Coherent Superconducting Qubits (CSQ)

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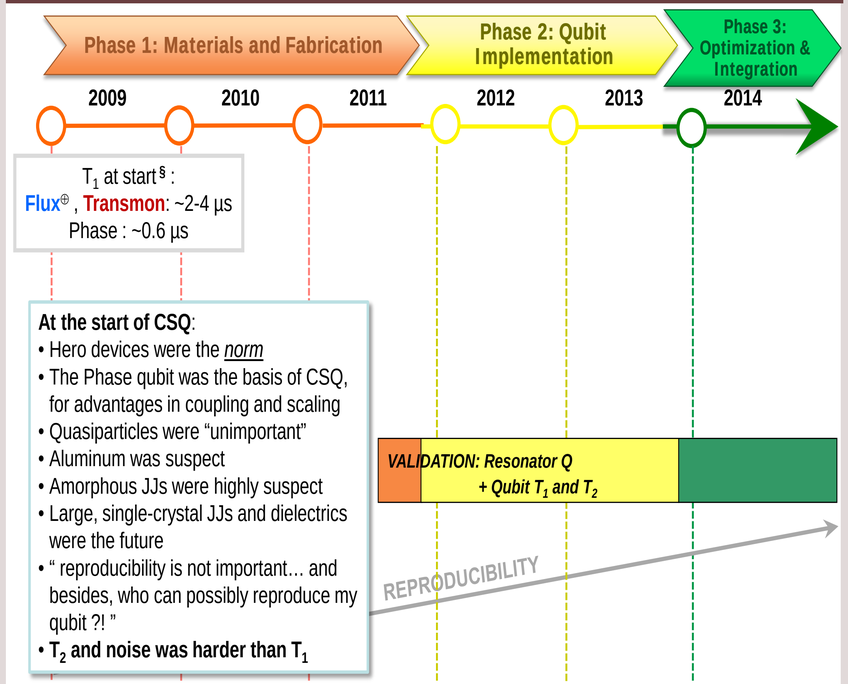
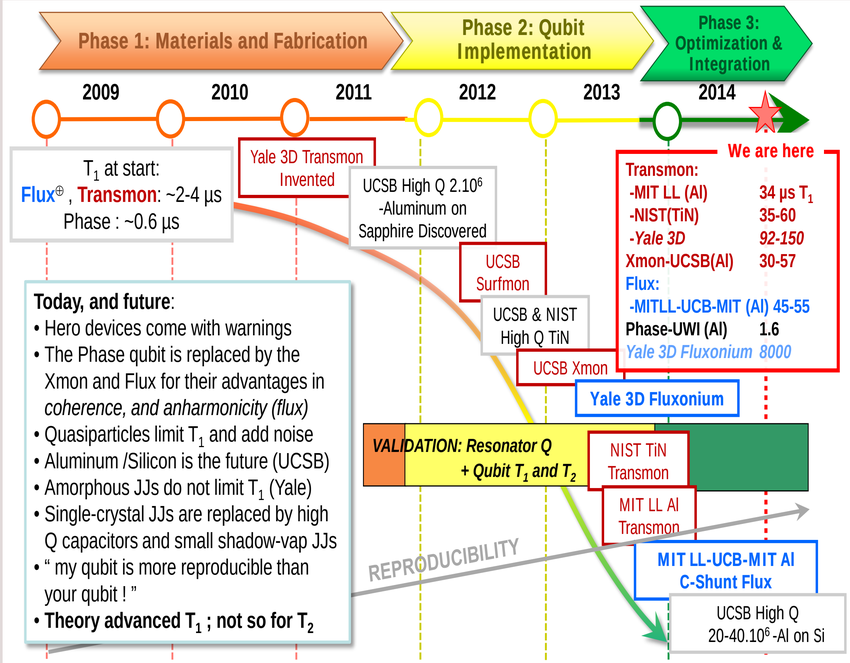
In 2009 superconducting qubits looked promising for their fast gate speeds, but short coherence lifetimes made them unusable



