Astro 426/526

Fall 2019

Prof. Darcy Barron

Lecture 23: Sub-millimeter and Millimeter-Wave Detection

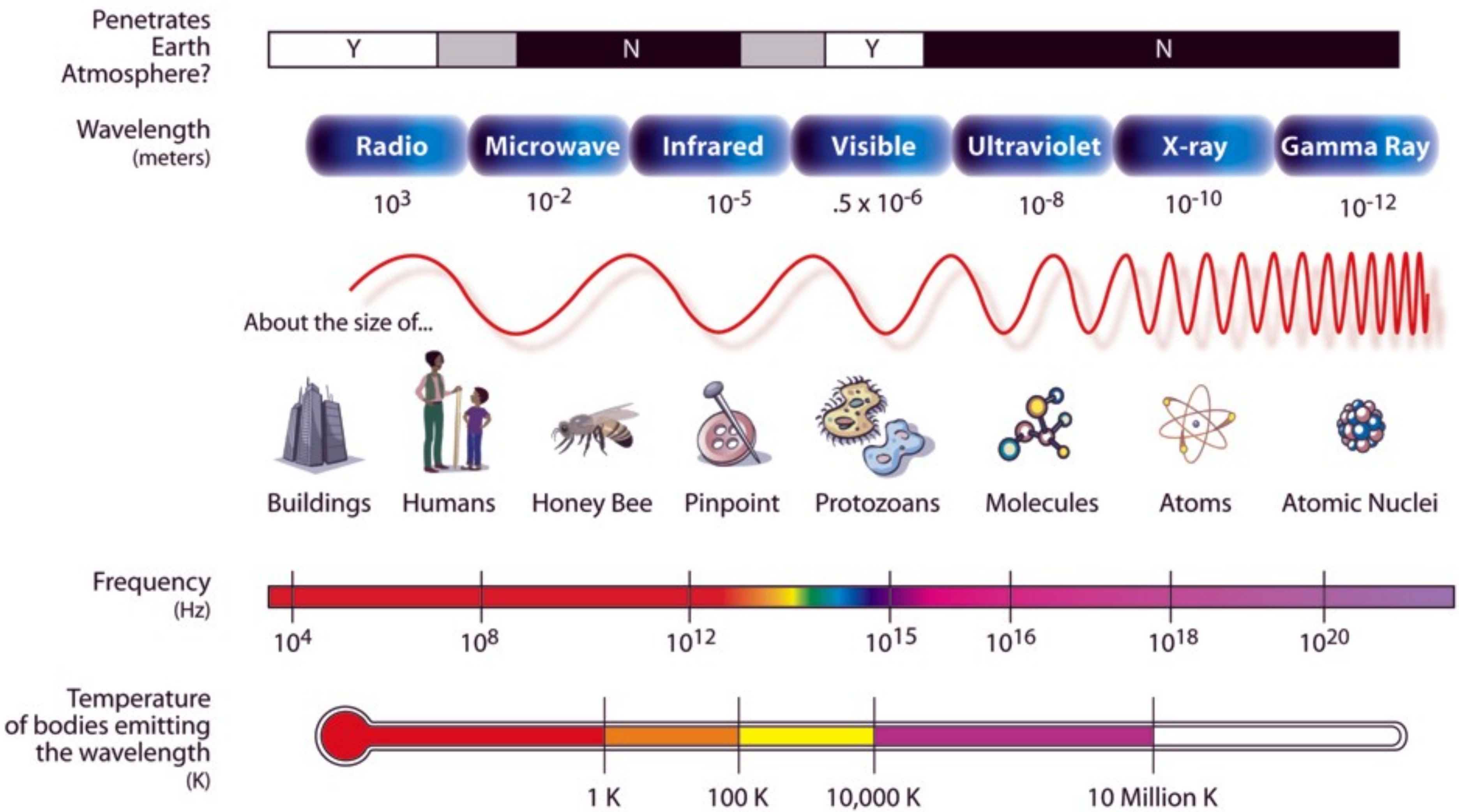
Project Update

- Research-style paper summarizing your methods and results is due **Monday, November 25 at 4pm**
  - Group submission *on Learn* (as pdf or word document)
  - I will make sure to allow unlimited submission attempts
- Final deadline for revisions to "Results" section: Tuesday, December 3 at 12pm (*send via email*)
- Analysis code (*submit via email*) and project contribution statement (*submit on Learn*) due at start of class, Wednesday, December 4, 2019
- All three groups will give in-class presentations on Wednesday, December 4 (25 minutes per group)
- Project guidelines and grading posted on Learn

Syllabus update

- No class Wednesday November 27 (Wednesday before Thanksgiving break)
- 6 regular classes left, covering material from *Measuring the Universe*
  - Today, Wednesday Nov 13 (spectroscopy: Chapter 6)
  - Mon Nov 18, Wed Nov 20 (mm, sub-mm: Chapter 7)
  - Monday November 25 (TBD)
  - Monday December 2 (TBD)
- Take-home final will be handed out at final class (Wednesday Dec 4), due by 12pm Wed Dec 11

THE ELECTROMAGNETIC SPECTRUM



Source: NASA

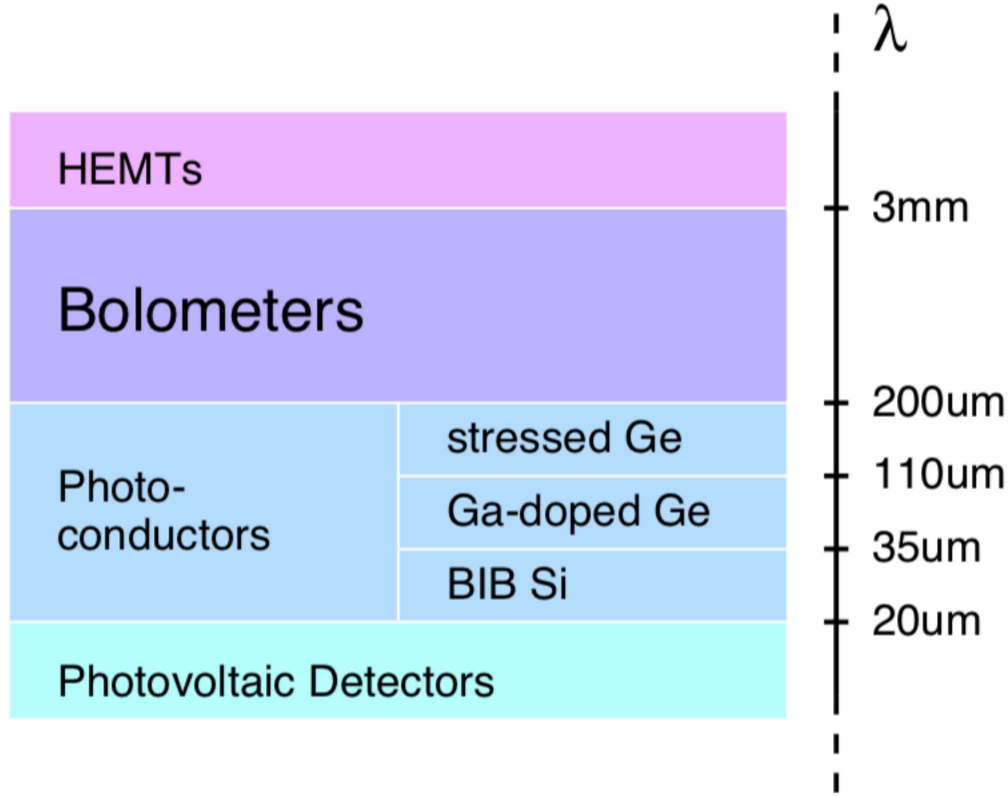
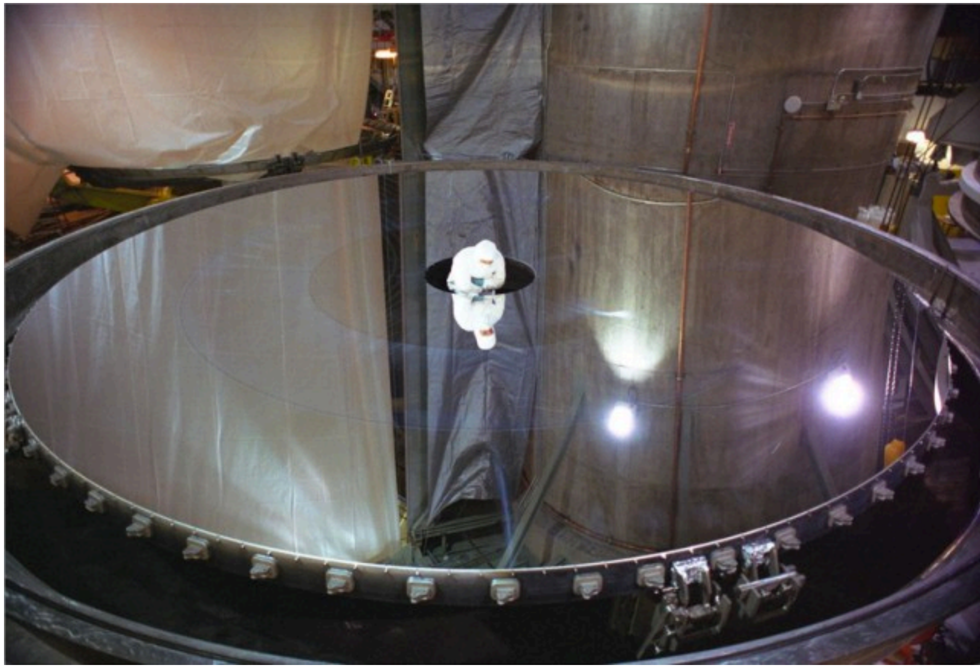


