Digital Readouts for Superconducting Microresonators

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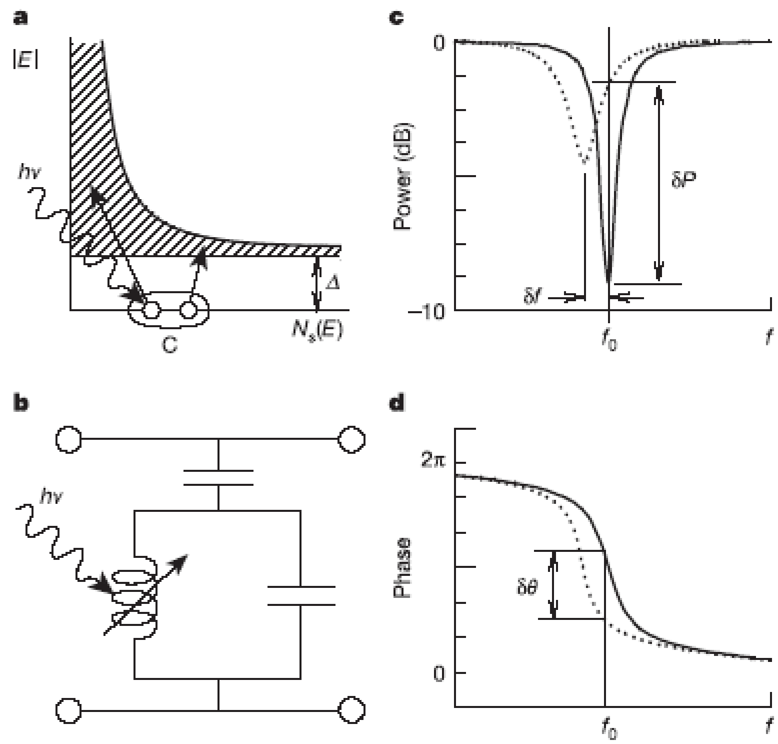
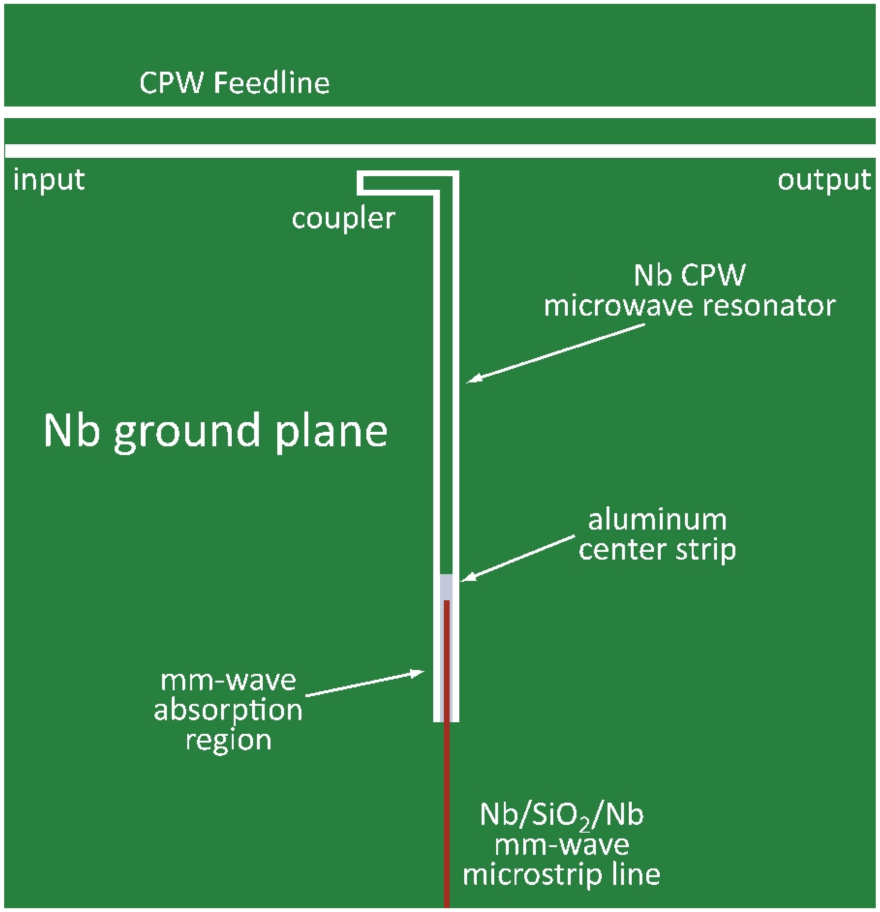


