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Neuromorphic Optoelectronic Circuits with Integrated Josephson Junctions and Superconducting-Nanowire Single-Photon Detectors

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***Abstract*–The field of neuromorphic computing seeks to develop the next generation of hardware for artificial intelligence using biological neural systems as inspiration. Existing neuromorphic hardware has demonstrated impressive performance and efficiency but is limited in scale and speed by the digital communication infrastructure that routes signals throughout the network. Optical communication between neurons can eliminate these tradeoffs and is particularly attractive in conjunction with superconducting single-photon detectors that support communication at the physical limit of optical power [1]. Cryogenic operation also enables the use of Josephson junctions and other superconducting devices for high-speed, low-power nonlinear computation within artificial neurons. In this work, superconducting-nanowire single-photon detectors are monolithically integrated with Josephson junctions to demonstrate a variety of neural behaviors. First, synapses with programmable weights are experimentally demonstrated by coupling a superconducting memory cell to an analog circuit that is sensitive to single-photon inputs [2]. These synapses support over 400 internal states, are programmable at the single-fluxon level, and showed no change in state over a 48-hour measurement. Additionally, multi-synaptic circuits are presented that perform a variety of bioinspired operations including coincidence detection, sequence detection, and inhibition. The same circuits also have applications in single-photon sensor arrays for medical imaging, circuit evaluation, quantum information, and astronomical observation. These results demonstrate the promise of a new superconducting optoelectronic hardware platform that would enable neuromorphic computing with unprecedented scale and performance.**

***Keywords (Index Terms)*–Neuromorphic, optoelectronic, SNSPD, analog, Josephson junction**

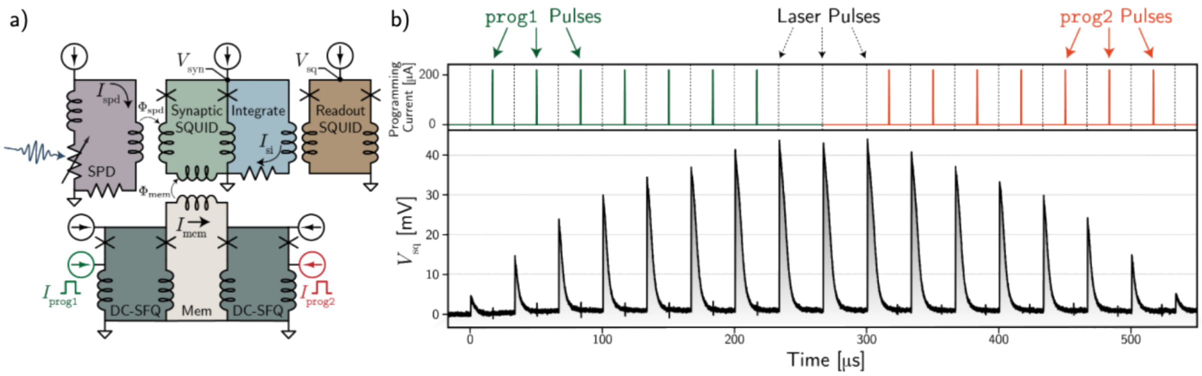

Fig. 1: (*a) Circuit diagram of a programmable synapse. The single photon detector (SPD) transduces optical inputs into electrical signals for processing with Josephson junctions. A memory cell (bottom) sets the weight that is applied to the optical inputs. (b) The output of the synapse (Vsq) is a function of the state of the memory cell which is programmed with electrical pulses* prog1 *and* prog2.

References

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