Figure 1.1: An overview of different broad band receiver technologies and the range of wavelengths in which they are predominantly used.

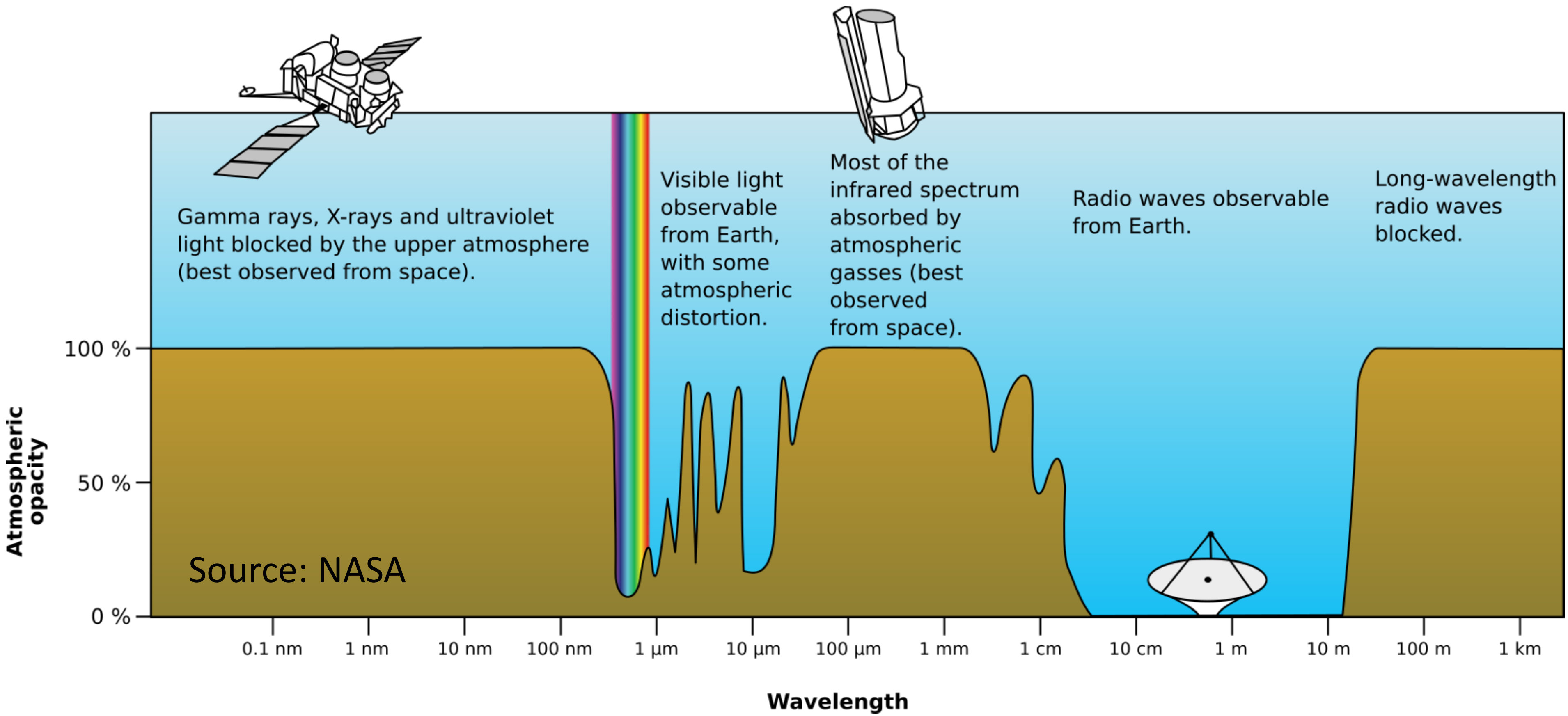
Figure from Gildemeister PhD Thesis, 2000

APEX telescope (sub-mm and mm)

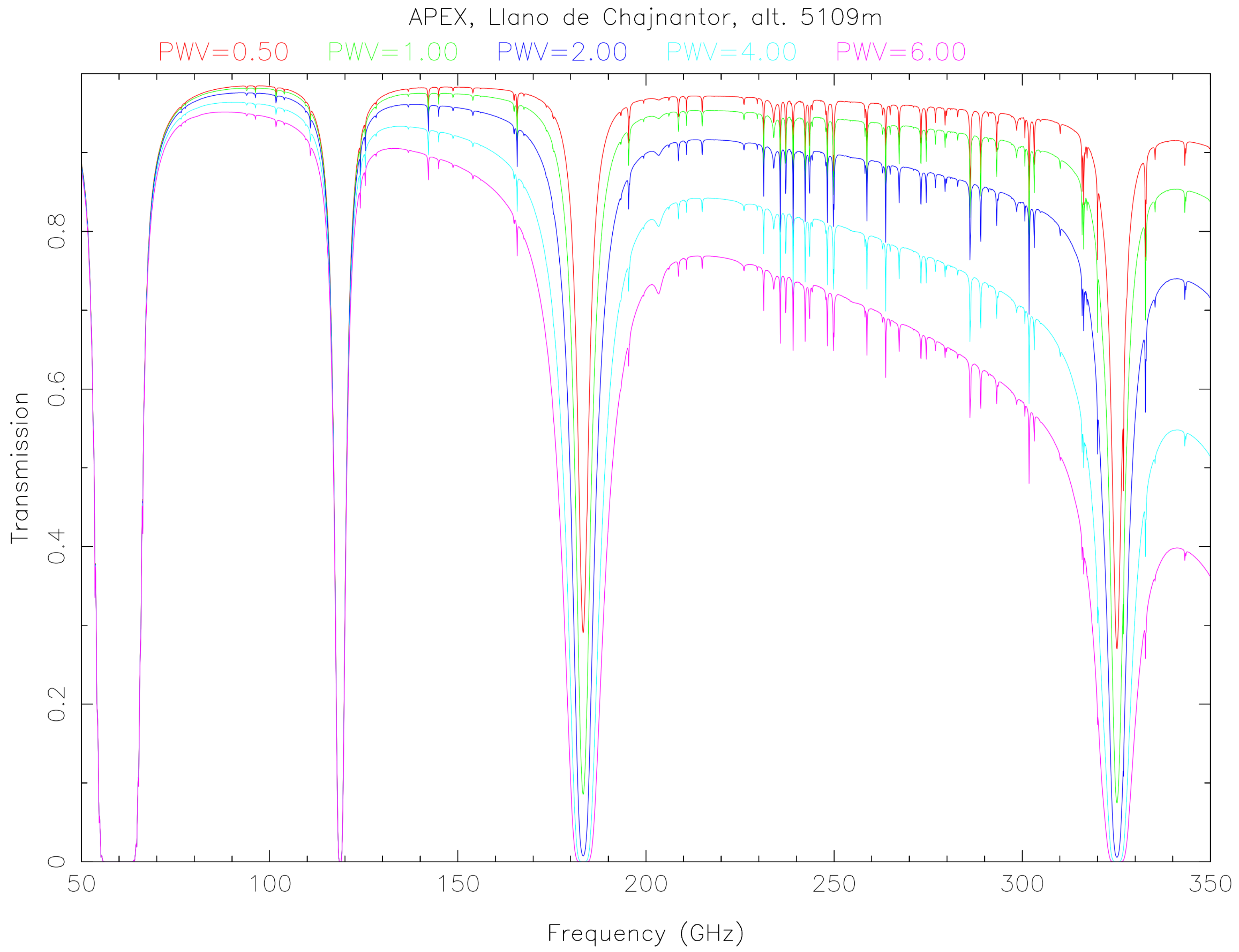
Gemini mirror (optical)



