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Photos placed in horizontal position with even amount of white space between photos and header

Response of an SET to large rf interference signals

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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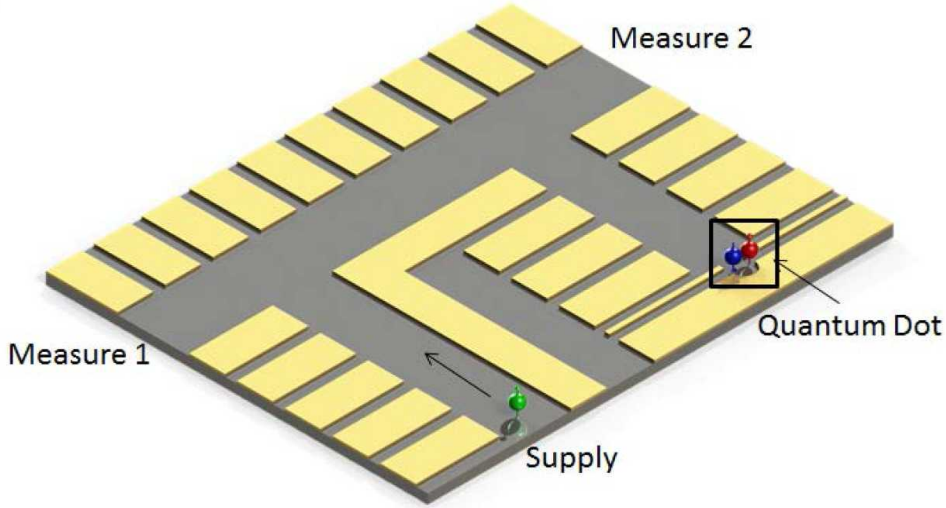
Understanding how to use SETs in environments with large interference signals opens up applications

Electrons on Helium

Many Shuttling gates



Need Charge sensor here!

Other applications: quantum dots, quantized mechanical motion …

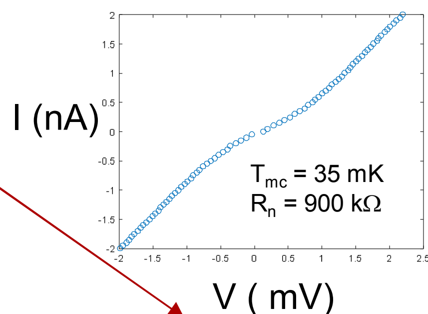
Outline for this talk

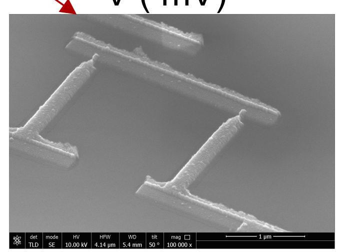
- Device
- Measuring rf interference
- Results
- Cancellation of large rf signals
- Conclusions

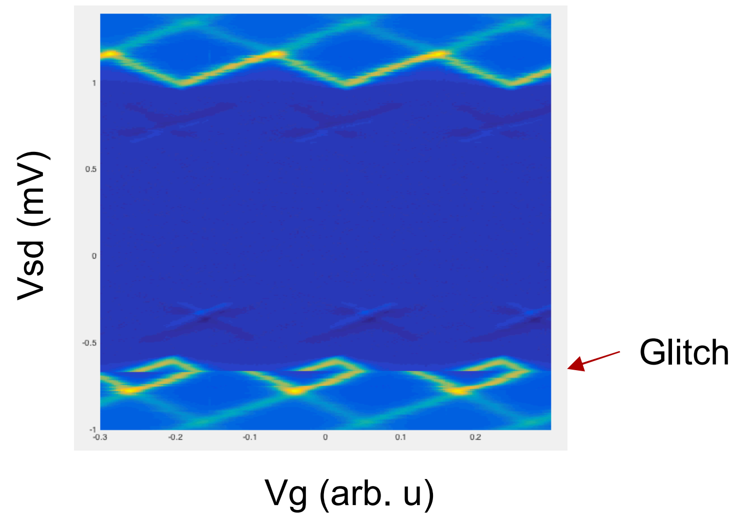
SET device parameters

- Shadow evaporated JJs, approx 70 nm by 65 nm in area
- R_n = 900 kΩ
- Charging Energy: $E_c \approx 1$ K
- Gates: Lithographed gate (shown) C1 = 73 aF +/- 3aF
- 2) Additional gate (Vrf): C2 = 0.6aF (This was a wire bond over the device!)
- Bandwidth of gate lines ~ 80 MHz set by filtering

