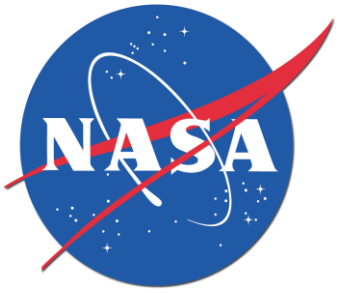


Ultrasensitive Graphene THz Photon Detectors

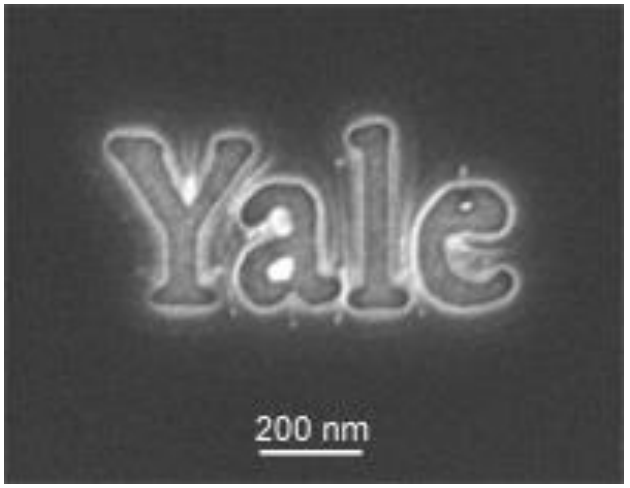
D. Prober, Yale Univ. Depts. Applied Physics and Physics

with thanks for collaborators and Yale colleagues

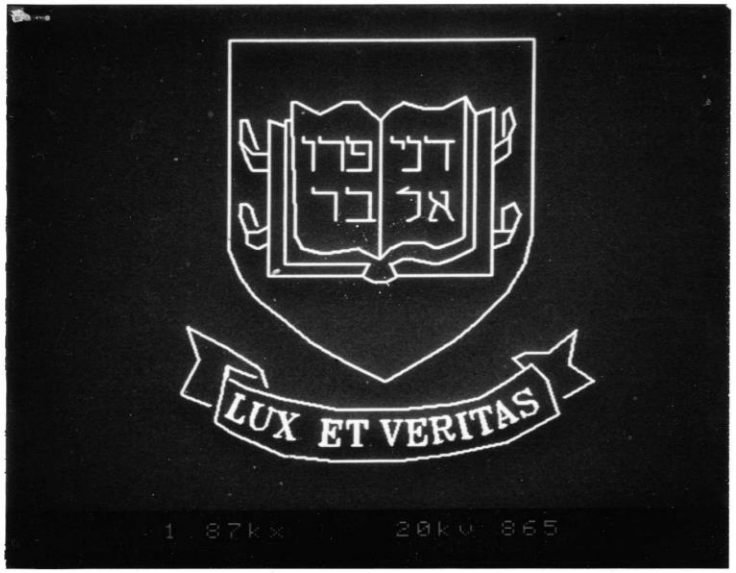


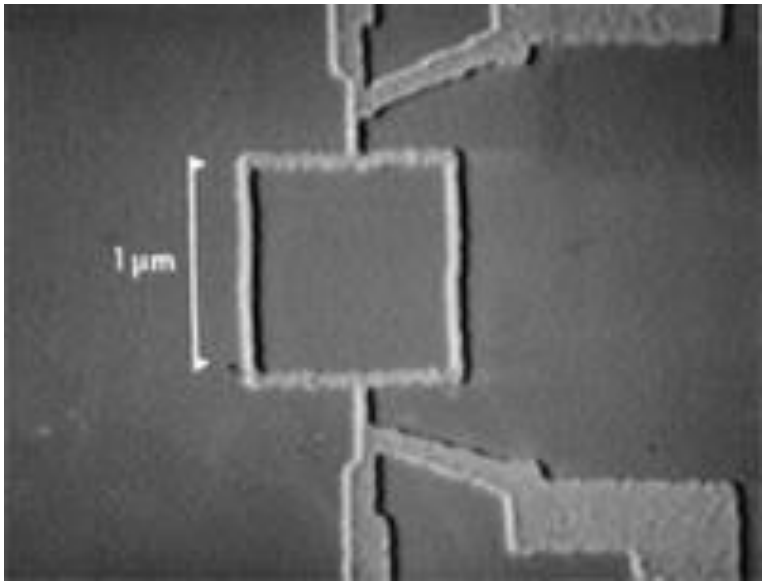


Outline



- Detectors in general
- Astronomy applications + others
- Graphene measurements, detector projections