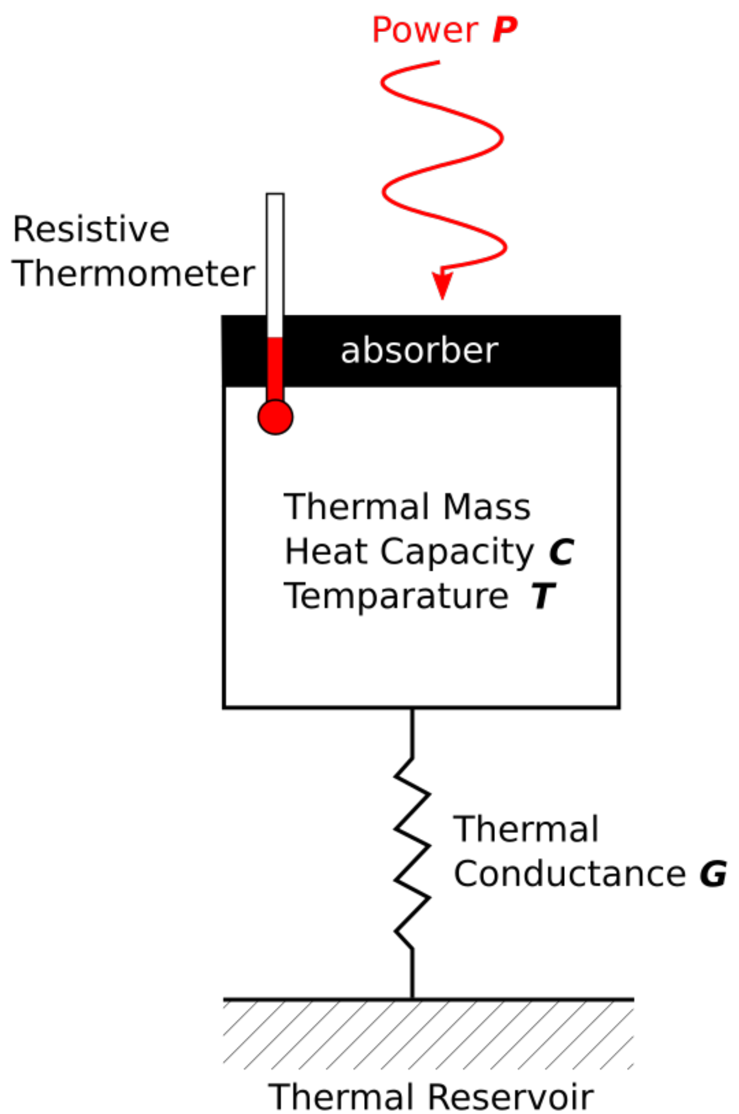
Electromagnetic spectrum and our atmosphere



