



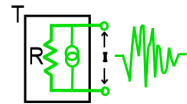
# Noise Thermometry Using Tunnel Junctions

Lafe Spietz, Konrad Lehnert, Irfan Siddiqi and Rob Schoelkopf  
Department of Applied Physics, Yale University



## Thermometry and Noise

- Thermometry at low temperatures (less than 1 Kelvin) unsatisfactory
- All current low temperature thermometers suffer from some combination of slow speed, complexity of use, inaccuracy, and limited range
- Temperature metrology has a missing piece: below .6 Kelvin, an official definition of the unit does not exist.

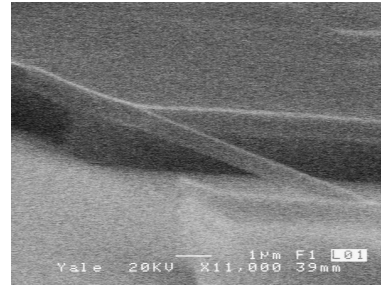


Johnson Noise: thermal agitation of electrons in a resistor

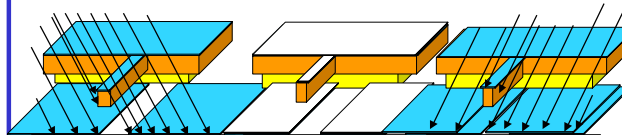
- Frequency independent
- Power directly proportional to temperature ( $S_V = 4k_B T/R$ )
- Hence used as a thermometer: wide temperature range, accurate, *but* slow and very tricky to calibrate

## Fabrication of Devices:

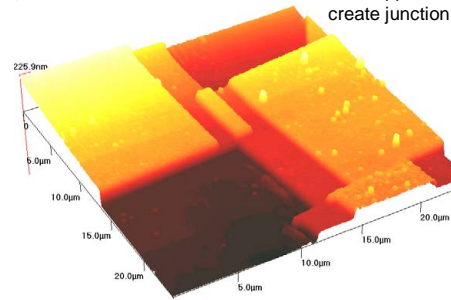
### Dolan Bridge Technique



Scanning electron microscope image of suspended photoresist bridge made by electron beam lithography



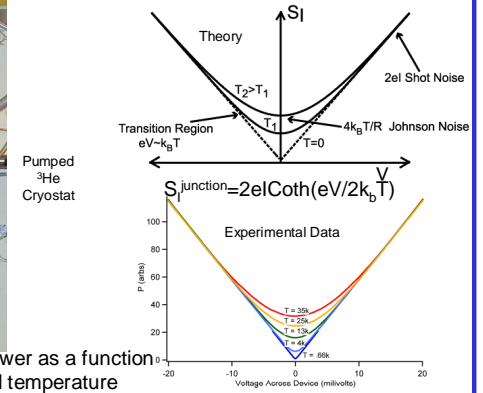
Evaporate Aluminum at an angle    Oxidize Aluminum    Evaporate Aluminum at an opposite angle to create junction



Atomic force microscope image of finished junction

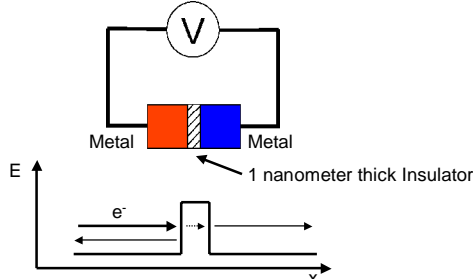
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## Measurement of Thermal-Shot Noise of Tunnel Junction

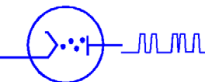


Measure noise power as a function of voltage and temperature

## Tunnel Junctions

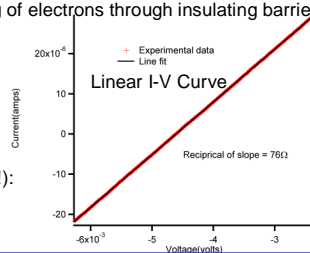


Quantum mechanical tunneling of electrons through insulating barrier



Because of discrete nature of tunneling events, generates shot noise (like a vacuum tube!):

- Temperature independent
- directly proportional to  $I$



## Conclusions: Primary, Fast, Self-Calibrating Thermometer

- Have experimentally verified functional form of noise from tunnel junction over wide range of temperature
- Calibrate temperature dependent Johnson Noise using Temperature independent shot noise
- Primary, accurate and wide temperature range like traditional Johnson noise thermometry *and*
- Self-calibrating measurement removes difficulties of traditional noise thermometry from calibrating amplifier chain
- Hence can measure with  $>100\text{MHz}$  of bandwidth, and do a *fast* measurement
- Improved noise thermometry has implications for temperature metrology (possibility to define the Kelvin at low temperatures!)