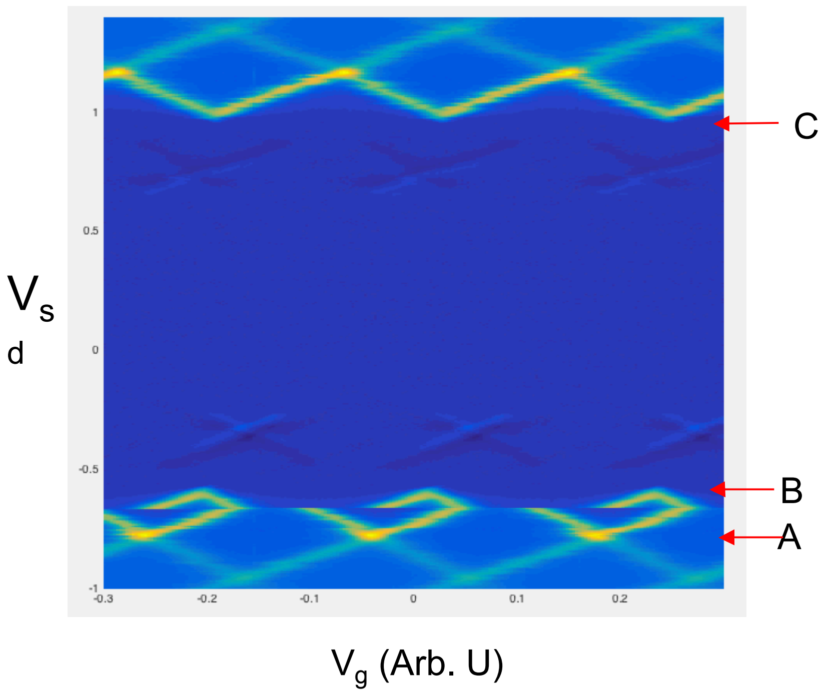
Device intrinsic bandwidth:
$f_c = 1/2\pi R_n C_j \approx 1.4$ GHz