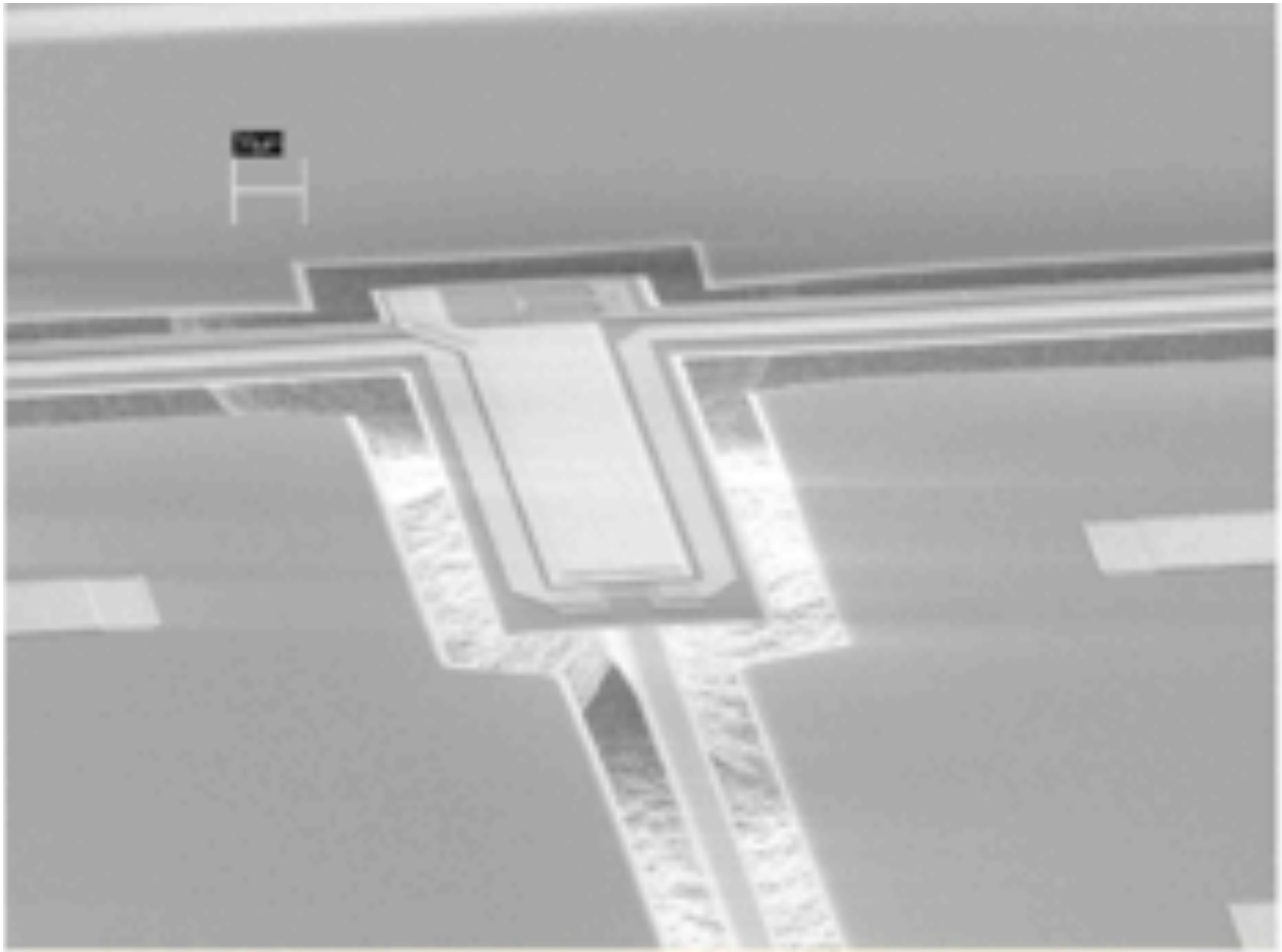
Atmospheric transmission for microwaves

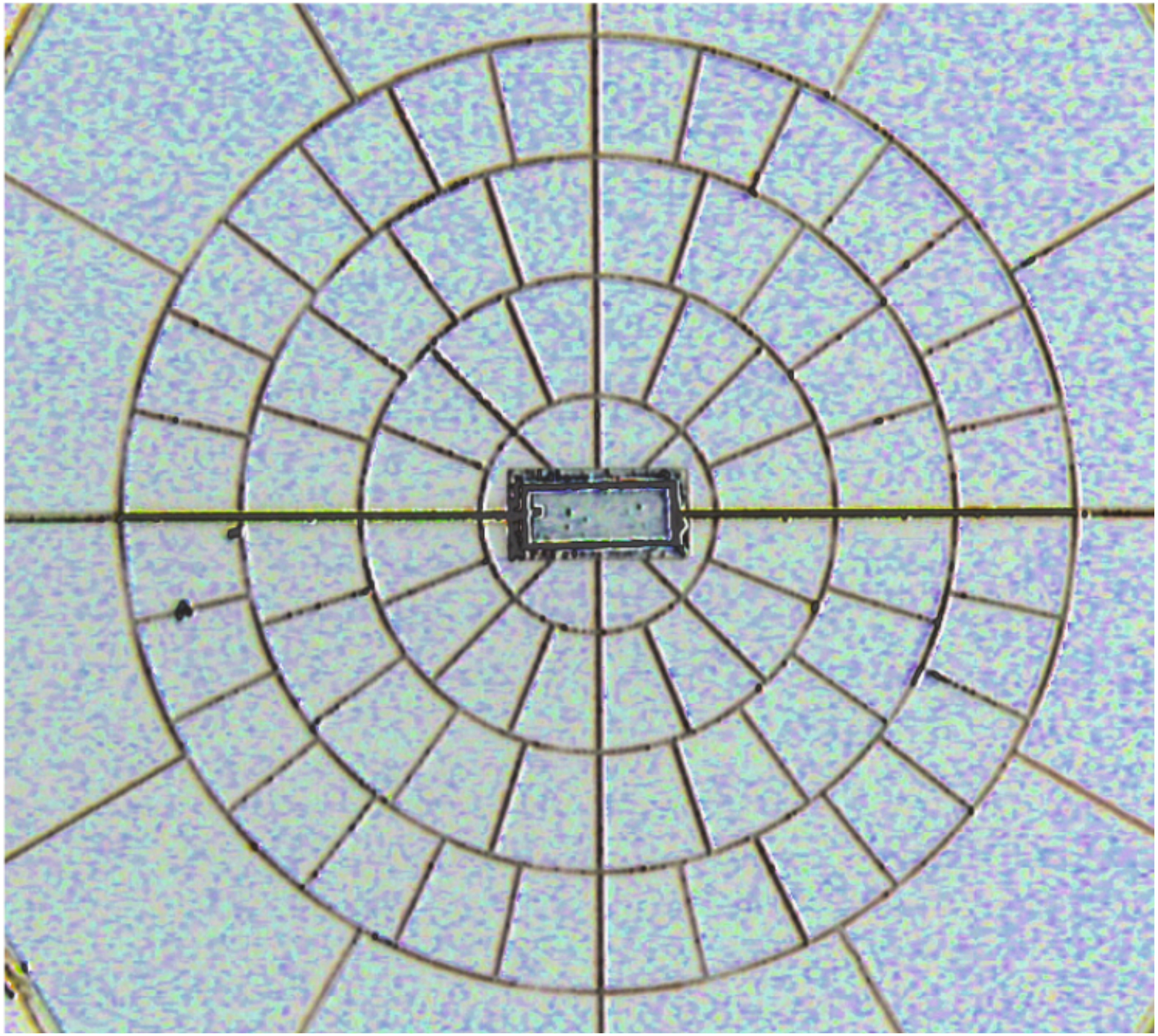


Bolometer: device to measure incident power