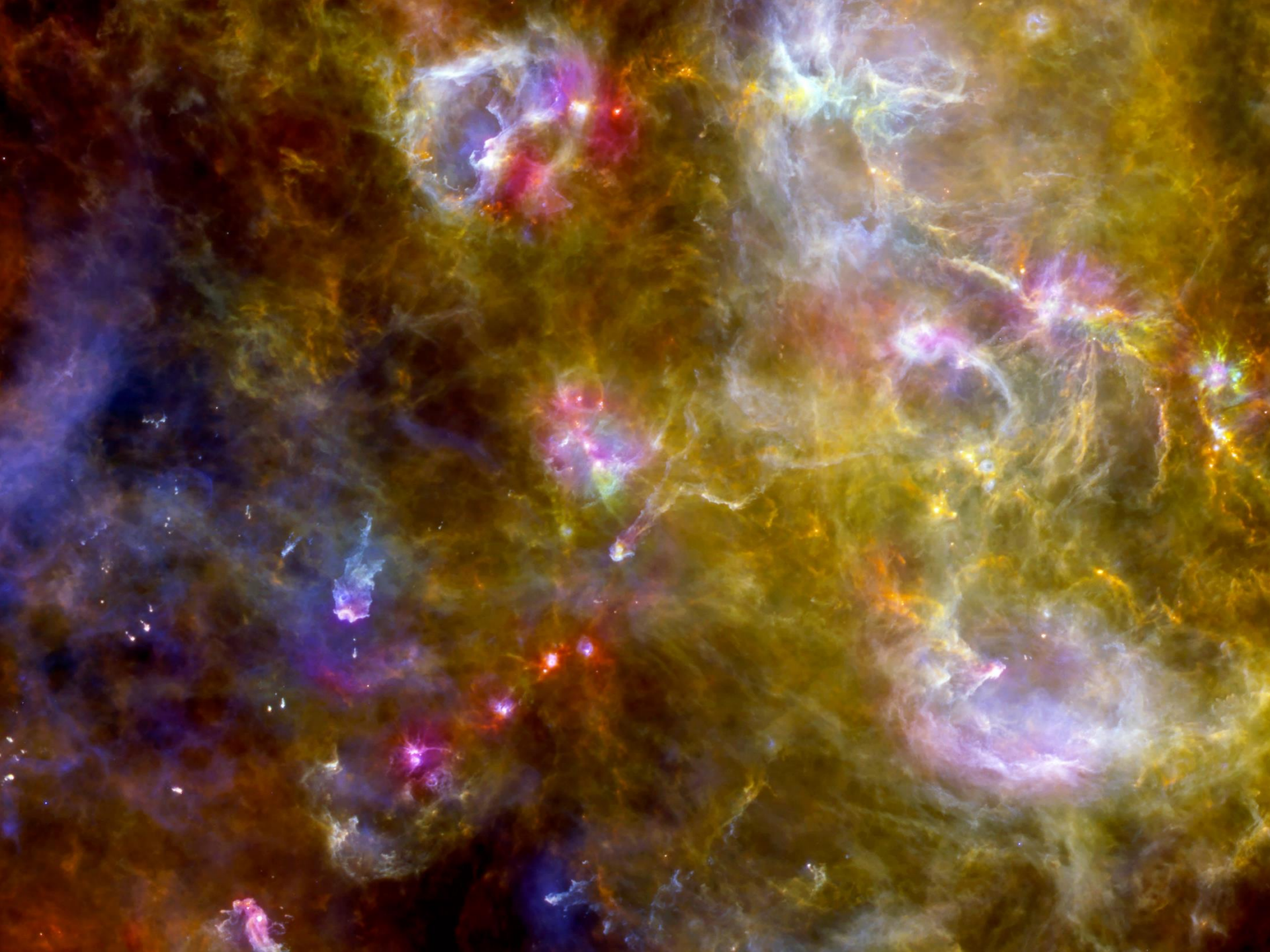




Acknowledgements

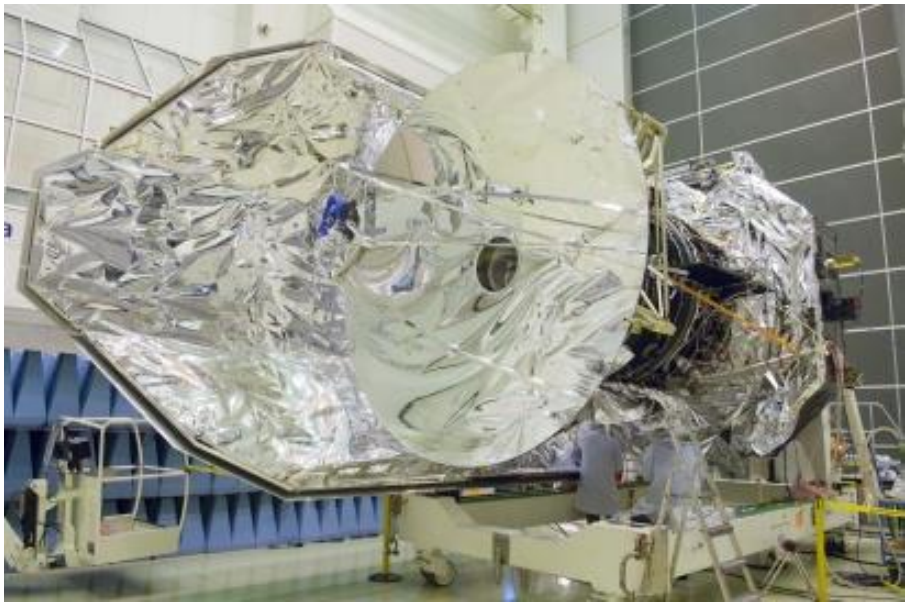
- *Spectroscopy demo*



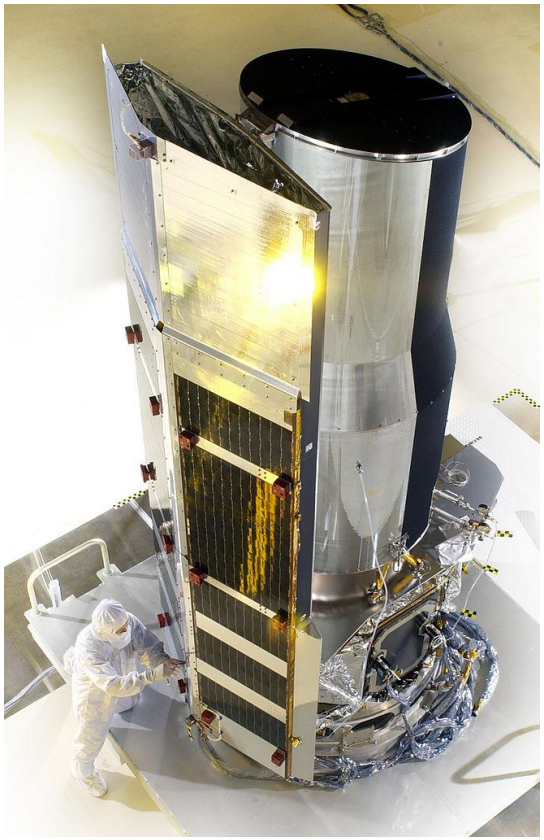


Terahertz: the next steps

Terahertz $\equiv 10^{12}$ Hz , $\lambda = 300$ μm



Herschel Space Observatory

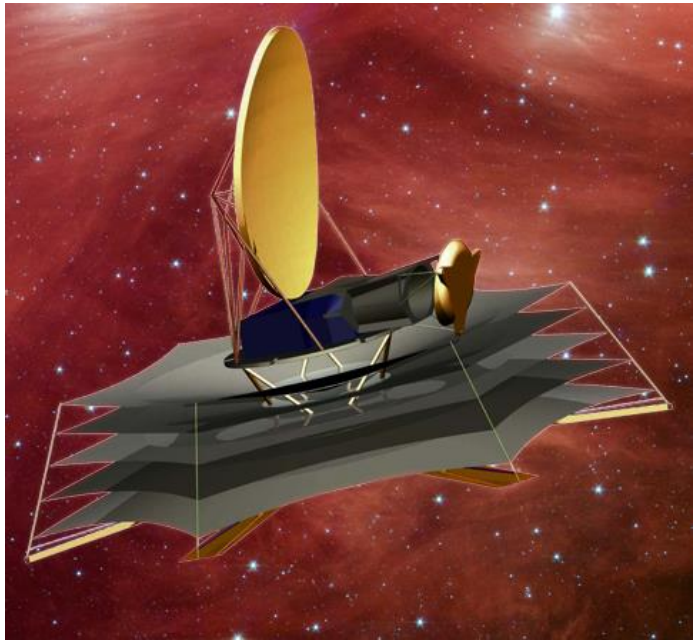


Spitzer Space Telescope

Outline

- Graphene as a photon detector
- Performance predictions
