Superconducting devices based on coherent operation of Josephson junction arrays above 77K

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Outline

• SQUID-arrays @ 77 K better than single-SQUID @ 4.2 K

• First flux-flow microwave generators @ 77K

• Josephson vortex-flow transistors with record amplification @ 77K

• reversible flux-flow ratchets
SQUID-arrays @ 77 K better than single-SQUID @ 4.2 K
B. Chesca, American Institute of Physics, press release October 2015:
https://publishing.aip.org/publishing/journal-highlights/hot-new-development-ultracold-magnetic-sensors

\[ \text{Noise}_{\text{Array}} = N^{1/2} \text{Noise}_{\text{SQUID}} \]
\[ V_{\text{Array}} = N \times V_{\text{SQUID}} \]

flux coherent & non-interacting SQUID array
$V_{\text{Array}} = N \cdot V_{\text{SQUID}}$, small arrays (N=10)

Chiu-Hsien Wu et al, J. Appl. Phys. 100, 064510 (2006);
$V_{\text{Array}} = N V_{\text{SQUID}}$, small arrays ($N=10$)

$V_{\text{Array}} = N V_{\text{SQUID}}$ true for 10 SQUIDs but SQUIDs are too large; this design is not suitable for large $N$!

Large SQUID arrays ($N=484, 770$)


SQUID arrays @ 77K better than SQUIDs @ 4.2 K

First flux-flow microwave generators @ 77K
10x10 JJ array as tunable microwave generators @ 4.2K
53-230 GHz

FIG. 1. (a) Photograph of a 10×10 array (left) coupled to a fin-line antenna (right), and (b) I-V curve of a 10×10 array without (1), and with (2) the antenna. The latter is displaced by 1 mV. Some of the resonance bands b are indicated with arrows.

Flux-flow resonances in asymmetric 440 JJ arrays

*B*-field tunable power of about 0.1 µW within the range (1.5-25) GHz @ 77K

\[ P = 0.5 \left( I \times I_{\text{step}} / I_c \right)^2 R_N / N \]

Flux-flow resonances in asymmetric 440 JJ arrays

Array of 22 x 20 JJ
T=84 K
IVCs: 1-16

Josephson vortex-flow transistors (JVFT) with record amplification @ 77K
Previous JVFT designs: asymmetrical bias current

Small symmetrical arrays (6JJ), maximum current amplification @ 77K: 3.5

Anomalous flux-flow in large asymmetric arrays

Large asymmetrical arrays (440 JJ) maximum current amplification @ 77K: 19

Parallel array of 22 x 20 JJ
T=77K

$g_{\text{max}} = 0.28 \text{mA}/15 \mu\text{A} = 19$

Current amplification in large asymmetric arrays

Reversible flux-flow ratchets
Which ratchet?

\[ \eta = \left| \frac{V(I)+V(-I)}{V(I)-V(-I)} \right| \times 100\% \]

Reversible flux-flow ratchets

Conclusions

- Remarkable performances shown by very large arrays-based devices @ 77K
  series arrays: magnetometers
  asymmetric parallel arrays: flux-flow microwave generators
  transistors
  reversible ratchets

- Great potential
  to replace single-JJ or single-SQUID based devices @ 4.2K
  performance can be further improved by optimization