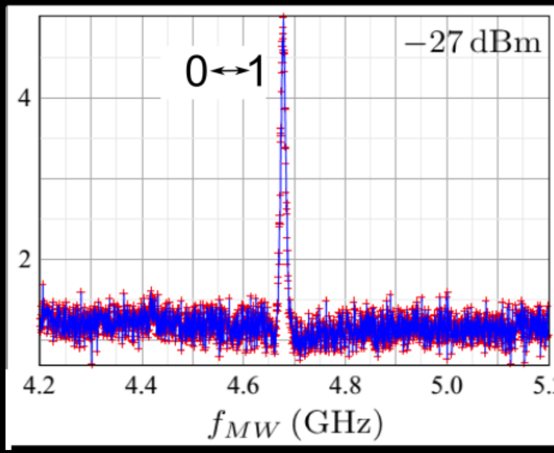
- 24 filtered DC lines, 18 coax lines
- 5 HEMTs, 2 microwave switches

Engineered quantum circuits

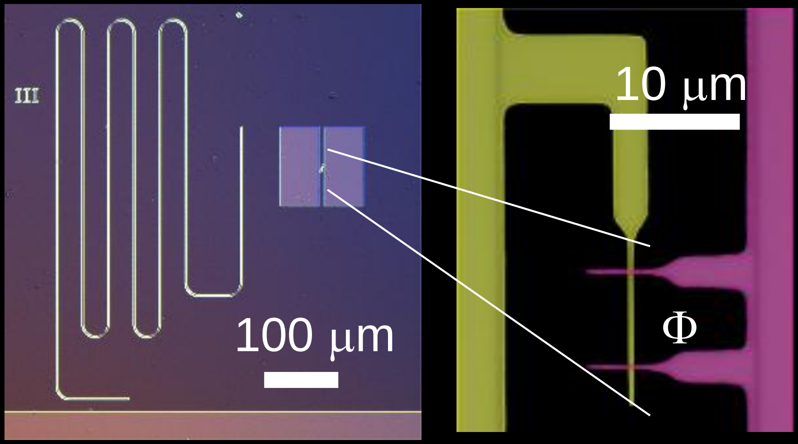
- Circuit simulation, design and in-house implementation
- Toolbox of circuit designs, fast turnaround
- Al-AlO_x-Al cross and shadow junctions
- AlO, NbN high kinetic inductance films

Research projects:

  - lifetime& coherence limitations
  - Ultra-compact circuits
  - Multi-quantum systems

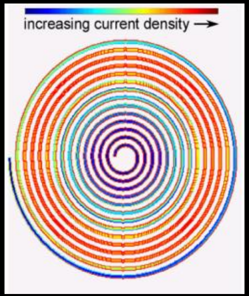


Flux tunable microstrip transmon



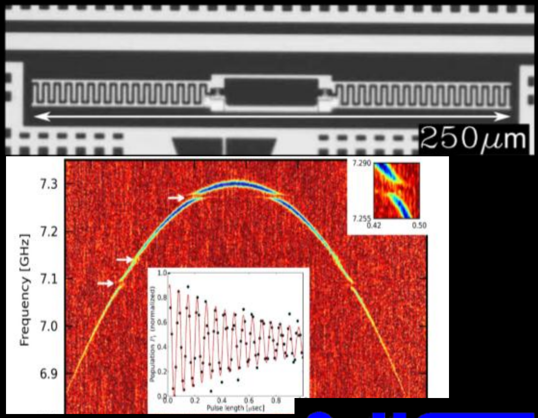
Braumüller, MA thesis '13

Resonator current distribution



Kiselev, BA thesis '13

Epitaxial transmon qubit



Weides, APL '11 NIST

Research

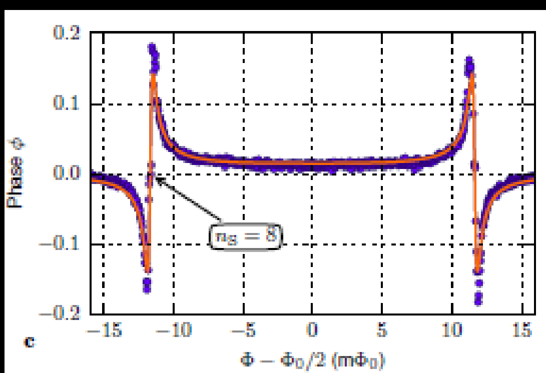
- 2 Postdocs, 1 technician, 7-10 students
- Simultaneous manipulation and time resolved msmt. of 3 qubits

