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VORTICES IN LONG JOSEPHSON JUNCTIONS(U) WISCONSIN
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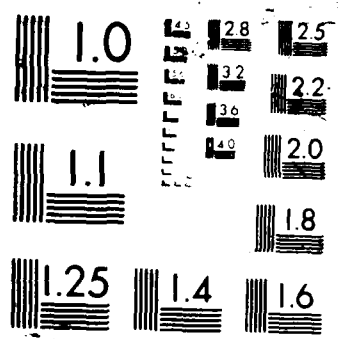
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 entitled
VORTICES IN LONG JOSEPHSON JUNCTIONS
 by
 James E. Nordman and James B. Beyer

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SUMMARY

Research during the second year of this grant extended the studies begun during the first year on fabrication and modeling of long Josephson junction structures. The Nb-Pb technology, although reliable, is not versatile enough for proposed multilayer structures and considerable effort was expended in the development of an all Nb and a parallel all NbN technology. This effort is not over but recently we were able to demonstrate an all NbN vortex flow transistor possessing superior properties to the Nb-Pb version. New progress was made toward solution of the problems of high frequency testing of the very low impedance vortex flow transistor and towards determination of its potential for high frequency applications. It was demonstrated that the device exhibits active behavior in the form of a measurable transresistance out to frequencies of about 10% of the theoretical transit time cutoff frequency. Capability for higher frequency testing was developed with the design of novel new impedance matching structures. A new type of distributed amplifier was also proposed and modeled. Modeling of spatially nonuniform long junction structures is continuing. It was found that inclusion of the superconductor film surface resistance was necessary in order to obtain realistic simulations. The unusual magnetic field dependence we had seen in...



certain Nb-Pb VFT configurations is undergoing study with the design of new double junction NbN devices.

RESEARCH OBJECTIVES

A prime objective of this research is to further the fundamental understanding of fluxons and fluxon motion in long Josephson tunnel junctions through the use of experiment and model development. The need for good experimental data on such structures produced a second important objective, which is to develop a reliable way to fabricate large area junctions in a multilayer technology allowing for a variety of types of probes. A third important objective is to understand the physical mechanisms involved in the various long junction amplifiers and oscillators that have been proposed, including the vortex flow transistor. This has led to the need for development of high frequency testing configurations and techniques.

STATUS OF RESEARCH

A. Modelling

A sine-Gordon simulation program was completed and shows the correct features of fluxon motion on a long junction. In attempting to determine maximum step current values it was determined, contrary to our original assumption, that the power loss in the superconducting films can be more important than the normal tunneling loss. Inclusion of this loss involved an extensive rewrite of the code. At the present time, we are using the model and additional analytical calculations to try to determine the causes of the step fine structure seen on experimental flux flow volt-ampere curves. It will be necessary to control this fine structure in the vortex flow transistor if it is ever used for low noise applications.

B. Fabrication

A prototype all NbN vortex flow transistor has been made and its operation in the vortex flow regime was demonstrated. This device consists of two series-connected overlap long junctions and a separate input control line. The static volt-ampere characteristics of the device show relatively small vortex flow current step amplitudes, large subgap current leakage and significant step fine structure. Work is underway to improve the tunneling barrier to reduce the subgap leakage. The other two problems are being attacked using geometry variations suggested by theory and simulation. The maximum step current is very sensitive to bias current distribution and the fine structure appears to be very sensitive to boundary effects at the junction ends.

One significant reason for making devices with NbN is the fact that the large London penetration depth in this material allows for convenient investigation of the effects of kinetic inductance on device behavior. At this time it appears that kinetic inductance can be used to significantly increase or decrease the amplification of the vortex flow transistor depending on configuration. This will be studied experimentally along with the use of superconducting overlays to alter the spatial distribution of film inductance in the long junction.

Niobium junction and coupling structure fabrication has been enhanced by the incorporation of new sputter guns in our magnetron sputtering system. This has resulted in a significant increase in resistivity ratio for these films and should allow much better high frequency characteristics.

A large effort was made this past year on the design, purchase, debugging and fixturing of a new dual ion beam-magnetron sputter deposition system which we expect to use as the primary tool for Nb and NbN junction fabrication in

the future. A somewhat incomplete system was delivered in late summer and is now ready for experimentation on Nb and NbN.

