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Nanosecond Rise-time, Laser Diode Driven, Wide Bandgap Photoconductive Switches as Fast, High-Voltage MOSFET Replacements for Bioelectrics and Accelerator Applications*,†

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High-voltage MOSFETs are fundamentally limited in rise-time and PRF because of the slow transit-time of carriers through the drift region that supports the high-voltage. Large numbers of low voltage devices are used to overcome this limitation, but systems are complex, rise-time limited, and can exhibit electrical instability caused by fast transients. In contrast, photoconductive switches have been developed as nanosecond rise-time, high-voltage, high peak current devices for pulsed power applications. Triggering is usually accomplished with single-shot/low duty-cycle, high peak power Nd:YAG lasers. However, recently introduced, nanosecond rise-time, ≈100-W, integrated laser diode modules and methods to increase optical efficiency make a fast, integrated, photoconductive MOSFET-like switch module possible. By using wide bandgap materials, a linear transconductance-like control property is exhibited. As an initial proof-of-concept for electric grid applications, we present results of a 50% duty-cycle, 20-kV, vertically integrated device that demonstrated a PRF ten-times faster than an equivalent MOSFET; fiber isolation enables cascaded/floating device applications. Control over a large range was observed by varying the laser intensity. Bulk illumination and conduction eliminated carrier transit-time and resulted in rise-times limited only by the laser. We also report on progress driving the switch with a ≈2-ns rise-time laser diode, but at lower duty-cycle for ns-PEF/bioelectrics (e.g., sanitization, therapeutics, etc.) and accelerator applications. Delivered pulse-width was easily varied with the TTL-level input pulse duration to the fast laser driver. Finally, we detail the physics of the carrier dynamics explored with a 70-fs rise-time super-continuum laser: carriers are excited in sub-picosecond times and recombination is controlled by trap density introduced into the mid-bandgap. As a result, fidelity of the output pulse can be optimized by trading laser power against carrier recombination time.

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