Review:
Transition-edge microcalorimeter for tritium beta decay

L.S. Erhardt, D. Deptuck, J.P. Harrison, *Nuclear Instruments and Methods in Physics Research A,* 444 (2000) 92-95

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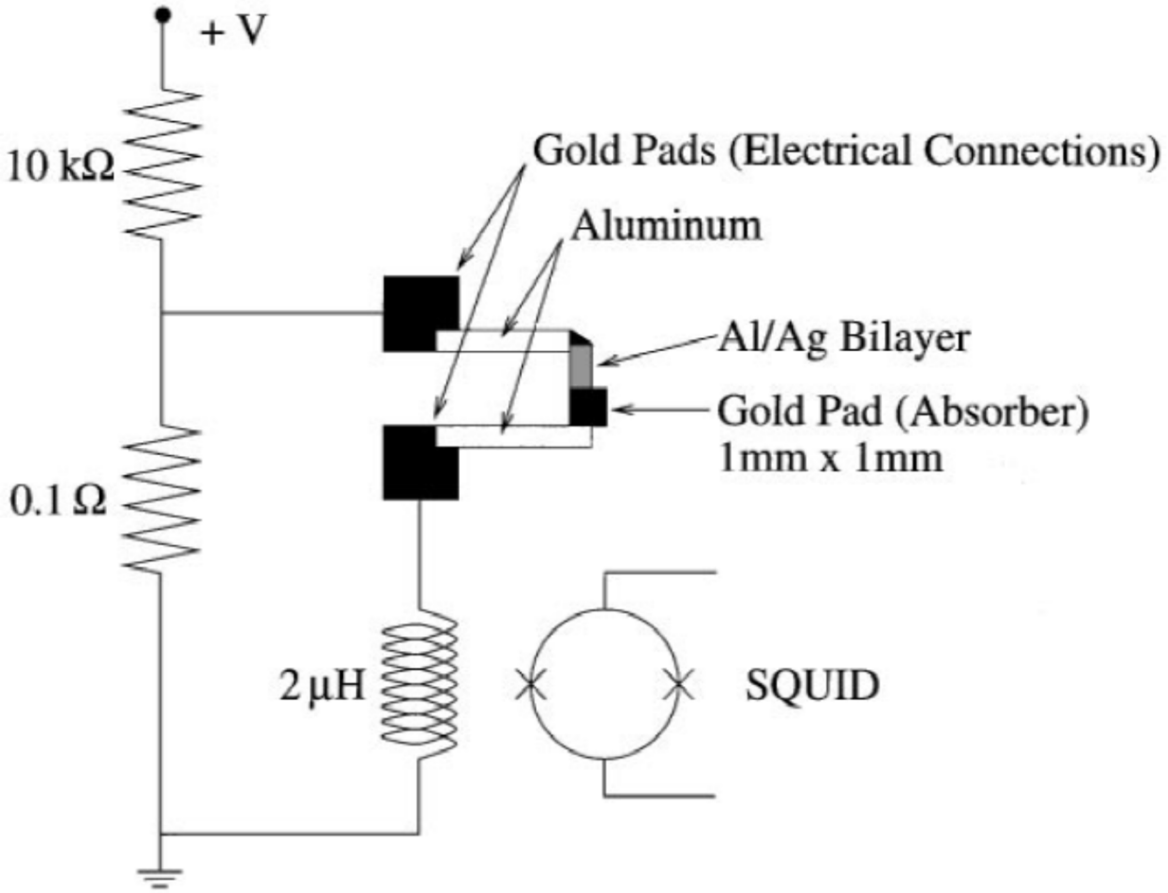
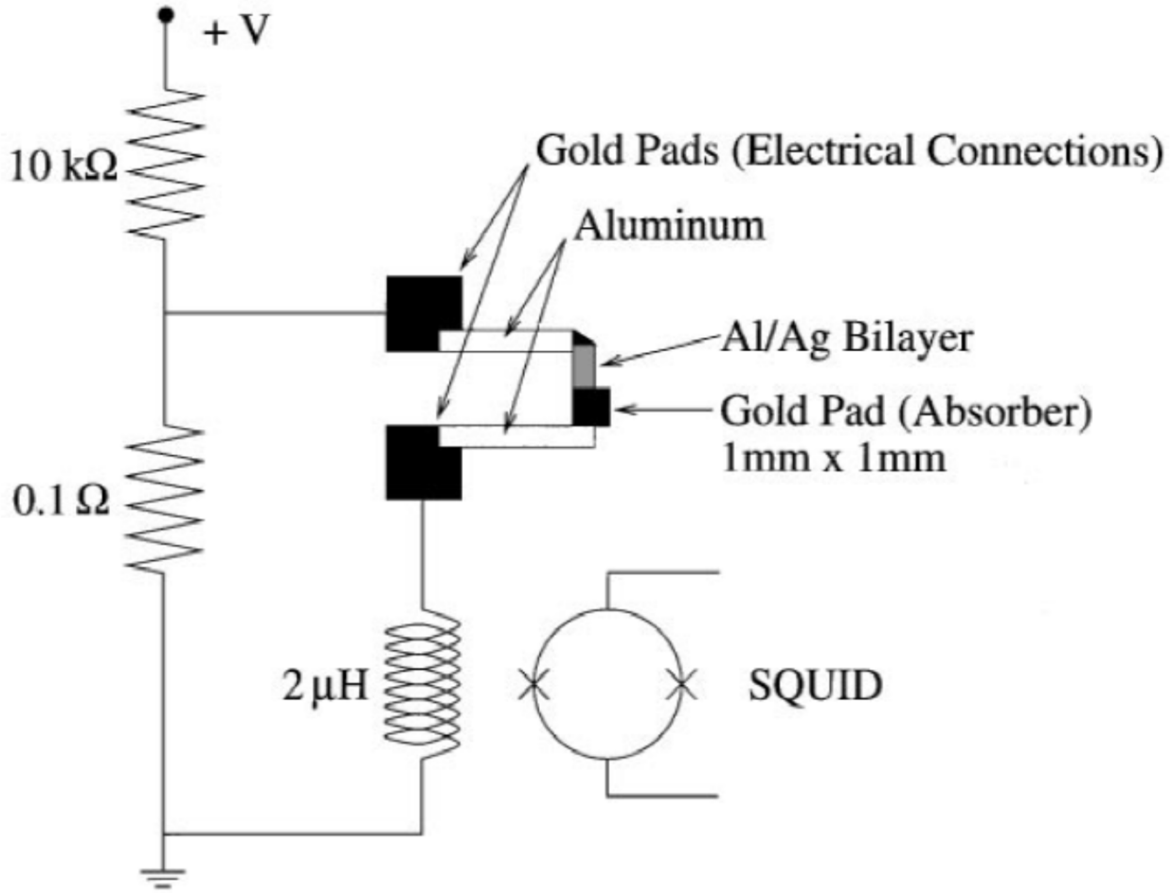
Detector Design