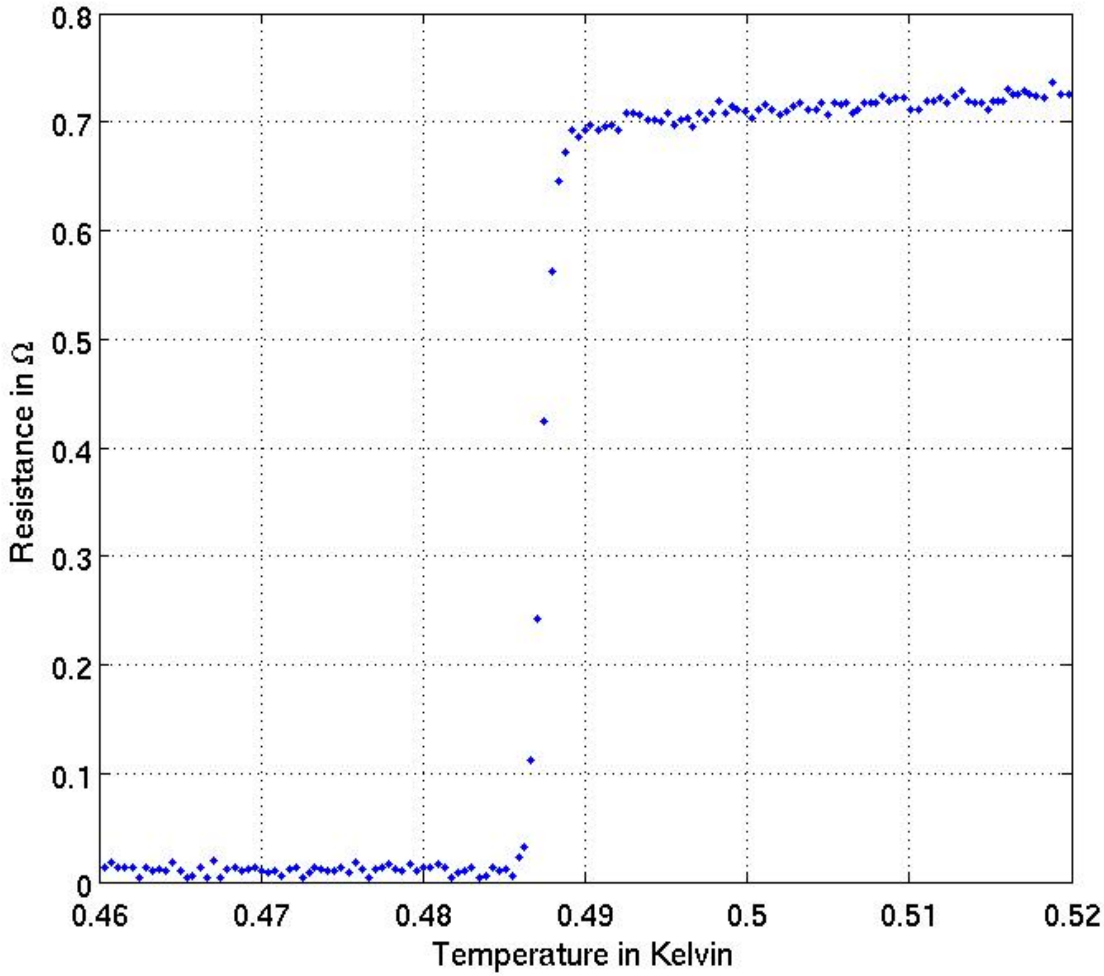


Bolometer

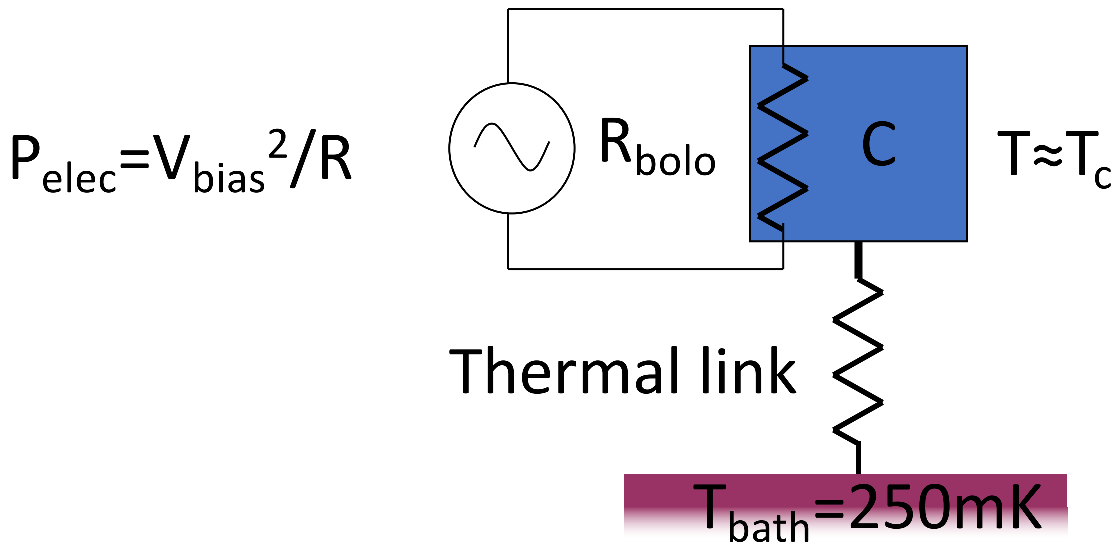




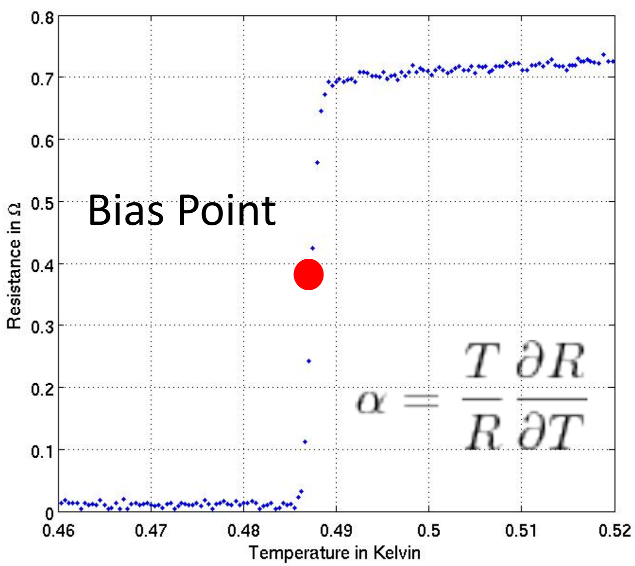
Superconducting transition (AlTi)