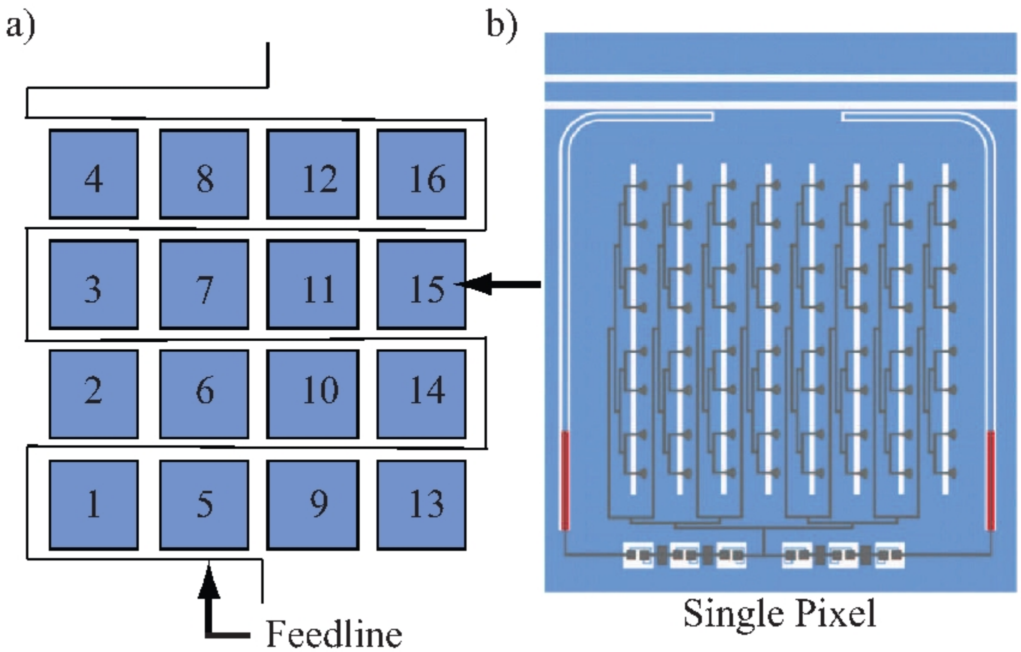
a) Absorbed photons break Cooper pairs in superconducting film which is
b) part of lithographed microresonator circuit; this causes change in surface resistance and reactance, which
c) shifts resonant frequency and reduces quality factor; detect by measuring amplitude and
d) phase of microwave output signal



Microstrip-coupled mm-wave detector made with hybrid Nb/Al quarter-wave resonator.

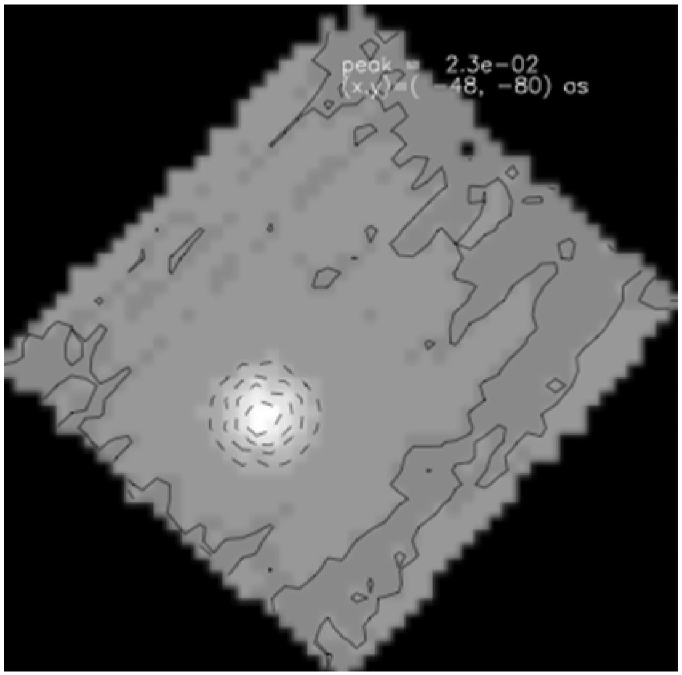
Photons with $\nu > 90$ GHz are absorbed in the Al center strip.