C. High Frequency Studies

After optimizing the low frequency parameters of the Vortex Flow Transistor (VFT) (paper presented at the 1986 ASC conference), the next step in characterizing the VFT was to investigate its high frequency properties.

A cryogenic system for measuring the radio frequency properties of the VFT was developed. This scheme featured a low crosstalk RF launcher with solderless contacts, a cryogenic cooling system that permitted room temperature access in close proximity to the VFT, and a circuit configuration that allowed vector S-parameter measurements at power levels below -90 dBm.

With this system vector S-parameter measurements of the VFT were made. The measurements were obtained for frequencies up to 100 MHz on VFTs that had a calculated transit time cutoff frequency of 5 GHz. An equivalent circuit model that includes calculations of the VFT transresistance, input inductance, and feedthrough capacitance was derived from these measurements. The measurements shows that the transresistance response of the VFT was nearly independent of frequency as predicted by theory. The flatness of response indicated that the transresistance signal of the VFT is present at higher frequencies. However, large crosstalk levels which were attributed to the low impedance 2-port structure in which the VFT was embedded obscured the signal at higher frequencies.

Next, a unique modulation signal tagging scheme was employed that overcame the low impedance level limitations inherent to the 2-port VFT configuration. This scheme permitted the frequency response of the VFT transresistance to be measured to 500 MHz which is one tenth of the predicted transit time

cutoff frequency. The upper frequency obtained in the measurements was determined by the combination of the low pass frequency characteristics of the input circuit network and the finite frequency line width of the RF input signal. Again, as predicted by theory, the transresistance response of the VFT was nearly independent of frequency. The flatness of response indicates that the transresistance signal of the VFT is present at still higher frequencies. The measured transresistance values show that the VFT is a viable active device for use in RF superconducting electronic systems.

In parallel with the experimental investigation of the VFT, we have begun exploring the theoretical possibilities of the Modified Superconducting Current Injection Transistor (Modified Super CIT). The Modified-Super CIT is based on the principle that the maximum Josephson current of a resistively shunted long junction can be controlled by a magnetic field applied to the junction. The Modified Super-CIT can be modelled as a current controlled current source. Computer simulations have calculated current gains on the order of 6 for a Modified Super-CIT configuration with a transit time cutoff frequency greater than 300 GHz.

Unlike the VFT, the modified Super-CIT's feedthrough capacitance can be absorbed in a distributed amplifier configuration. The result is much lower crosstalk levels. Also, because of the large current gains associated with the Modified Super-CIT, fewer devices are needed in a Modified Super CIT distributed amplifier as compared to the VFT distributed amplifier.

To investigate the high frequency properties of the VFT and Modified Super-CIT in the 1-20 GHz regime, a broadband microwave transformer is being developed. This transformer is based on a Dolph-Chebyshev distribution and provides a 25:1 impedance transformation.

To provide the tolerances needed for the fabrication of the transformer, our present photolithographic mask making system was refitted. The system now allows the 10 μm tolerances that are reproducible over a 1 cm^2 area.

PUBLICATIONS, SEMINARS, CONFERENCE PAPERS

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- D. P. McGinnis, J. E. Nordman and J. B. Beyer, "Optimization of Circuit Parameters for the Vortex Flow Transistor," IEEE Trans. MAG-23, 699 (1987).
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- J. E. Nordman, "Superconductor Distributed Amplifier Configurations," Invited presentation at 1987 Workshop on Superconductive Electronics: devices, Circuits and Systems, Coto de Caza, California, October 1987.

PERSONNEL

J. B. Beyer, Professor

J. E. Nordman, Professor

D. P. McGinnis, Graduate Student Research Assistant and Post-Doctoral Fellow

Jin-Shyong Jan, Graduate Student Research Assistant

Michael Petras, Graduate Student Research Assistant

Jon Martens, Graduate Student Fellow (not funded by grant)

David Dawson-Elli, Graduate Student Research Assistant (not funded by grant)

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McGinnis, David, Ph.D., University of Wisconsin, May 1987.

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