- Constructed on a 1” diameter silicon wafer
  - A three-step, lift-off, photolithography process
  - 1 & 2: thermal evaporation and lift-off patterning of Au and Al part
  - 3: production of Al/Ag Bilayer TES(transition-edge sensor)



Detector Design

- TES
  - By thermal evaporation
    - One evaporator with two thermal sources
  - 30 nm Ag – 18 nm Al - 0.2 nm Ag
- Mountation
  - A mixing chamber of a dilution refrigerator
    - A base temperature ≈ 45 mK

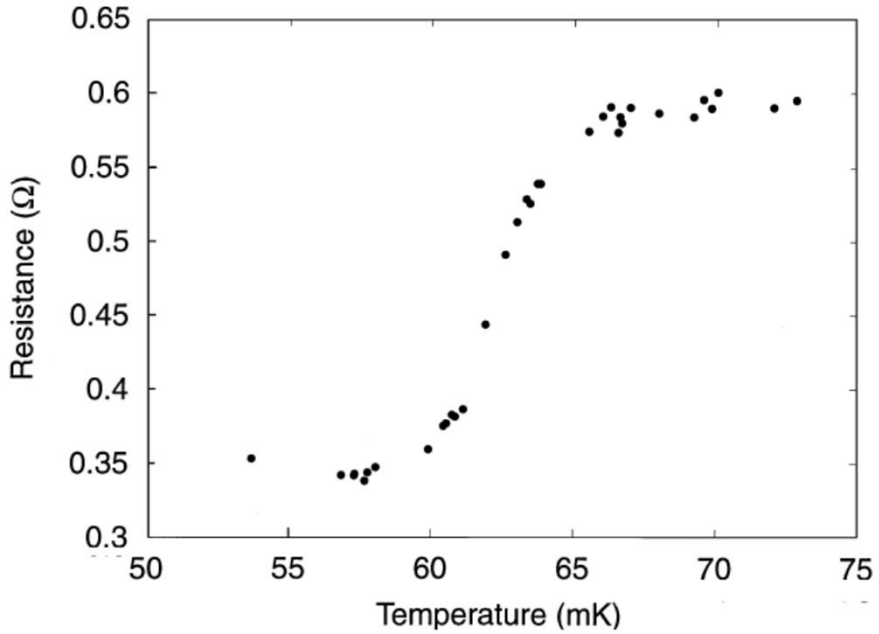


Detector Design

- Tritium-implanted copper foil
  - Implantation – ^{3}He(n,p)^{3}H nuclear reaction
    - Neutron capture
    - $^{3}\mathrm{He} + n \rightarrow {}^{3}\mathrm{H} + p$
    - Q-value: 765 keV
    - Emitted tritium: 191 keV
  - Deposited up to a depth of 1.2 μm(copper foil: 12.5 μm thick)
  - Folded in half
  - Soldered to the gold absorber pad with indium

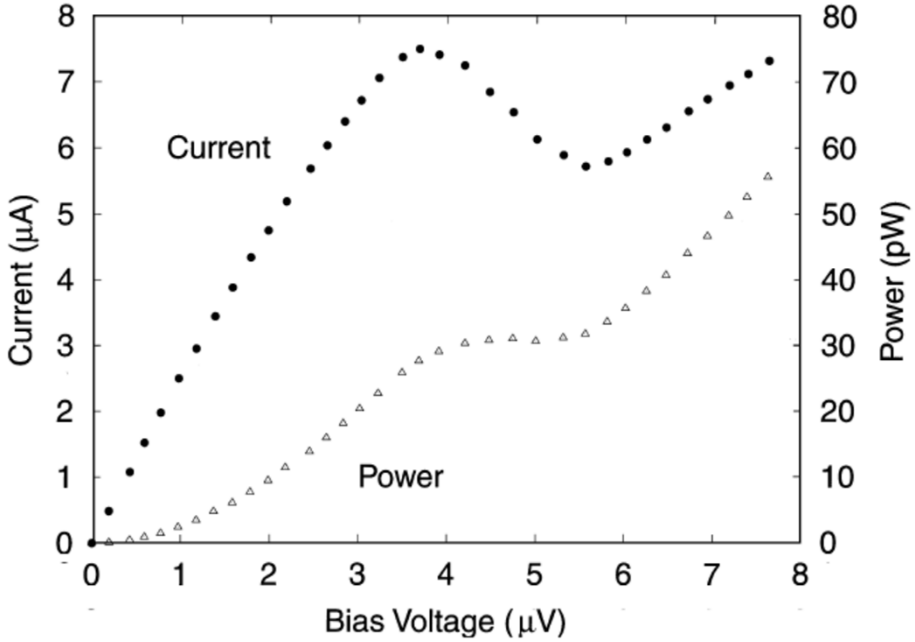
Status

- Superconducting Al/Ag bilayer
  - T_c between 35~90 mK
  - Sensitivity $\alpha = \frac{T}{R}\frac{dR}{dT} \approx 11$ (complete device)