  Power Rabi, $T_1 \approx 1$ μsec, $T_2 \approx 200$ nsec
- Spectroscopy on qubit chain-resonator

  → quantum metamaterial

$$\hat{H}^{TC} = \hbar\omega_c \hat{a}^\dagger \hat{a} + \sum_{j=1}^{n} \frac{\hbar\omega_{a,j}}{2}\hat{\sigma}_z^j + \hbar g_j(\hat{\sigma}_+^j \hat{a} + \hat{\sigma}_-^j \hat{a}^\dagger)$$

Tavis-Cummings



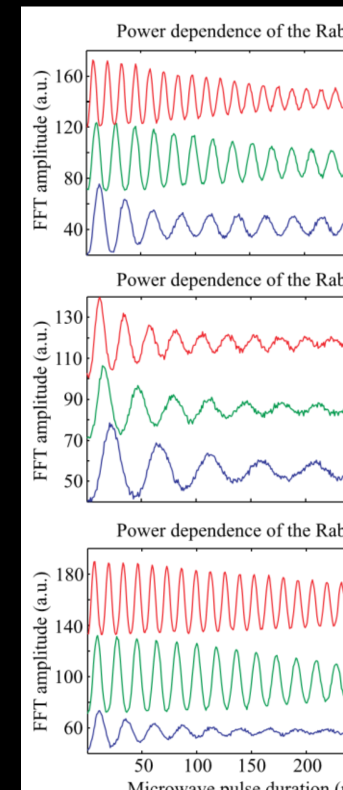
8 qubits-1 resonator ensemble

Macha *et al.* arXiv 2013

Qubit 1

Qubit 2

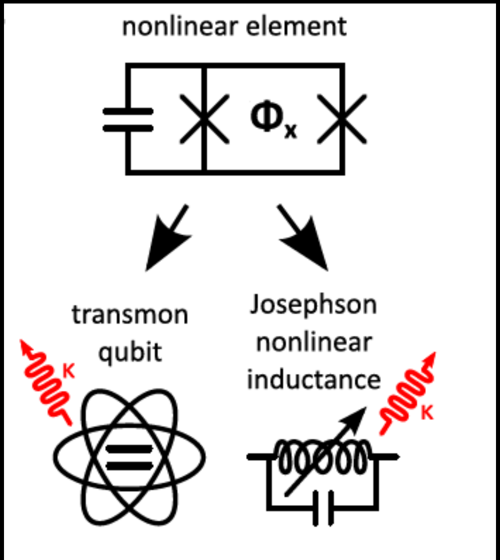
Qubit 3

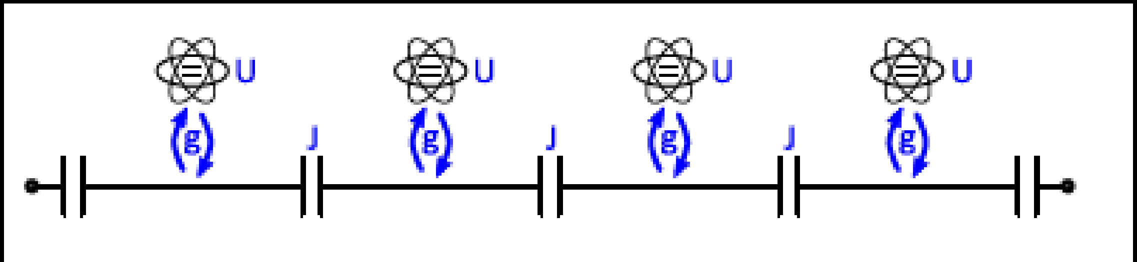


Jerger *et al.* APL 2012

- Coherence KIT fabricated qubits
  - 1st G: 0.1 μsec (12/2013, optical litho, cross-JJs)
  - 2nd G: +1 μsec (in work, e-beam, shadow-JJs)

Research interests: Quantum chains





$$\hat{H}^{JC} = \hbar\omega_c \hat{a}^\dagger \hat{a} + \hbar\omega_a \frac{\hat{\sigma}_z}{2} + g\hat{E}\hat{S}$$

$$\hat{H} = \sum_j \hat{H}^{JC} - J \sum_{<i,j>} (\hat{a}_j^\dagger \hat{a}_i + \hat{a}_i^\dagger \hat{a}_j)$$

- Highly integrated multi-partite quantum system, cooperative radiation phenomena in qubit chain/resonator systems
- Chains of transmons or non-linear resonators (Jaynes-Cummings, Bose-Hubbard or Holstein polarons)
- Spin-bosonic/fermionic bath w/ super, sub ohmic spectral density

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