- Microwave measurements of graphene
- Detector outlook

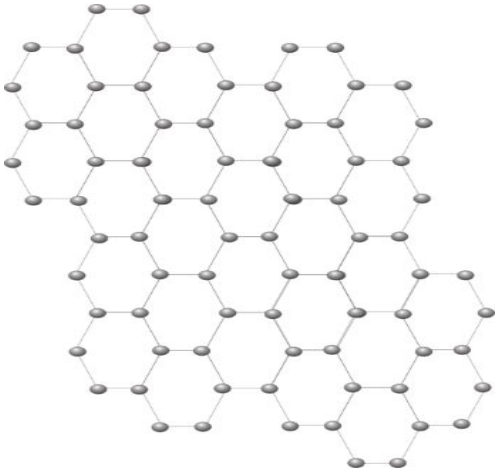
Use our microwave (and THz) expertise + past physics studies



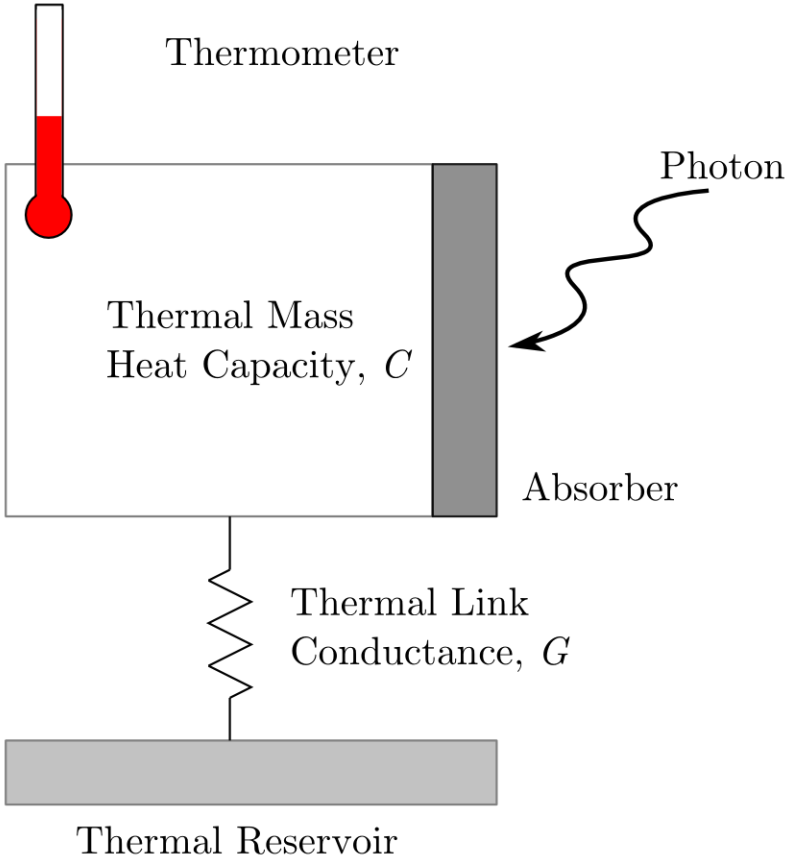
SAFIR

Graphene Photon Detection

- Tiny heat capacity, large ΔT predicted for THz single photon (BUT consider if non-linear)
- Early measurements of thermal conductivity suggested promise
- Claims of device performance