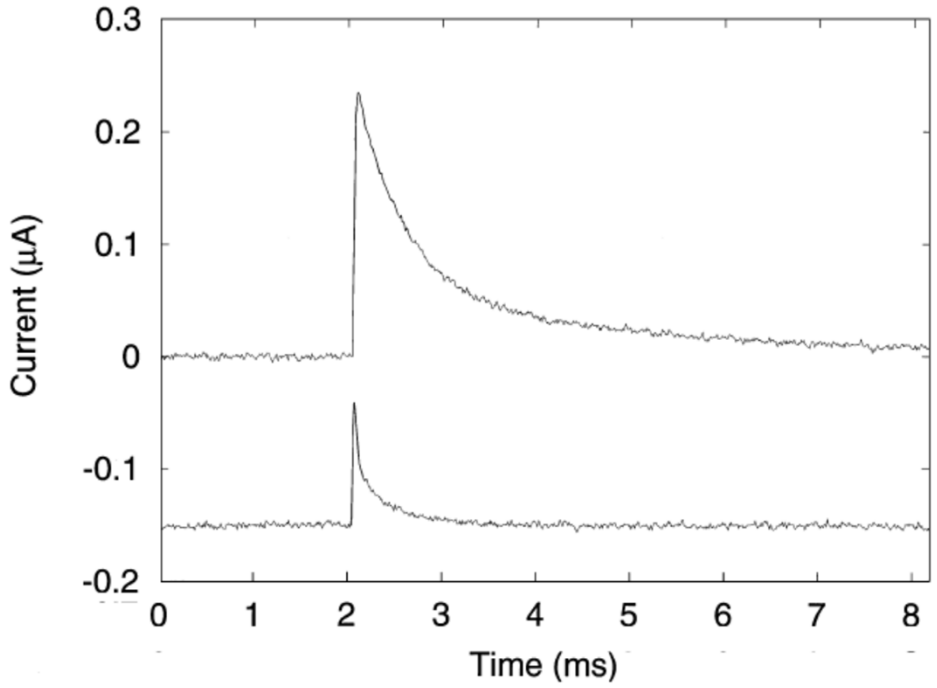
Status

- Bias curve



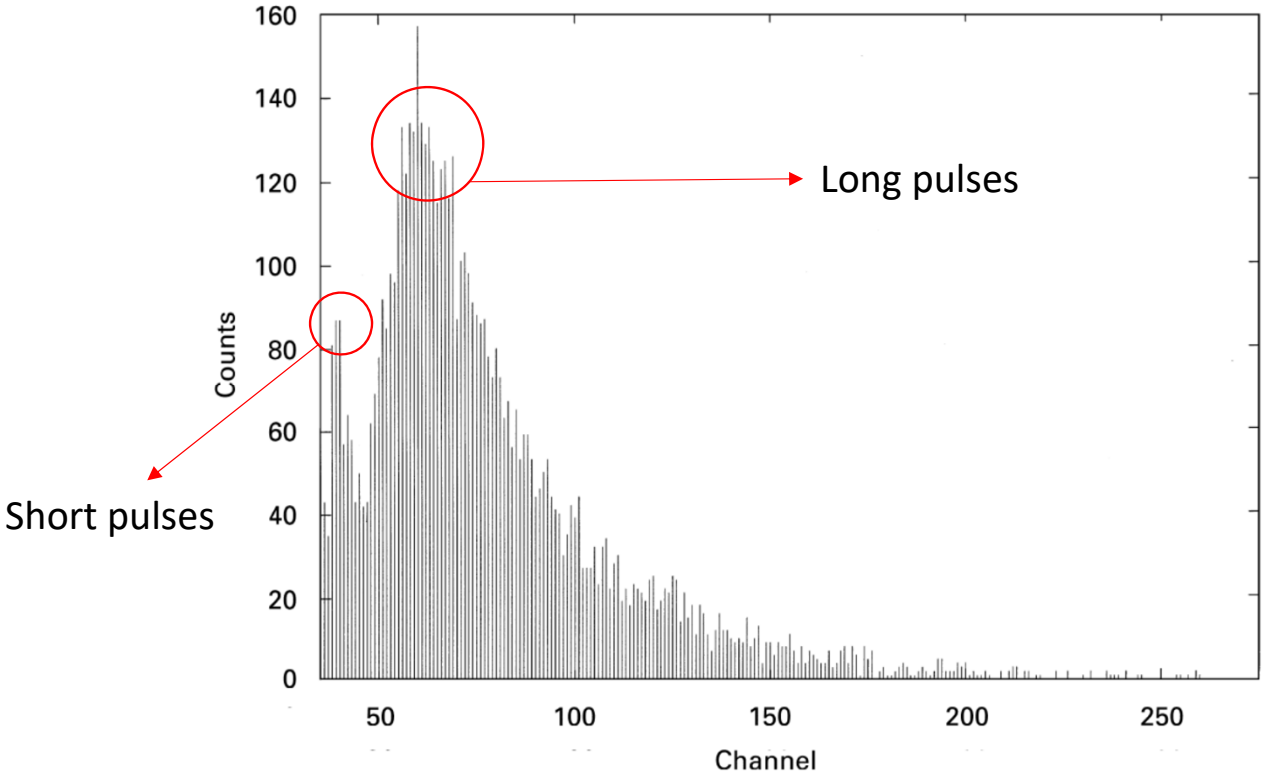
Status

- Tritium pulses
  - Detectable, but at a count rate 3 orders of magnitude lower than expected
    - Possibly due to liberation during soldering
    - Can be resolved by more implantation
  - The shape
    - The rise time: 4~10 μs
    - Two main pulse shapes
      - Both have two decay times
        - Short: 40~500 μs
        - Long: 0.3~2.5 ms



Status

- The collective tritium spectrum
  - an exponentialfilter using a rise time of 80 ls and a single fall time of 1.6 ms



Discussion

- To set a neutrino mass limit on the order of 10 eV, the speed of this device will have to be improved
  - Shorter rise time -> 0.1 μs
    - Higher count rate -> supply the necessary statistics near the end-point of the beta spectrum
  - Shorter fall time -> ~ 100 μs
- Methodology:
  - Make the device small
  - Use non-superconducting soldering
  - Improve the thermal sinking