Microwave readout signal excites resonator via coupler section; length of coupler and distance from feedline determine Q_c .



Democam 4x4 dual-band array

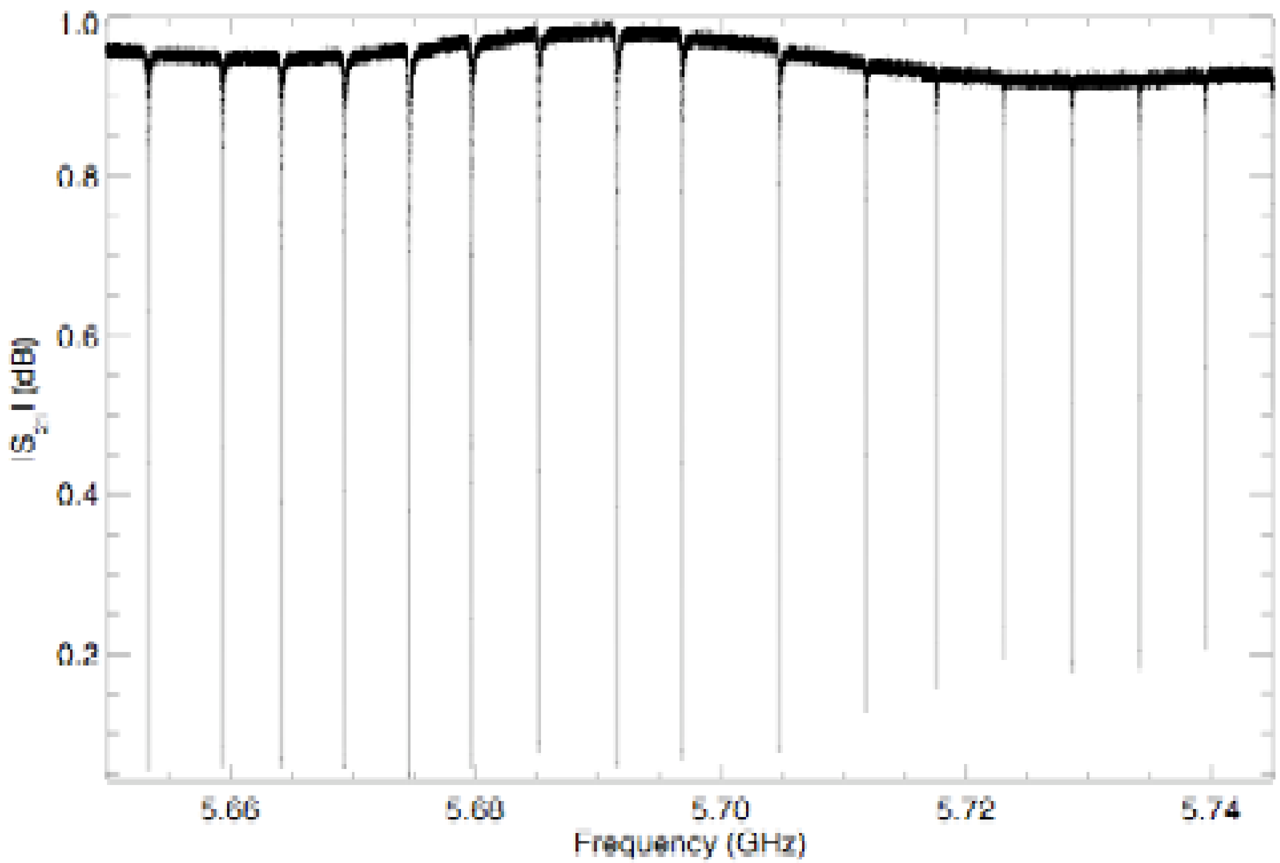
Each pixel consists of a multislot antenna plus in-phase combining array, on-chip filters, and two Nb/Al resonators



Democam Jupiter observation

- Away from resonance, transmission is unity.
- Resonators have very high quality factors – Q ~ 10^4 – 10^6.