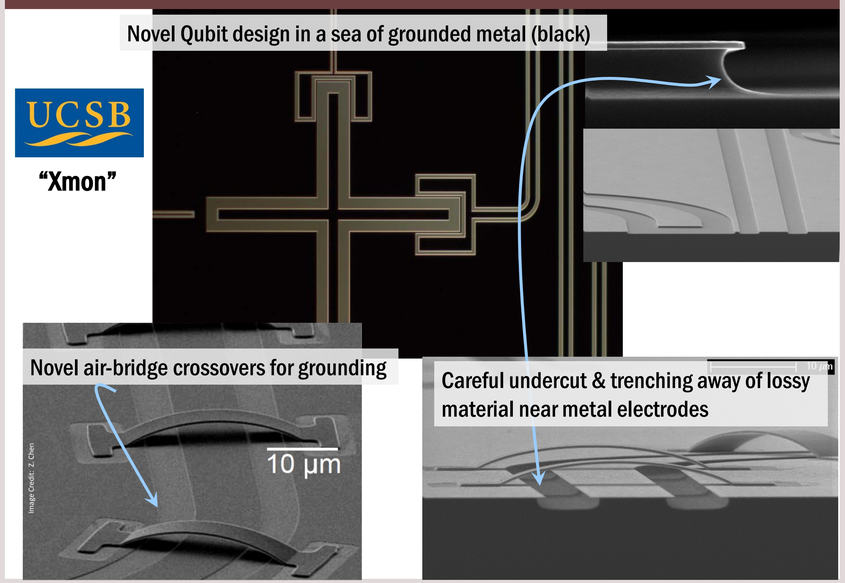
Challenging 5-year goals and an emphasis on reproducible results drove an order of magnitude increase in coherence times



CSQ qubit fidelity, while not yet sufficient for gate-based computing, could be revolutionary for quantum annealing (QA)

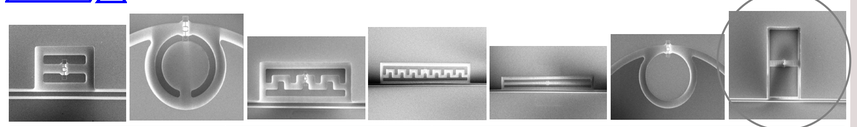
QA Parameter Space	Classical Annealing	Current QA Technology	New Capability of Interest
Spin-Qubit Coherence	N/A	~ < 10 ns ? (Nb Trilayer)	> 100 µs from CSQ *Is there a "sweet" spot?*
Entanglement of multiple spins	N/A	Apparent evidence for large gaps; utility TBD?	Yes
System Size	50 spins (3D) 100 – 300 spins (2D)	512 spins, envisioning thousands	Progressive test-beds
Calibration precision	N/A	Low	High: beyond limiting energy scale
Graph connectivity	N/A	2-spin + programmable multi-spin by limited connectivity	Diverse, dynamic connectivity with intrinsic, multi-spin interactions
Types of annealing / quantum fluctuations	N/A	Transverse field only	Broad range & non-stoquastic
Adaptive annealing schedule	N/A	No	Yes
Control of annealing process	N/A	Integrated control with limited resolution (DAC bits) and BW	Fast, stable, high-res control to maintain coherence
Real-time monitoring of annealing	N/A	No	Yes – to optimize active feed-back

Novel designs and materials enabled >10-fold advances



New flux qubits remove sharp corners and E-field spikes

MIT LL reestablished the competitive potential of the flux qubit



Geometry	T_1 (µs)	T_2 (µs)	T_{2Echo} (µs)
Square	**55**	**30**	**43 80 (multi-echos)**
Parallel Bars	29 (30 µm gap), 32 (20 µm gap)	TBD	TBD
Rounded IDC	23	13 (10 µm gap) 11 (30 µm gap)	18 (10 µm gap) 21 (30 µm gap)
Circle	26	16	TBD

The Work of CSQ is unfinished

- T_1 & T_2 vary randomly in time and over timescales that are widely disparate (from milliseconds, to days)
- Sources of noise remain unknown, and uncontrolled
- **IARPA has begun a study of the enhancements possible for quantum annealing (QA) via novel architectures and operation**
  - QA parameter space is vast and uncharted
  - "Optimal" for QA is unknown (i.e., coherence, designs, architecture, programming, operation…), and highly complex; even for single qubits
  - Removing *and circumnavigating* noise sources – by design, programming and adaptive annealing – present a significant challenge *and opportunity*