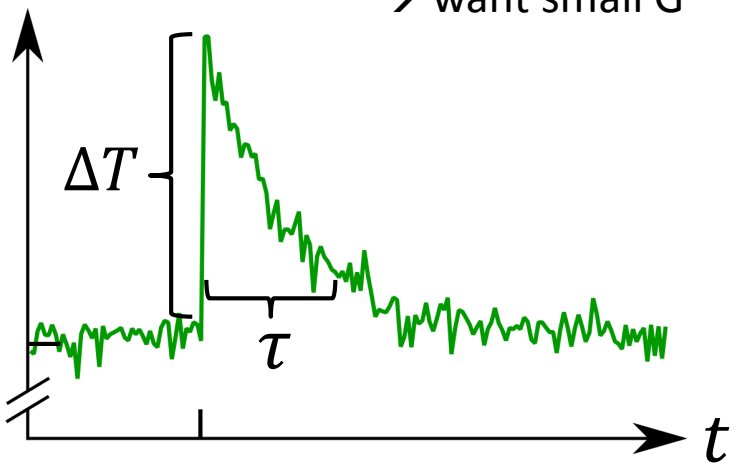
Hot electron bolometer/calorimeter



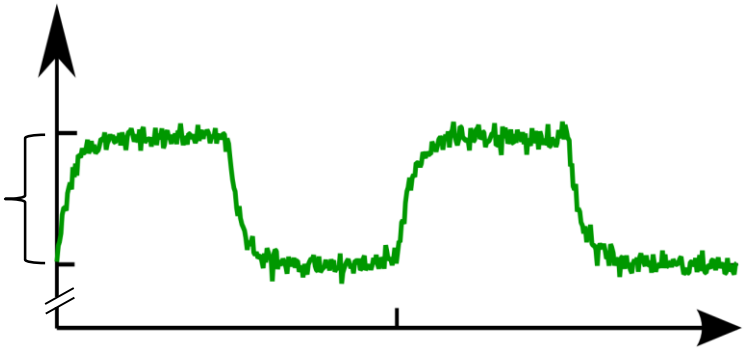
(wikipedia; Google images)

$\Delta T \approx E/C$ $\tau = C/G$

→ want small G

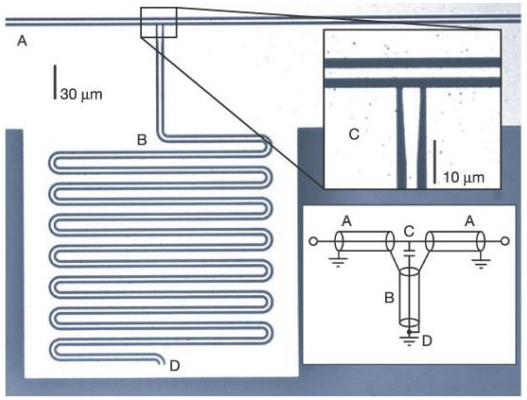


$\Delta T = \frac{P}{G}$

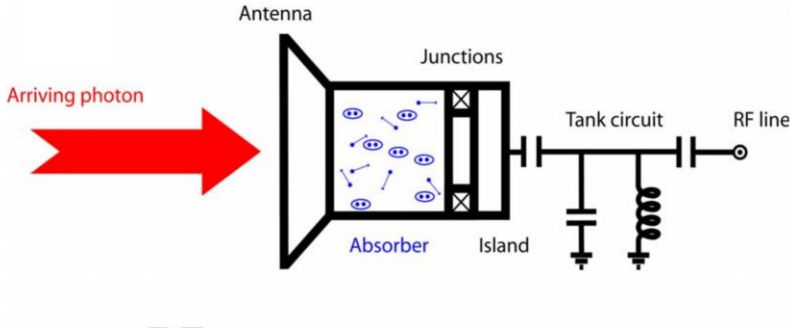


Terahertz photon detectors

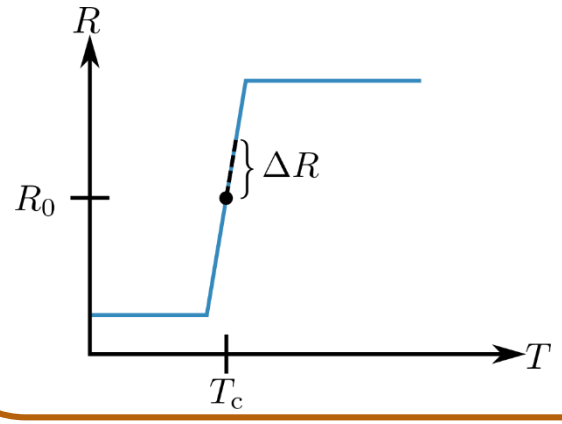
Kinetic Inductance Detector (KID)

