Interaction between flux-flow and phonon resonances in small Bi-2212 mesa structures

S.O. Katterwe, A. Rydh and V.M. Krasnov
Experimental Condensed Matter Physics Group, Department of Physics, Stockholm University, AlbaNova University Center, SE-10691 Stockholm, Sweden

Characterization in zero field:

Bi(Pb)SrCaCu$_2$O$_{8+x}$ mesa with $T_c=91$ K, size 1.9 x 1.4 µm$^2$ and with $N = 25$ intrinsic Josephson junctions in the stack (determined from the number of quasiparticle branches). The current voltage characteristic is measured at $T=1.6$ K.

![Image of current-voltage characteristic](Image)

Characterization in parallel magnetic fields:

Appearance of a flux-flow branch with a flux-flow (velocity matching) step at $V_{FFS}=HN_{FFS}c_s$.

$N_{FFS}$: number of junctions in flux-flow state ($N_{FFS}$)

$x$ : interlayer spacing in Bi-2212 (15 Å)

$c_s$ : velocity of electromagnetic waves inside the junctions

In the flux-flow state, the quasiparticle-branch separation is reduced according to $\Delta V_{QP} = H_{FFS} c_s / V_{FFS}$.

$V_{FFS}$ : voltage per junction in the quasiparticle state

$V_{FF}(H)$ : voltage per junction at the flux-flow step

From the branch separation, the flux-flow voltage per junction can be determined ($\Delta V_{QP} = 0.65$ mV/T).

Flux-flow branch in magnetic fields up to 17 T:

$V_{FFS}(H)$ is linear up to $10$ T, ($V_{FFS}(H)=11.0$ mV/T) and saturates at high fields.

From $V_{FFS}(H)$ and $V_{FF}(H)$, the number of junctions in the flux-flow state is determined:

$N_{FFS} = \frac{V_{FFS}}{V_{FFS}(H)} = 17 \times c_s = 4.3 \times 10^9$ m/s

Phonon resonances in zero field:

On the quasiparticle branches, phonon resonances are clearly seen at voltages $V_{QP}$. Phonon frequencies are calculated from the AC-Josephson relation $f=\Phi_0/2\pi$.

<table>
<thead>
<tr>
<th>$V_1$ (mV)</th>
<th>$V_2$ (mV)</th>
<th>$V_3$ (mV)</th>
<th>$V_4$ (mV)</th>
<th>$V_5$ (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1</td>
<td>7.9</td>
<td>11.2</td>
<td>14.5</td>
<td>20.5</td>
</tr>
<tr>
<td>(2.9 THz)</td>
<td>(3.8 THz)</td>
<td>(5.4 THz)</td>
<td>(7.6 THz)</td>
<td>(9.8 THz)</td>
</tr>
</tbody>
</table>

Voltage positions of the phonon resonances are temperature independent (the first quasiparticle branch is shown in the figure):

![Image of voltage positions of phonon resonances](Image)

Conclusions

- The quasiparticle-branch separation is reduced in the flux-flow state. From the separation of the branches, the flux flow voltage per junction can be determined.

- An interaction between flux-flow and phonons is observed. The interaction may be due to the change of the velocity of electromagnetic waves inside the junctions near voltages corresponding to phonon resonances.

- The phonon resonances shift to higher voltages in magnetic fields.

- Resonant phenomena may be important for the use of intrinsic Josephson junction as THz oscillators due to the decreased linewidth of emitted radiation when biasing the junctions near a resonance.