→ Highly multiplexed readout: ~ 10^2 – 10^3 on single feedline, via comb of resonant frequencies



MKIDCam – currently under development

16 tiles of 6 x 6 spatial pixels, 4 colors (230, 290, 350, 405 Ghz = 1.3mm, 1.0mm, 850um, 750um) for total of 2304 channels

Advantages:

Detector fabrication is simple:

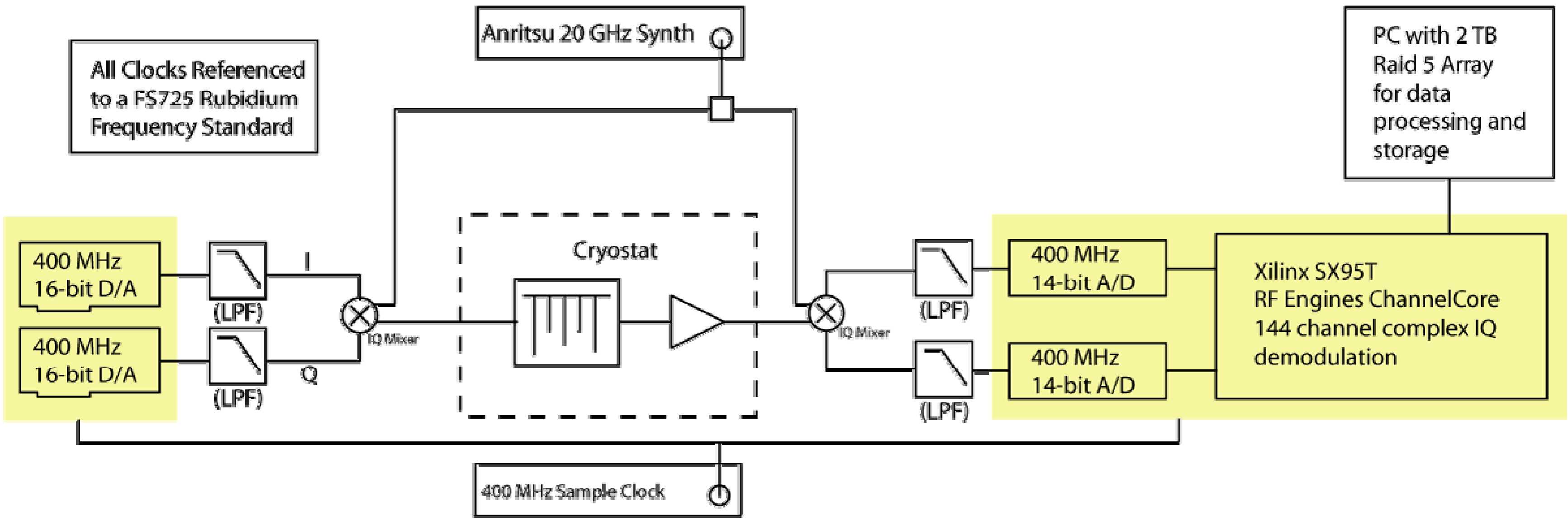
- 3-6 levels of lithography, depending on design; yields are high

Drastic simplification of focal plane:

- Single HEMT amplifier (at most) for each detector wafer
- Two wires leaving each wafer
- Complicated electronics (demodulation and decimation) moved to room temperature

Scalability:

- Huge multiplexing capability – MKIDCam will read out ~144 MKIDs per tile
- Limited by bandwidth of DACs, ADCs, accuracy of resonant frequencies



MKIDCam SDR readout scheme

Trade-offs:

Multiplexing requires hefty on-board demodulation/decimation – state of the art FPGAs – significant power requirements

Running up against current limits on large-bandwidth, high-precision ADCs, DACS

But...