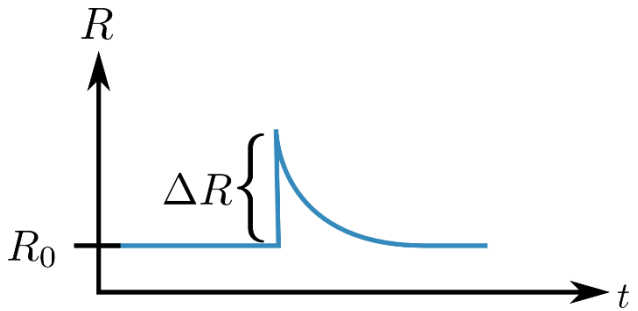


Quantum Capacitance Detector

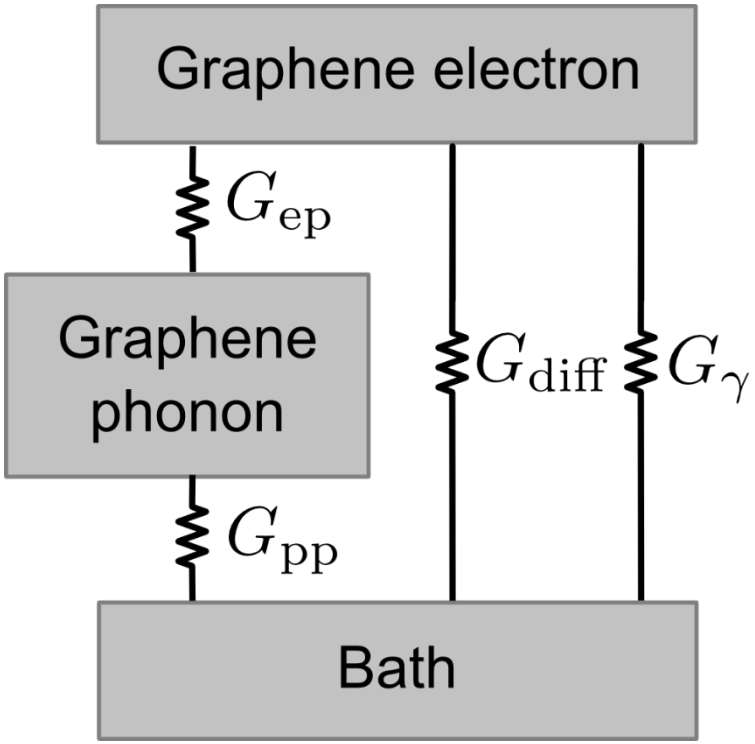


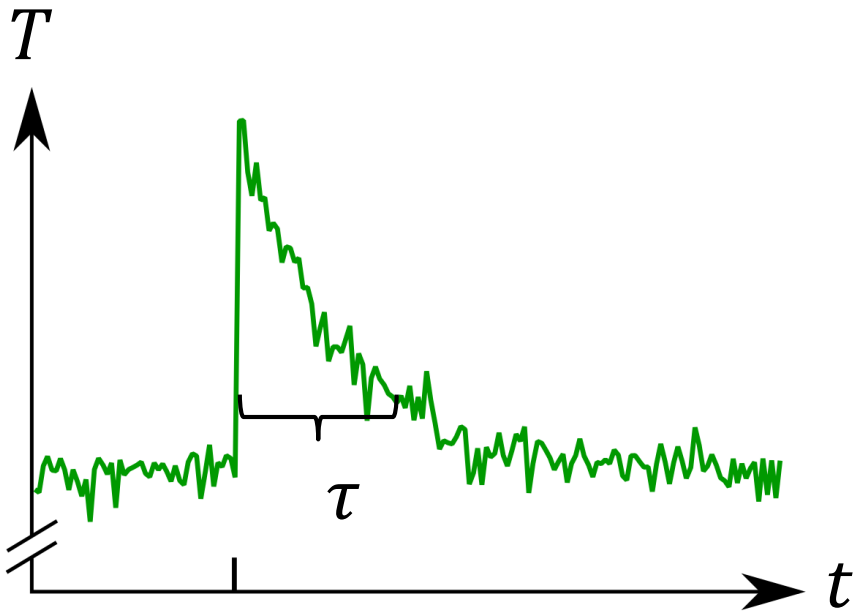
Transition-Edge Sensor (TES)