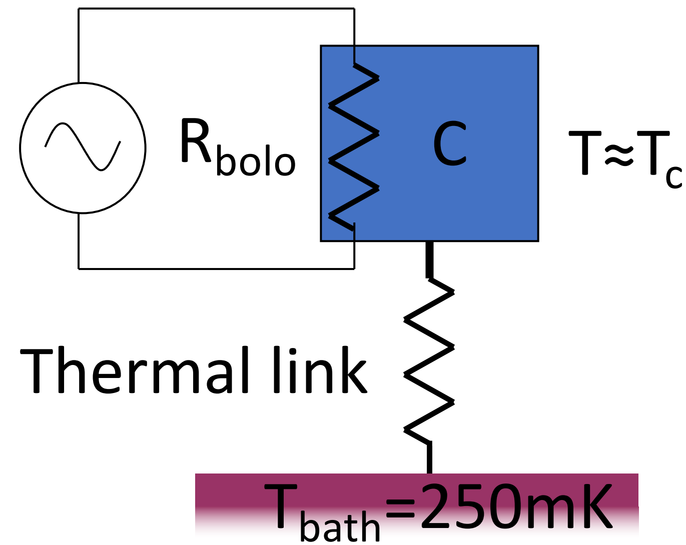
Transition Edge Sensor Bolometers



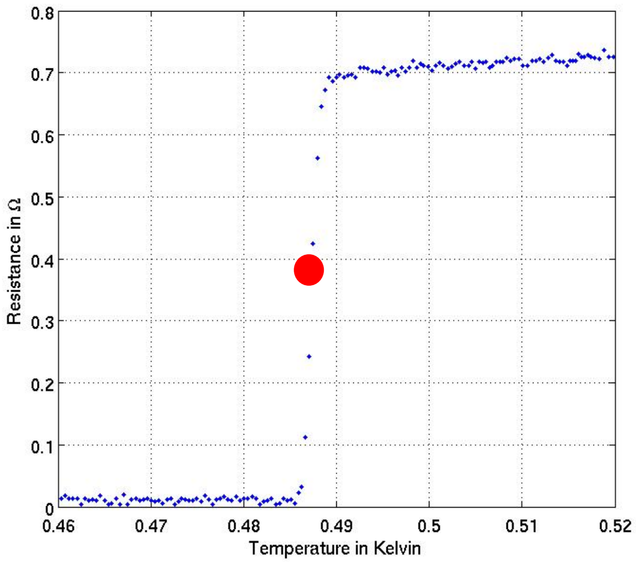
Transition Edge Sensor Bolometers



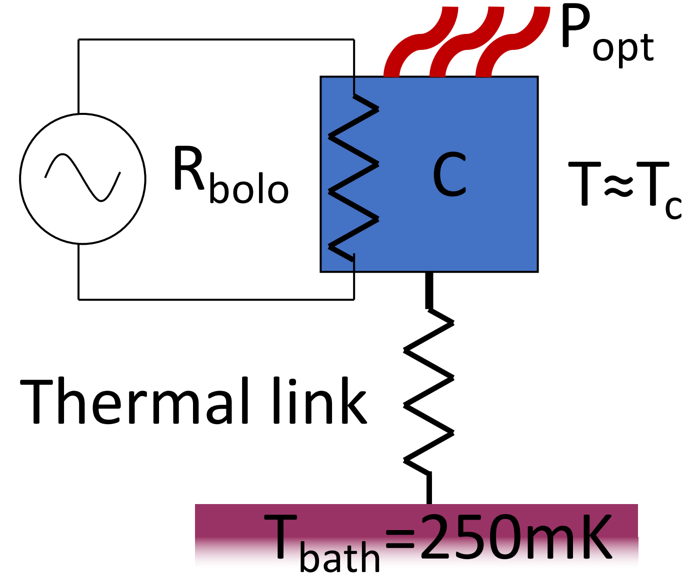
$P_{elec}=V_{bias}^2/R$



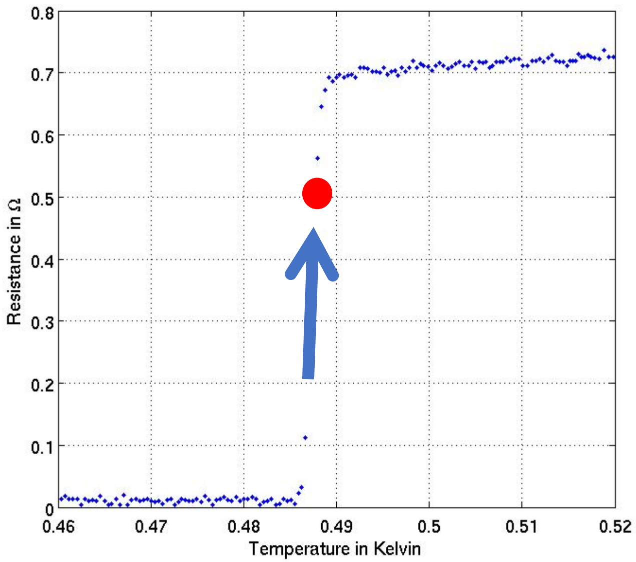
Transition Edge Sensor Bolometers



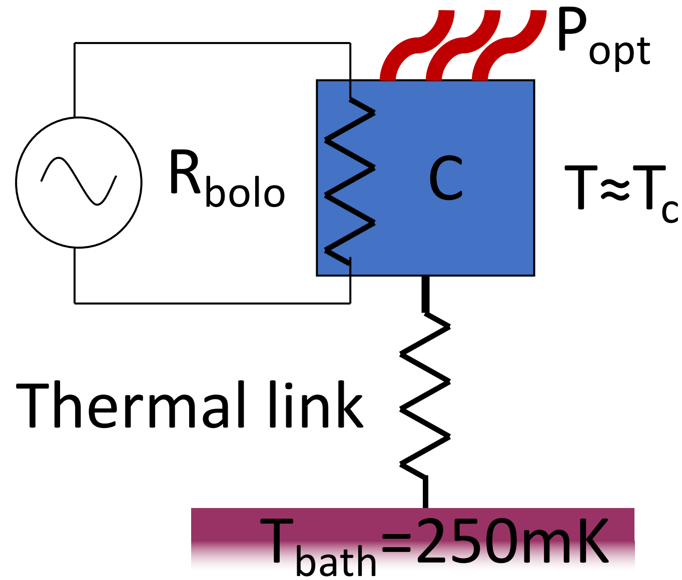
$P_{elec}=V_{bias}^2/R$



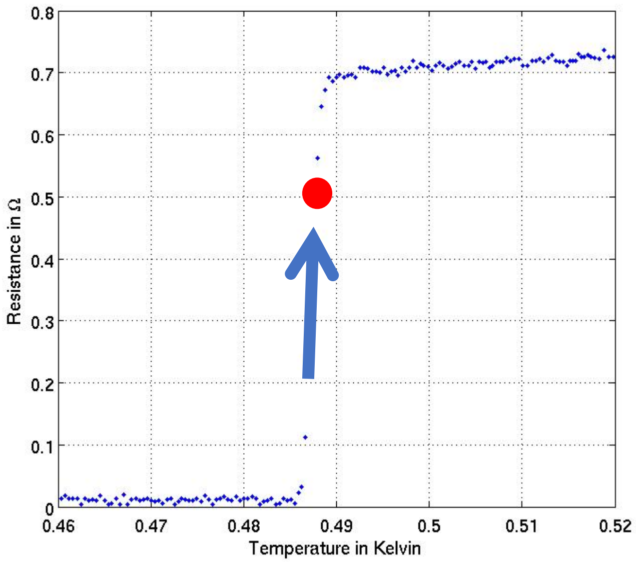
Transition Edge Sensor Bolometers

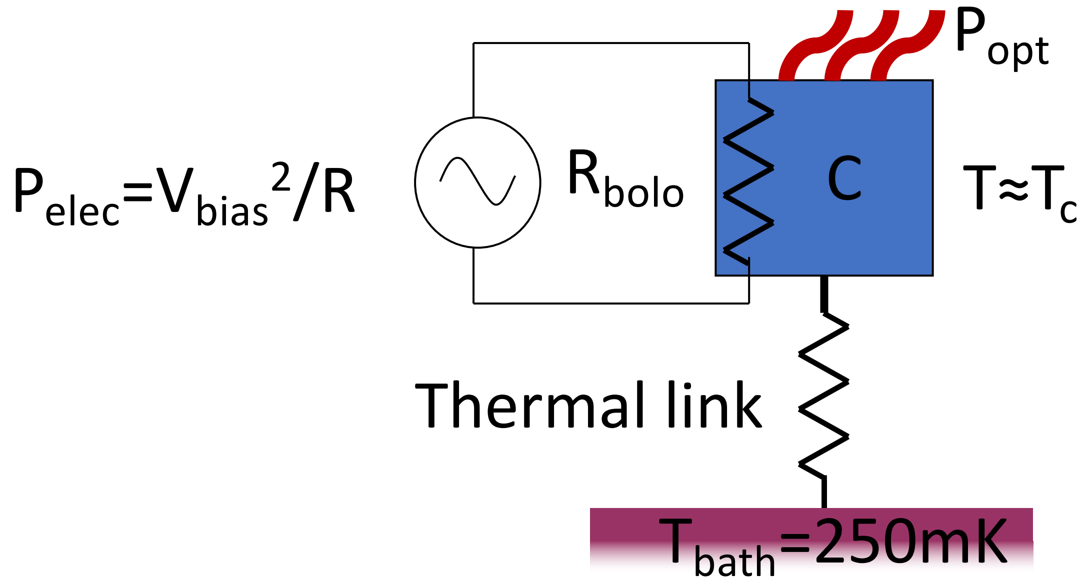


$P_{elec}=V_{bias}^2/R$

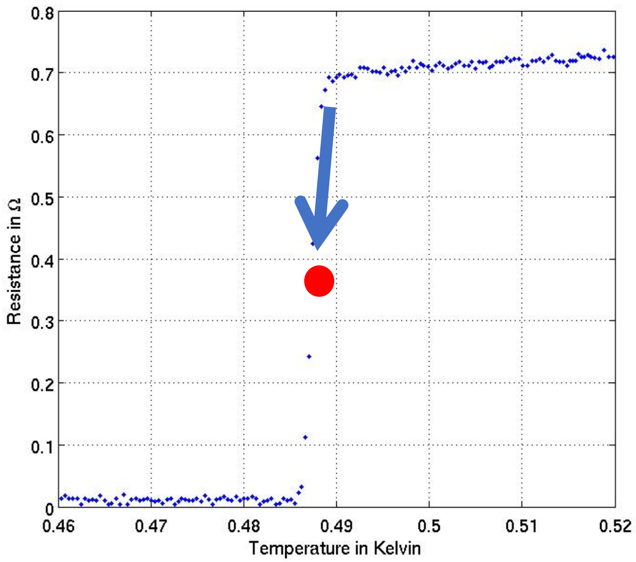


Transition Edge Sensor Bolometers

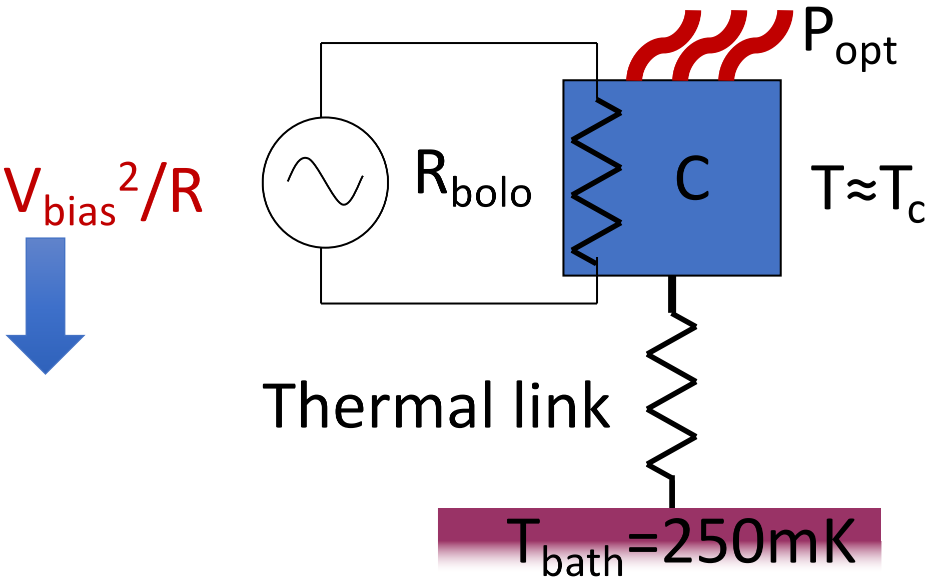