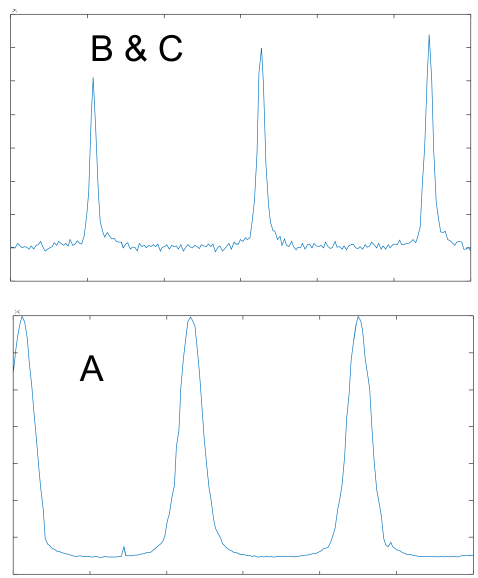






Set up for measuring charge sensitivity





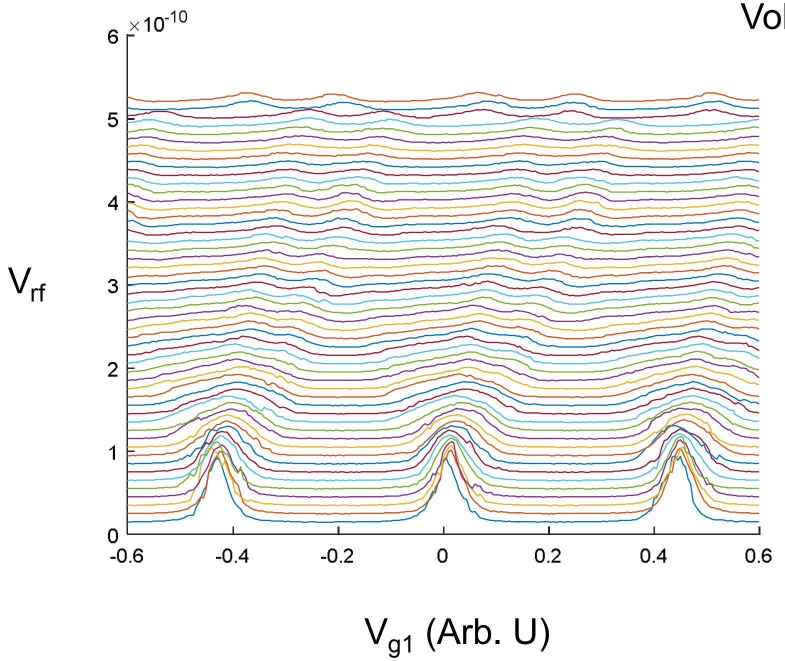
Procedure:

- Set V_{sd} = -0.77 mV (pt. A)
- Scan V_g through conductance peaks.
- rf signal applied to second gate
- Step rf amplitude

Slope of conduction peaks at A similar to B & C
Current measured with standard lock-in technique and a current amplifier at room temperature

We expected to see something like this–until we realized there is a ground loop

Rf = 10 MHz with wst1.