Energy relaxation





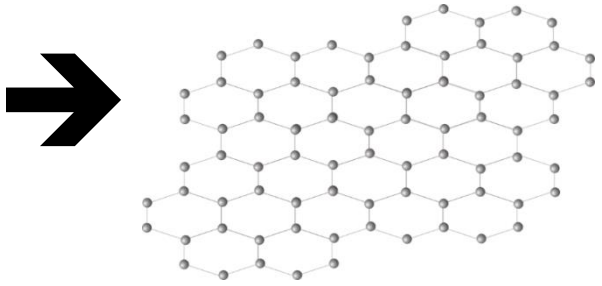
Want small G

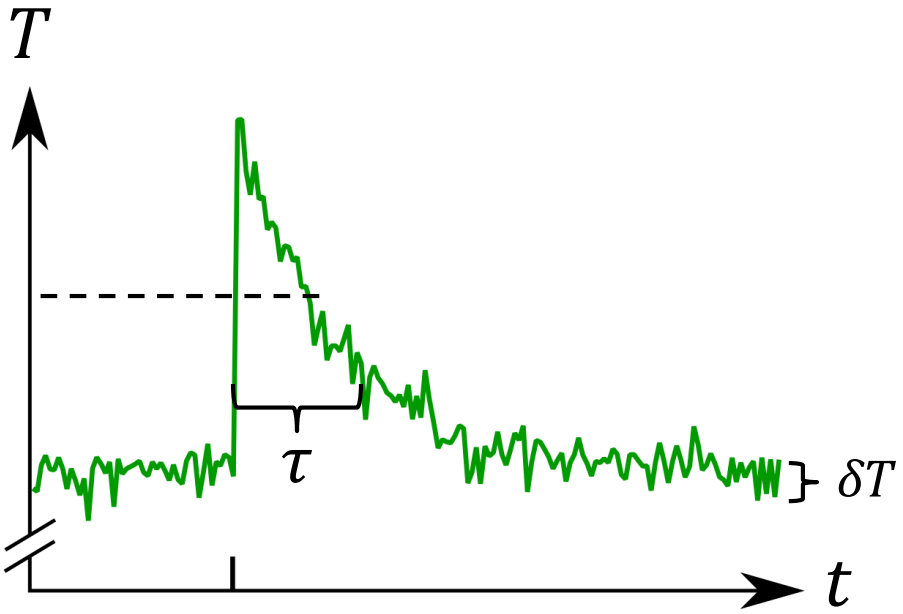
$$\tau = \frac{C}{G}$$

G_{photon} = kB at low frequency

Graphene as a photon detector

far-IR photons



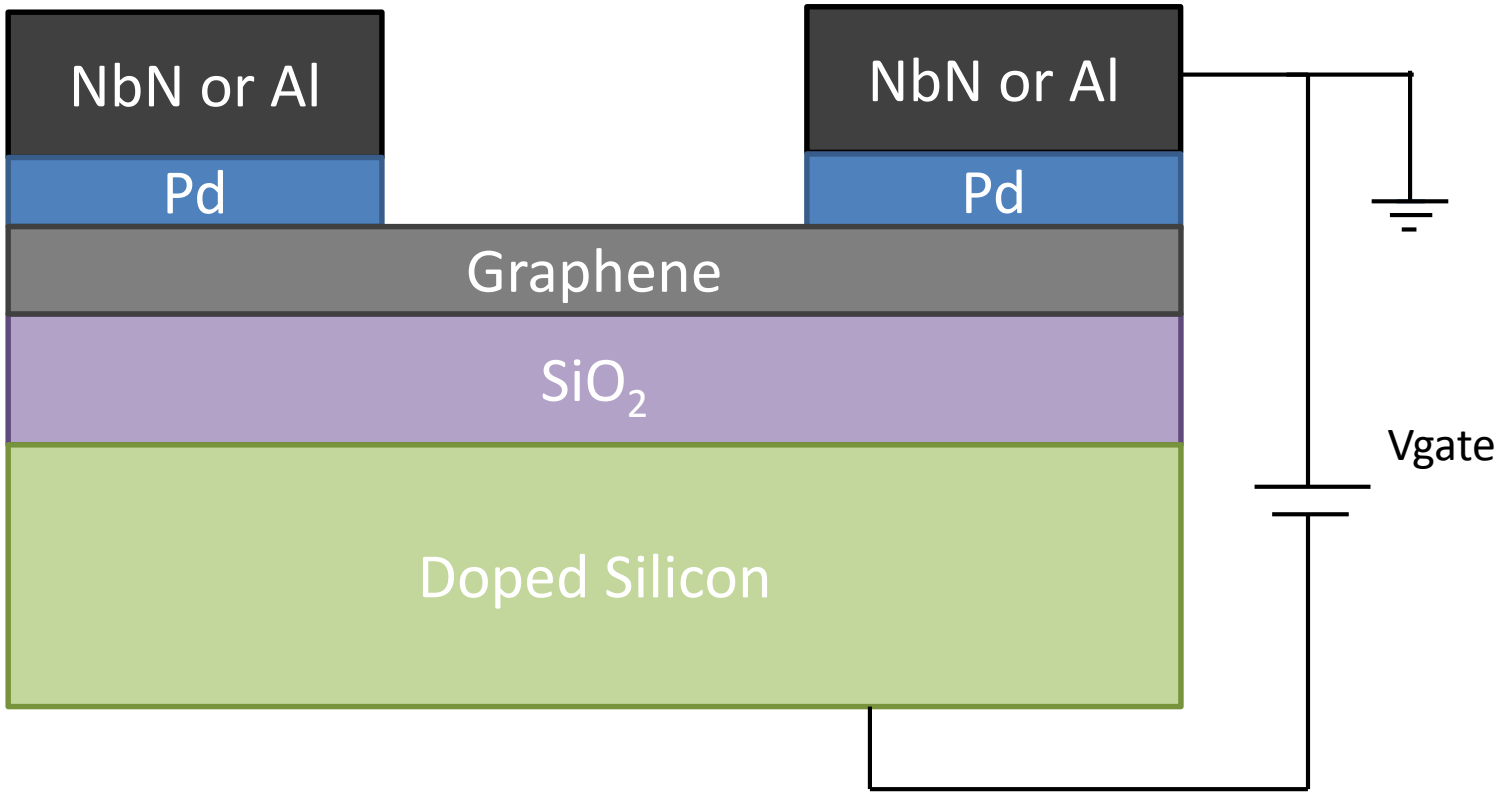


Johnson noise readout – want large ΔT

(for achievable parameters)

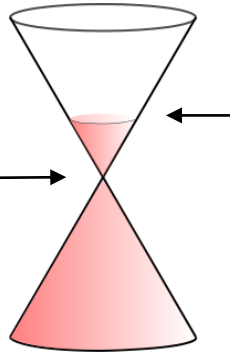
R = resolving power ≈ $\Delta T_{avg/} / \delta T$