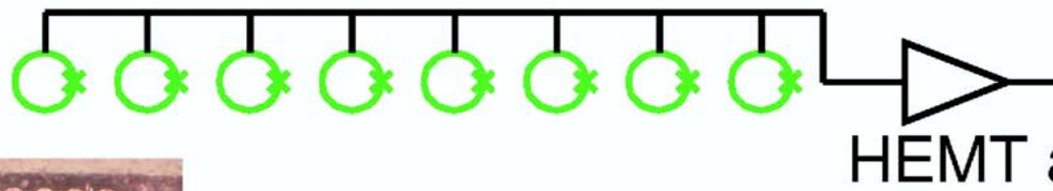
Huge commercial interest in SDR for communications

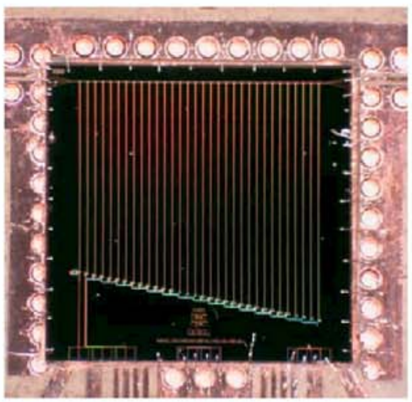
Cutting edge for both ADC/DACs and FPGAs advancing rapidly (factor of ~4 improvement in speed of 14-bit ADCs in 2 years)

Not just for MKIDs!

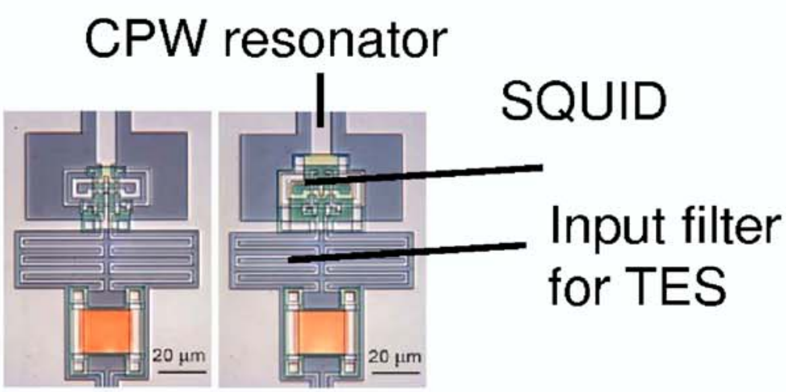
Dissipationless Microwave SQUIDs

- Enables TES detectors with superconducting microresonator readout
- Can use the same warm electronics as MKIDs
- No feedback necessary
- Low power dissipation in the focal plane (< 5 pW / resonator)

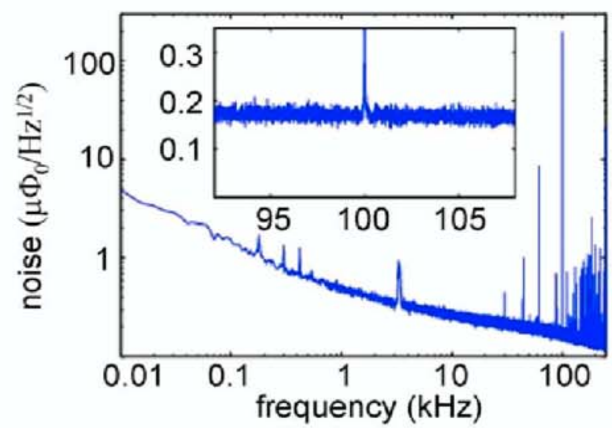




Prototype chip



Signal flux-modulated to 100 kHz



Noise performance: $0.17\mu\Phi_0/\sqrt{\mathrm{Hz}}$

Technological Readiness Level:

Currently around TRL4: Democam at the CSO served as a low-fidelity demonstration of the technology

MKIDCam: TRL6

Full system (all 16 tiles, 576 spatial pixels, 4 colors with simultaneous readout) scheduled for Spring 2010. Should be approaching BLIP limit.

Needed Investment:

- Resonator design/fabrication in early stages. Still a lot of lab work to be done to fully understand/optimize devices
- Hardware/software development: hardware (DACs/ADCs, FPGAs) is industry-driven
- Lag time for flight-qualified hardware. Low power dissipation readout system probably requires custom ASIC; develop schemes on FPGAs