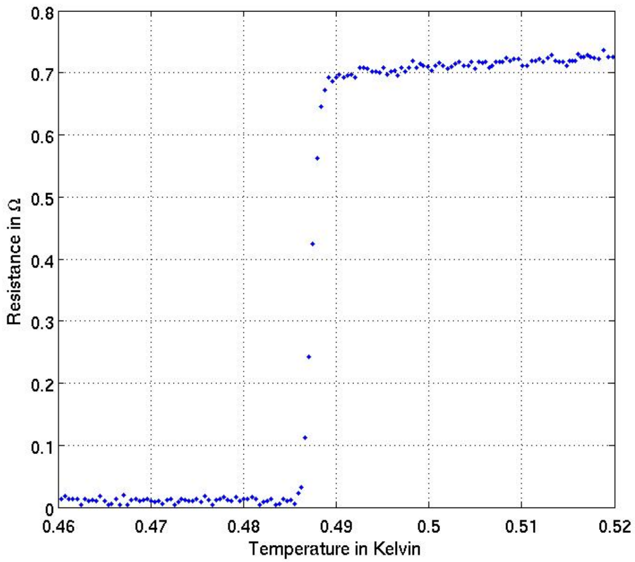
Transition Edge Sensor Bolometers

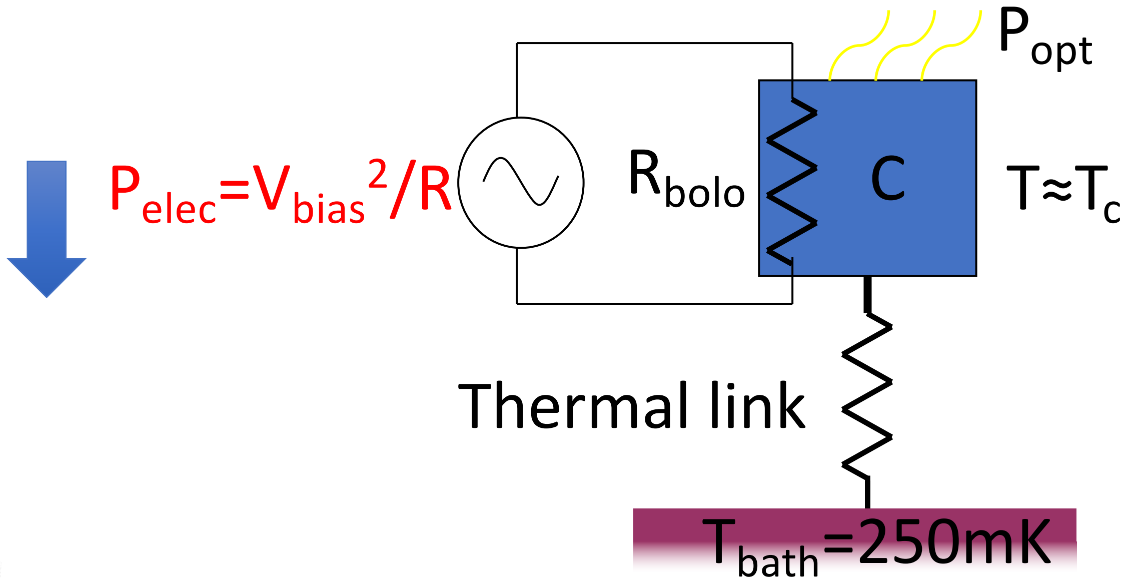


$P_{elec}=V_{bias}^2/R$



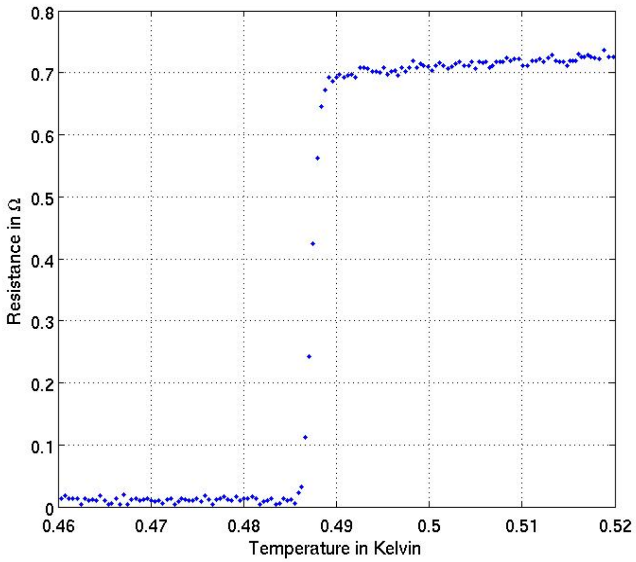
Transition Edge Sensor Bolometers

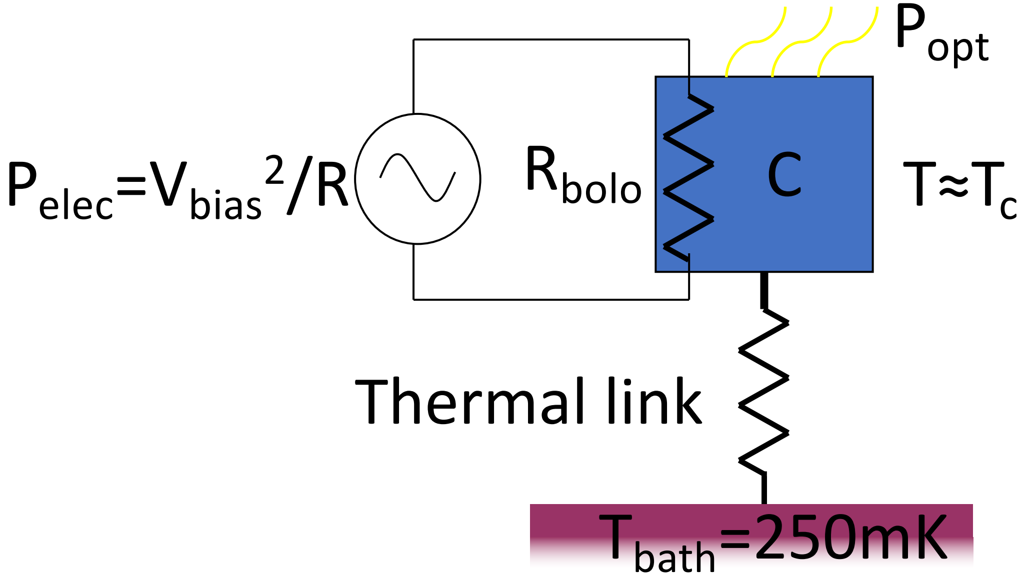




$$P_{total} = P_{optical} + P_{electrical} \approx Constant$$

Transition Edge Sensor Bolometers





$$P_{total} = P_{optical} + P_{electrical} \approx Constant$$

- Steep R vs T of superconducting transition allows sensitive detection of power on bolometer
- Strong negative feedback mechanism holds total power on bolometer constant:

