Heat Capacity and Thermal Conductance Measurements of a Superconducting/Normal Mixed State by Detection of Single 3 eV Photons in a Magnetic Penetration Thermometer


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**MPT operation**
- A persistent current is trapped in the bias circuit above the Tc of aluminum wirebonds that connect each sensor to its associated SQUID.
- As we cool or warm through the MoAu sensor's superconducting transition, the inductance of the meander changes as the MoAu film expands or allows entry of flux, and we measure a current proportional to the sensor's magnetic response.
- MPTs give us a unique avenue to probe superconducting effects in MoAu films.

**C and G Measurements**

1. Using 3-eV photons from a Blu-ray diode
   - An example data set at 1001 uA and 100 mK (photons number resolved)
   - 405 nm (3.08 eV) photons from a Blu-ray diode outside the cryostat
   - Photon pulse width: 0.7 us, repetition rate: 70 Hz
   - 10,000 triggered records at each T
   - $C = \frac{E_i}{\Delta T/\Delta N} = \frac{E_f}{\Delta T/\Delta N}$
   - $G = C/\tau$
   - Still able to calculate dI/dV and h

2. Noise spectra measurement
   - Measured C and G using 3-eV photon data only (left) and together with noise spectrum data (right)
   - The two methods share the same dI/dV and τ values

**Theory**

1. Free-energy difference between superconducting and normal states of MPT
   - $\Delta F = \frac{1}{2} \int_0^{T_c} \left( C_n(T) - C_s(T) \right) \frac{d^2F}{dI^2} dT$
   - $C_n(T) = C(T) - G(T)$

2. Heat capacity from second derivative of free energy
   - $C(T) = \int \frac{d^2F}{dI^2} dT$

3. Thermal conductance: quasiparticle recombination & electron-phonon cooling
   - In superconducting regions, recombination of quasiparticles into Cooper pairs should be dominant cooling mechanism.
   - In normal regions, quasiparticles cool by only phonon emission.
   - We estimated Kapitza's $\kappa$ and Wellstood's $\Delta$ from the electronic and mechanical parameters for Mo and Au. A priori values fit δc data within one order of magnitude.
   - Fit results: $\kappa_s = 0.02, \chi_s = 2.1 \times 10^{10} W/(m^2K)$

**Conclusions**

- We measured the variation in heat capacity and thermal conductance of a molybdenum-gold Magnetic Penetration Thermometer (MPT) near its field dependent Meissner transition temperature.
- We did this by two methods: detection of pulses in response to absorption of one or more 3 eV photons, and equilibrium noise measurements.
- Observed C & G show peaks in approximate agreement with a Ginzburg-Landau model of the superconducting intermediate state of an MPT.

**References**