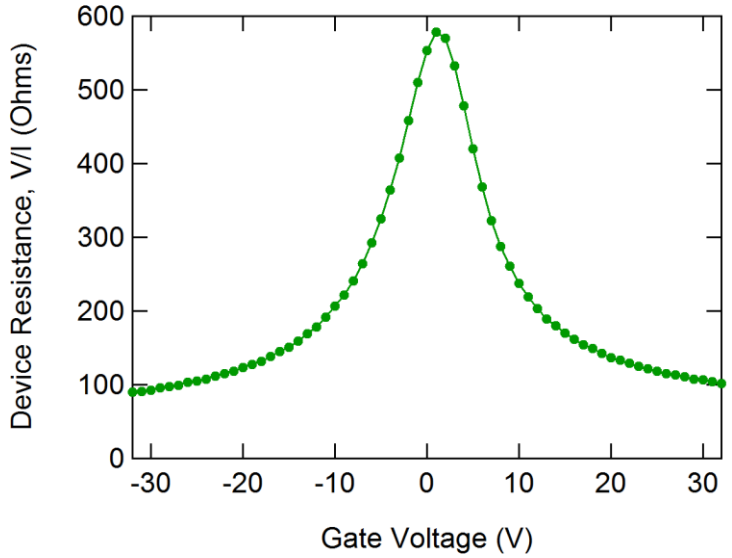
Graphene devices – expts. to find Σ, D

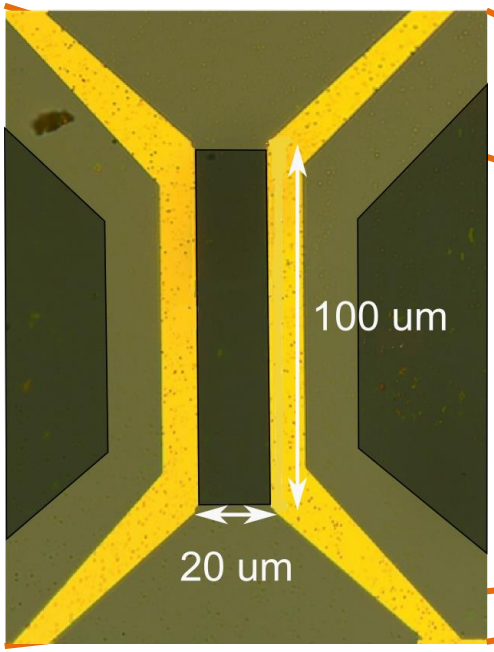


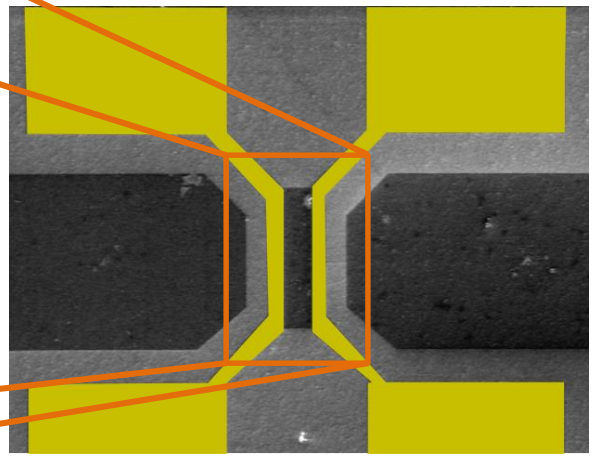
Graphene device

Charge Neutrality Point (CNP) (1 V)