Optical power modulates electrical power

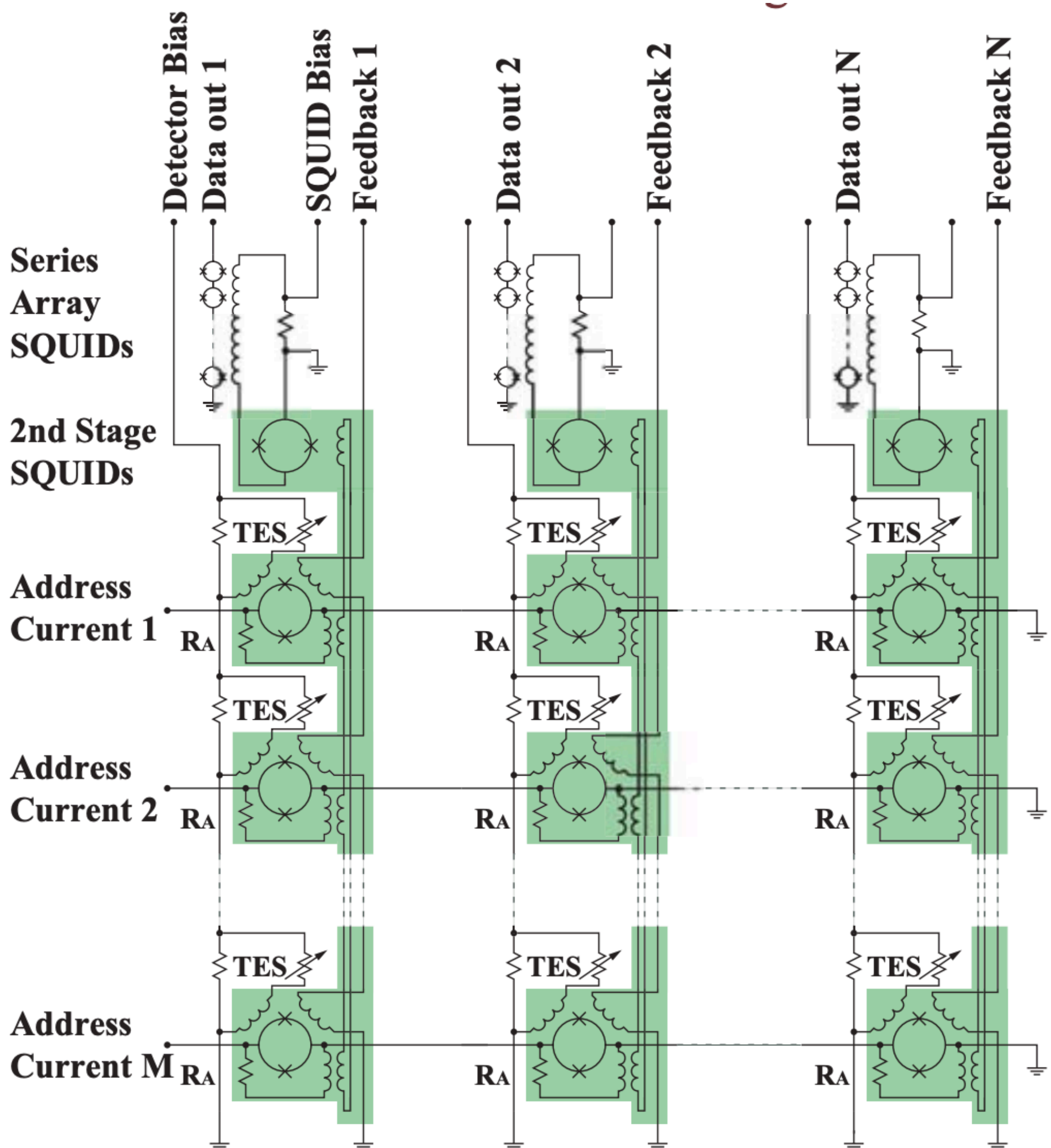
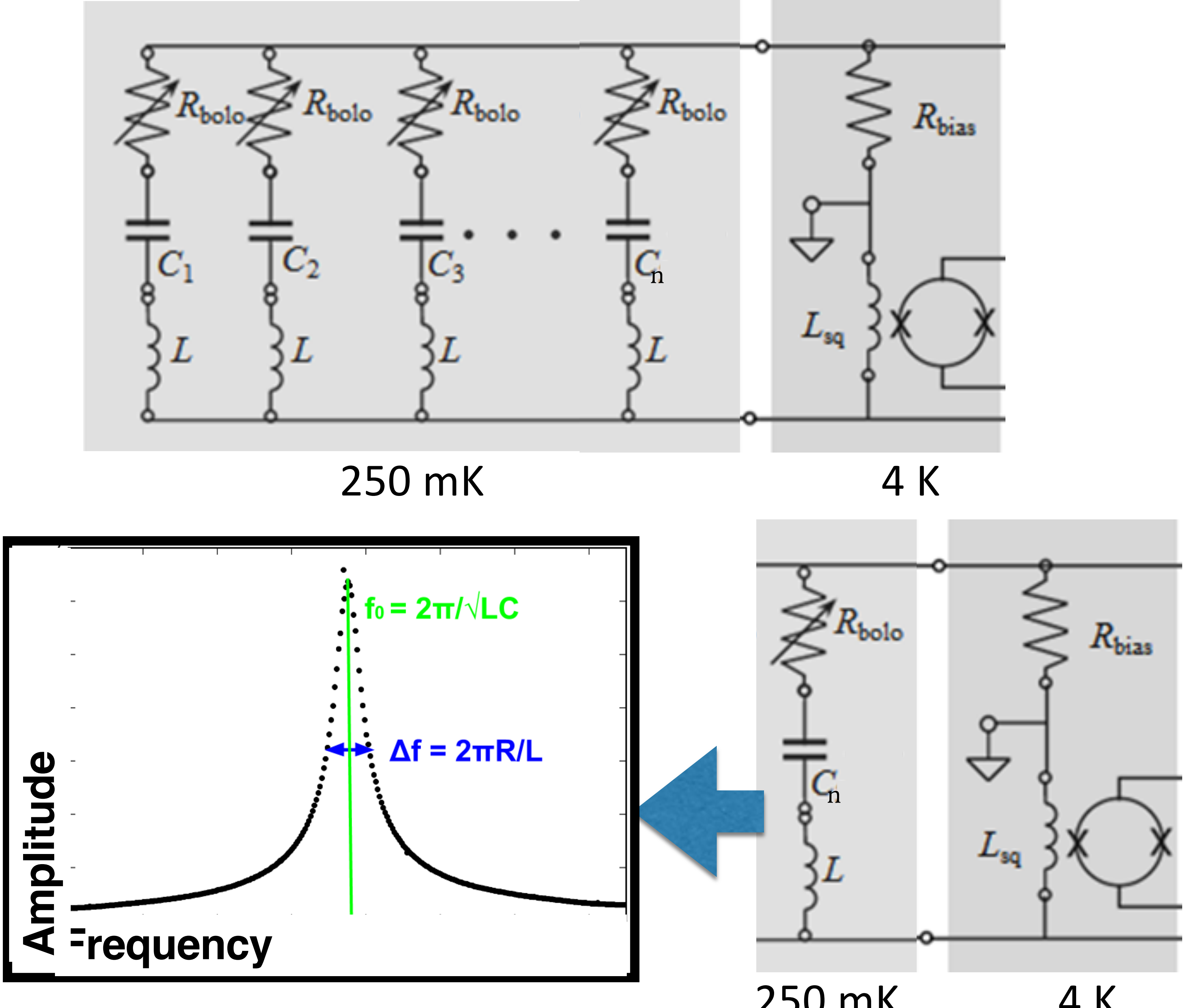


FIGURE 1. Circuit diagram for series-address SQUID MUX with $M \times N$ pixels. In this version, the first-stage SQUIDs are coupled through a common transformer to the second stage.


Rbolo
Rbolo
Rbolo
Rbolo
C1
C2
C3
Cn
L
L
L
L
Rbias
Lsq
250 mK
4 K
f0 = 2π/√LC
Δf = 2πR/L
Amplitude
Frequency
Rbolo
Cn
L
Rbias
Lsq
250 mK
4 K