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Modeling of Biological Neurons using Superconducting Circuitry

SHREEYA KHADKA, OLEKSIY SVITELSKIY, STEVE KAPLAN, KENNETH SEGALL, Colgate University, Hamilton, NY 13346 — With the goal of understanding the collective behavior of large network of neurons, we purpose a new analog method based on superconducting Josephson junction (JJ) circuitry. Through numerical simulations, we were able to show that these JJ neurons reproduce many characteristic features of biological neurons such as action potential, firing threshold and refractory period. For preliminary testing, we have designed and fabricated a superconducting chip consisting of two coupled JJ neurons, connected to each other in a closed loop. The numerical simulations of the two synchronized coupled neurons, showed a characteristic phase-flip-bifurcation where the two neurons would fire either in-phase or out-of-phase depending on their coupling strength. Thus, we are looking for the characteristic phase-flip-bifurcation in the experiment also. If these encouraging observations find further confirmation, our JJ model will open a way for developing a fast and low power method of studying the dynamics of large neural networks. We would like to thank Zictools/WRSpice for layout and simulation, and Hypres Inc. for fabricating the chip.

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