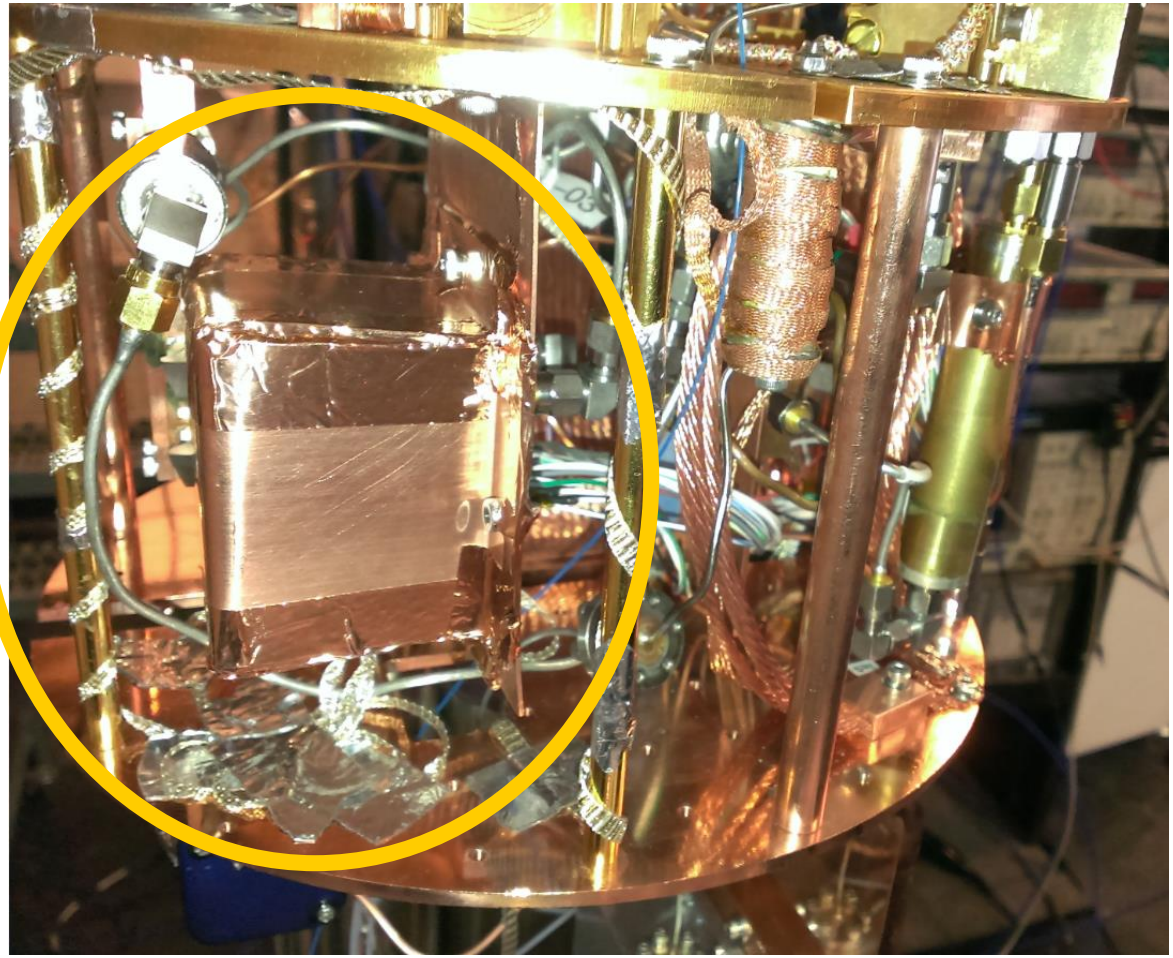




Measurement setup

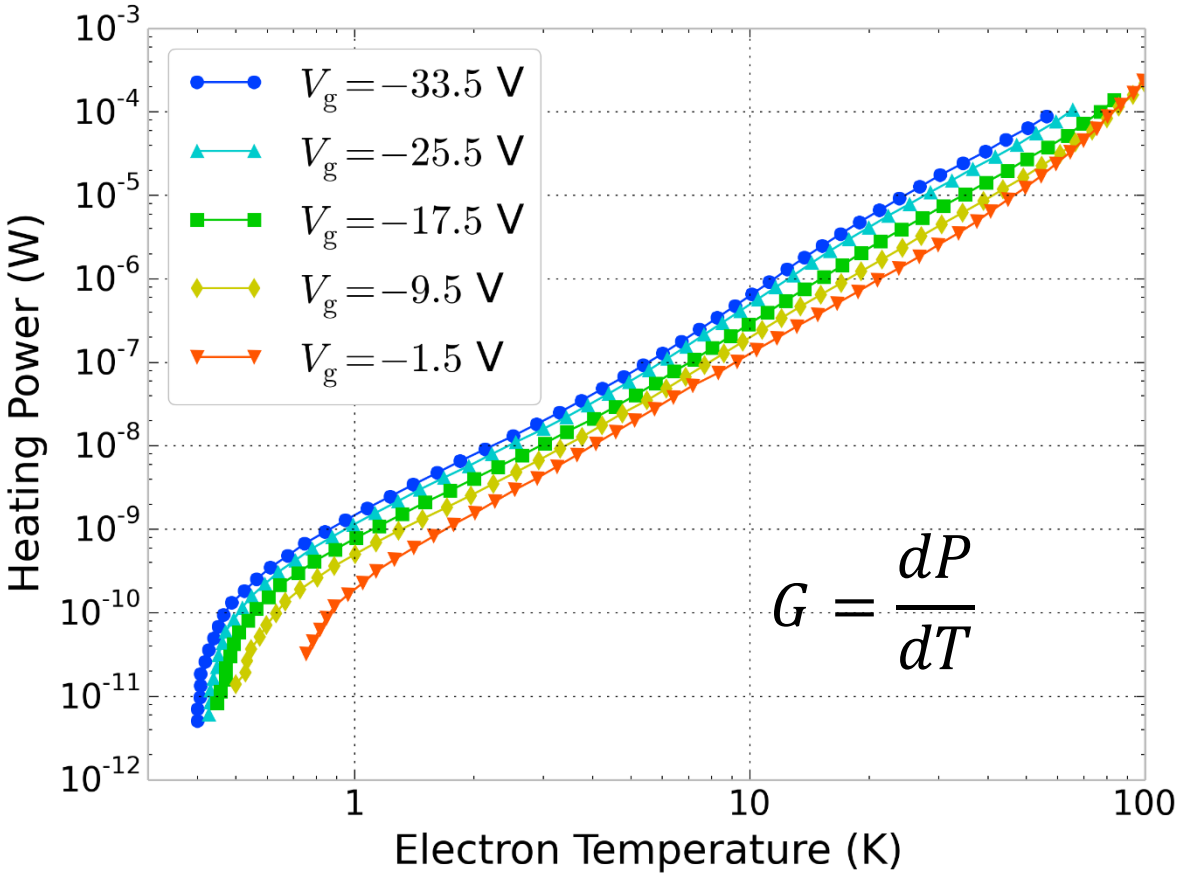


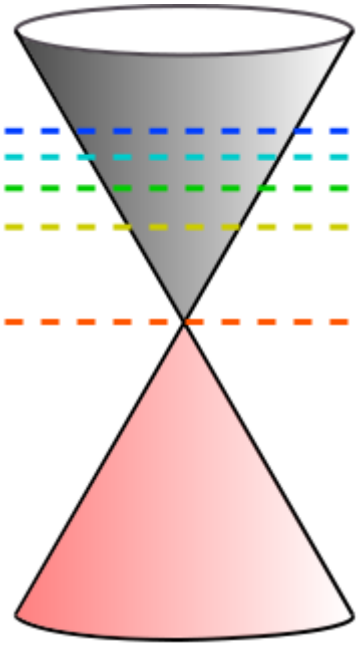
Measurement setup-dry dil. fridge



Noise measurements: 10 μm device (Lg)

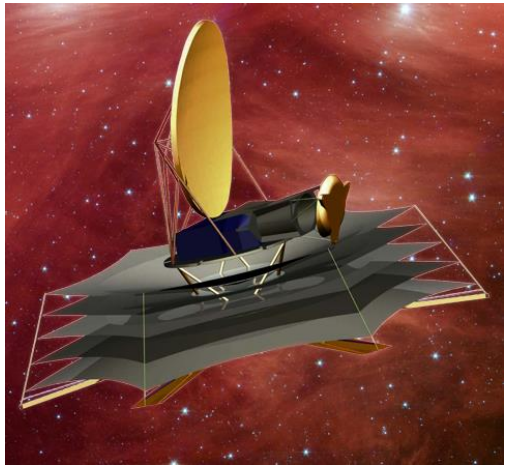
G = dP/dT Measure T with Johnson noise





Summary

- G_{ep} well described by theory at low T
- Single-photon – need smaller G
- Power detection ≈ good
- Careful measurements hard, but very useful
- Need SC contact confinement-materials development



Thanks again to
Xu D
Leonid Glazman
Robert Schoelkopf
Charlie Schmuttenamer
Michael Hatridge
Zaki Leghtas
Steven Touzard
Michel Devoret
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- International Conference and Exhibition on Mesoscopic and Condensed Matter Physics 22-24 June, 2015 Boston, USA