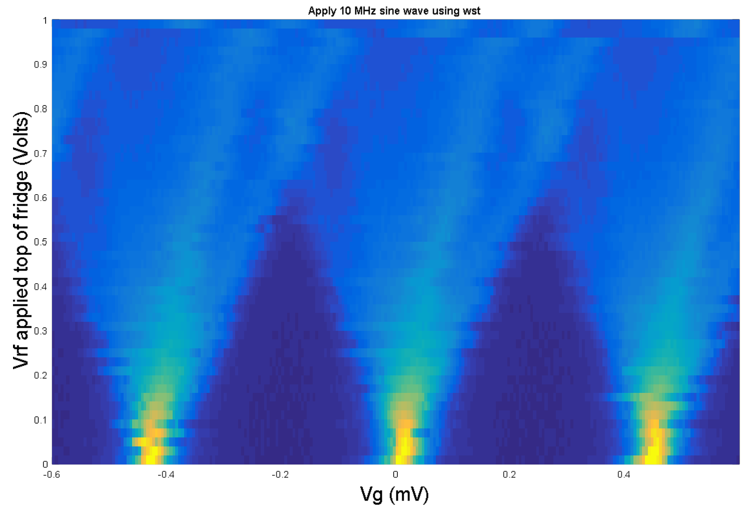


Voltage on rf gate

140 mV

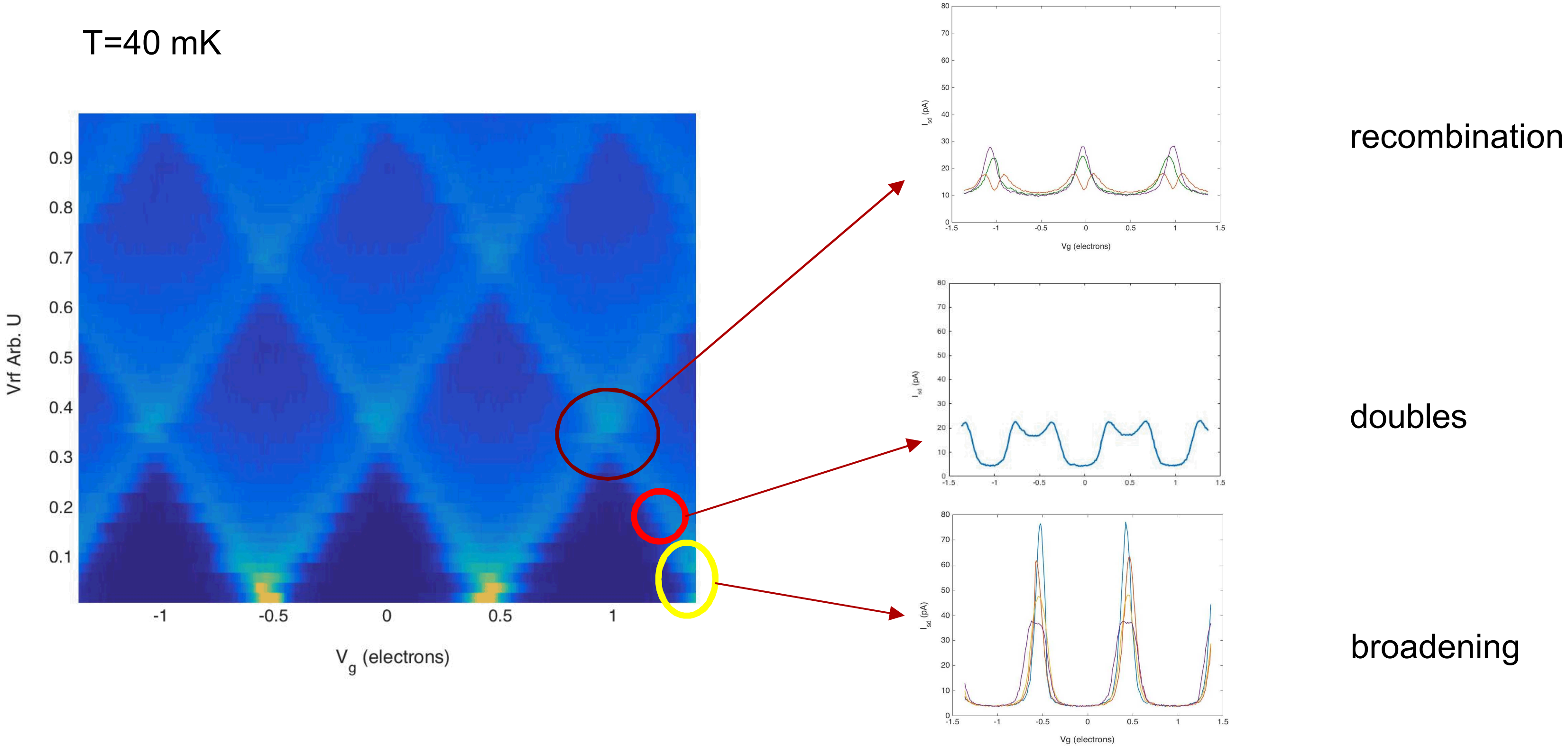
2.8 mV steps

0 mv

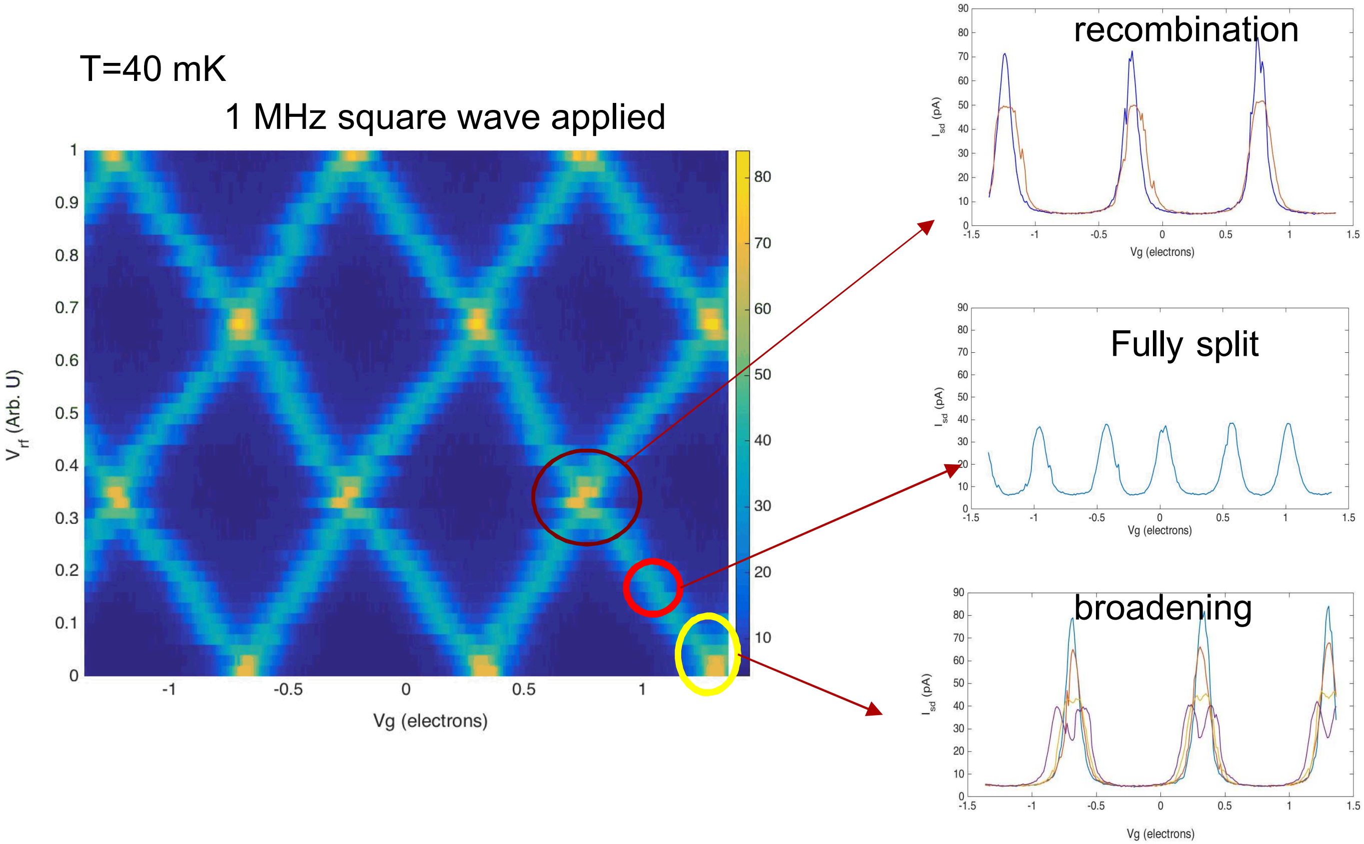


Fortunately, there was a ground loop

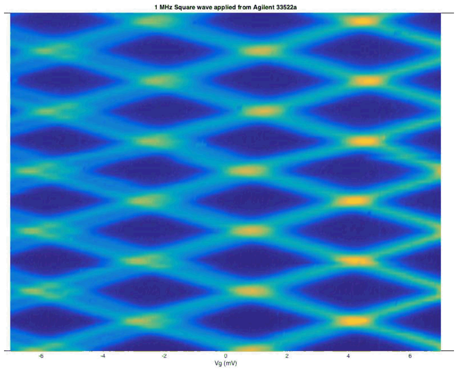
Driving the SET with a 1 MHz sine wave shows broadening and then splitting of peaks



