2D SQIF arrays using 20,000 YBCO high Rn Josephson junctions, a viewpoint

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2D SQIF arrays using 20,000 YBCO high RN Josephson junctions, a viewpoint.

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Since the pioneering research reported in [1-3] in the early 1990's there has been considerable interest in the development of electronic devices based on large number N SQUID-arrays made of low temperature superconductors (LTS) and operating coherently at 4.2 K or below. Such SQUID-array-based devices are very attractive in many applications: magnetic sensors, analog-to-digital converters, low-noise amplifiers, antennas, etc. This is because in SQUID-arrays the output signal ΔV/sensitivity linearly scales with N, their dynamic range increases as $N^{1/2}$, whereas noise decreases as $1/N^{1/2}$. Consequently, not only the noise properties of an N SQUID-array-based device are superior to a single-SQUID-based device but a much larger ΔV means their matching for room temperature readout is greatly simplified. Moreover, SQUID-arrays have the potential of also improving the bandwidth and the impedance matching as their impedance is significantly larger than that of a single-SQUID device. However, since cooling down to 4.2 K is both expensive and often impractical applications of LTS-SQUID-arrays have been limited. Increasing the operation temperature to 77K by implementing high temperature superconductors (HTS) would be the obvious choice since cooling down to 77K is both cheap and easy to handle. However, so far this has not been the case mainly due to two reasons: for almost 3 decades now HTS-SQUID-arrays were significantly inferior in comparison to their LTS counterparts, as far as, both array fabrication technology and their performances are concerned. Several recent very significant developments in both these areas may change all that. Here I will focus my attention on two such examples in the field of superconducting quantum magnetic filters (SQIF) and SQUID-array-based magnetic sensors/amplifiers.

SQIFs. Extraordinary progress has been reported in the area of step-edge junction technology [4, 5] that offers the advantage of using low cost MgO substrates and the flexibility of implementing complex 2D large array configurations involving many tens of thousands of SQUIDs. Based on this technology a SQIF field sensitivity of 1530 V/T for 20000 Josephson junctions was demonstrated with an RF response unambiguously detected at 30 MHz for the first time at 77K [5]. It is important to notice that this remarkable field sensitivity has been reached without any flux transformers/flux focusers usually implemented to enhance the SQIF's field sensitivity. So far, the best field sensitivity has been reached in SQIFs fabricated in the bicrystal technology. Thus a sensitivity of 8400 V/T has been reached with a 95 SQUID loops in series by implementing a flux-transformer in the flip-chip configuration with their SQIF [6]. In another example a sensitivity of 3500 V/T has been reached with a SQIF consisting of 100 SQUID loops by implementing large flux-focusers to increase their sensitivity [7]. These latest two examples are SQIFs implementations in a virtually 1D technology due to the single bicrystal line used and therefore this technology lacks the flexibility of the 2D step-edge junction technology. However, SQUIDs have been fabricated along 3 different directions in a tri-crystal configuration [8] and therefore M multi-crystal technology (with M= 4, 5, …) is potentially an interesting direction to explore in the future in order to gain a similar 2D flexibility required for the implementation of complex SQUID-array architectures. Another interesting direction of investigation is the implementation of flux-focusers/flux transformers for SQIFs/SQUIDs fabricated in the step-edge junction technology (that already possesses a 2D flexibility) in order to investigate to which extent their sensitivity would benefit/can be enhanced.

SQUID-array-based magnetic sensors/amplifiers. Magnetic sensors fabricated based on the implementation of large 2D-SQUID-arrays using the step-edge junction technology is also very encouraging. In [5] multiple SQUID-oscillations with peak-to-peak values of up to ΔV = 0.25 mV have been observed for the largest ever made hybrid series-parallel SQUID-array consisting of 20000 junctions. Preliminary results showed an increased sensitivity of 165 V/T compared to that of a single HTS-SQUID. However, a dramatic improvement is expected in their performances as soon as their 2D-design flexibility would be exploited in more advanced architectures. In particular, again, it would be very interesting to see how the performance of these 2D SQUID-array sensors can be improved by implementing flux focusers. Indeed, SQUID-arrays build in the bicrystal technology and benefiting from large area narrow flux focusers showed record SQUID oscillations as large as ΔV=10.1 mV and ΔV=17 mV obtained with 770 series SQUID arrays at 77K and 484 series SQUID-arrays at 40K, respectively [9]. These values are 500-1000 times larger than for single-SQUID devices. Such large values for ΔV allow a direct connection of the SQUID-arrays to a low-noise room temperature amplifier, while matching for such a room temperature readout is simplified due to their large impedances in the range (0.3-2.5)kΩ. The white flux-noise performances of these SQUID-arrays in the temperature range (40-83)K are much better than single optimized HTS-SQUIDs operating at similar temperatures and even outperformed single LTS-SQUIDs operating at 4.2K [9].

It is remarkable that in both cases [5, 9] a proof of concept of highly sensitive devices (SQIFs, SQUID-arrays magnetic sensors) could be provided without the need of systematic attempts for optimization of their design/technology. This strongly suggests that performances of such devices can be significantly improved offering great promises as a route to realizing high performance superconducting devices based on large arrays of SQUIDs operating at 77K.

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