Cooper pair splitter realized in a two-quantum-dot Y-junction

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Punchlines:

1. Constructed an EPR pair generator and tunable splitter in condensed matter system

2. Split pair and measure nonlocal correlations

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Tony
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Idea

- Cooper pair = two particles with entangled states
- Separate particles
- If states remain entangled, they have nonlocal properties
  - measure the state of one, project the state of the other (…correlations)
Device

- (Cooper pair) *source = Al*
  - 150nm wide
  - in situ Ar sputtering removes native oxide layer
- *splitter = InAs nanowire*
  - ~90nm dia \(\times\) >1.5\(\mu\)m length
  - two QDs formed by individual top gates, 100nm wide
- *drain = metallic leads to ground*
  - 300nm wide
  - in situ Ar sputtering…
Measurement Conditions

- $T_{\text{fridge}} = 20\text{mK}$
- Filtering:
  - room temp filters $\rightarrow$ pi
  - low temp filters $\rightarrow$ tapeworm
- $V_{\text{SD}} \rightarrow$ ac + dc
  - $V_{\text{dc}} \sim \text{mV}$ for QD characterization
  - $V_{\text{dc}} = 0$ for nonlocal measurements
  - $5 < V_{\text{ac}} < 10\mu\text{V}$
  - $127 < f < 600\text{Hz}$
Measurements

- $\frac{dI_1}{dV_{SD}}$ vs. $V_{g1}$
  - Coulomb diamonds
  - suppressed electron density of states in the SC gap

- Go to one point (yellow dot) and look for correlations between $G_1$ and $G_2$…
(Nonlocal) Measurements

- $G_1$ vs. $V_{g2}$
  - gate 2 is coupled to QD1 (~1000 times weaker than to QD2)
    $\rightarrow$ linear background
  - averaged 143 (black) traces
    $\rightarrow$ one (red) trace
- $\Delta G_1$ & $G_2$ vs. $V_{g2}$
  - definite correlation exists
(Nonlocal) Measurements

- $\Delta G_1 \& G_2$ vs. $V_{g2}$
  - “imperfect” because of finite $R_W$ of source lead

- Al...
  - normal vs. superconducting

- Next step: tune* the splitter...
(Nonlocal) Measurements

• $\Delta G_1$ & $G_2$ for varying $V_{g1}$
  – pos/neg crossover approaching CB resonance
  – size of $\Delta G_1$ “too large”

• efficient pair splitting predicted off resonance (well-defined #elec)

• $\Delta G_1 \sim \alpha T_1^2 + p(\delta r)T_1T_2$
  • perhaps due to $\delta r, k_F$
(Nonlocal) Measurements

- Temperature dependence of $\Delta G_1$
  - nonlocal conductance disappears near 200mK ($\ll$ SC gap)

- apparently not controlled by bulk gap alone
Conclusions

• Tunable EPR pair splitter achieved experimentally in two-quantum-dot / superconductor Y-junction
• Pair splitting efficiency of $\sim 2\%$ is much greater than for entangled photon pairs ($\sim 10^{-12}$)
• First step toward demonstration of EPR paradox in a solid state system