Performing the same experiment with 1 MHz square wave applied

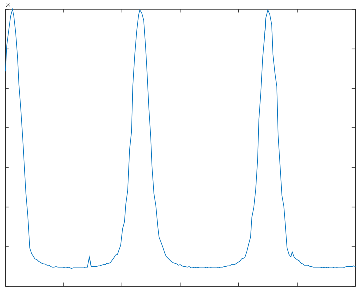


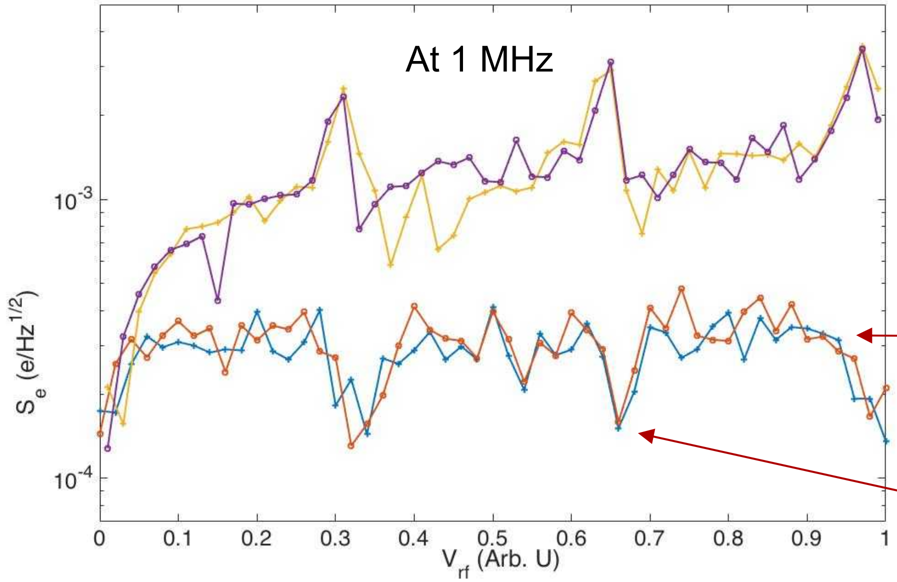
Repeat experiment for V_{rf} > 5 e periods



Charge sensitivity calculated from the previous data…

S_e = Δi/slope /BW





With sinusoid applied

~ 3 x 10^{-4} e/√Hz

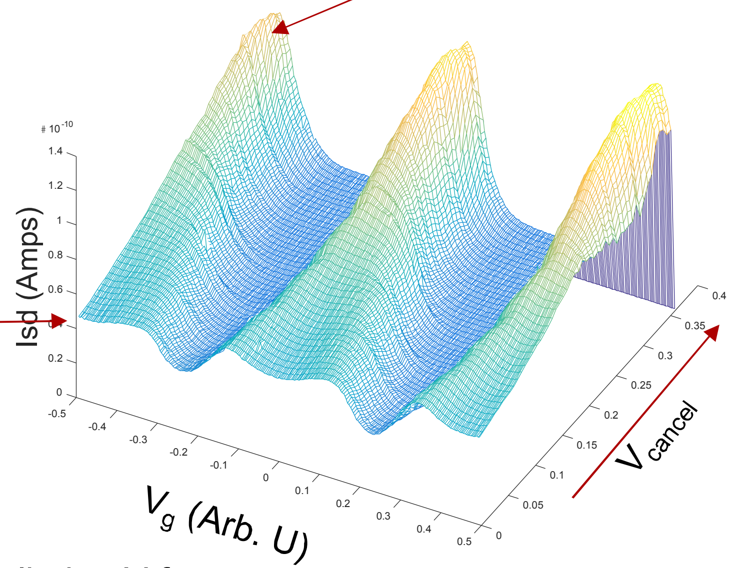
With square wave applied

1.5 x 10^{-4} e/√Hz

Usefulness as a charge sensor doesn't degrade as large signals (V_{rf}) are used!
Same results at f = 50 MHz! (also 100 kHz, 10 MHz, 20 MHz)

Cancellation of (known) sine wave interference at 1 MHz

cancellation achieved



Interference on, no cancellation
(rf is close to e/3 in amplitude)

Sinusoidal interference signal at 1 MHz applied to Vrf
Cancellation signal applied to Vg +Vdc

Conclusions

- SET maintains charge sensitivity in the presence of large rf signals
- Demonstrated this up to 50 MHz and ~10 e periods
- Since $f_{int} << f_c$, SET responds nearly instantaneously to rf
- Known rf interference can be cancelled ($f_{int} << f_c$)