Docket #: S20-443

Photonic transformer based on light-emitting diodes for DC voltage conversion

Stanford researchers in the Shanhui Fan Group have developed a new type of voltage converter capable of both AC and DC boost and buck operation. Utilizing a non-switching photonic mechanism, the voltage converter (hereafter referred to as a "photonic transformer") offers scalability across a wide range voltage ratios, supports high voltages, and provides excellent electrical isolation and Electro-Magnetic Interference (EMI) blocking, all within an extremely compact footprint with a substrate-transferrable thin-film profile.

The photonic transformer's basic design conceptually resembles a network of LEDs transferring energy to a network of Photo-Voltaic (PV) cells; however in the photonic transformer all of the LEDs and PV cells are monolithically integrated into a single thin-film device with one pair of input terminals and one pair of output terminals. The design utilizes a micron-scale high-index spacer to strongly couple the light-emitting and absorbing volumes, resulting in extremely high conversion efficiency. GaN-based implementations can achieve high output voltages with conversion efficiencies far above those of even today's best blue GaN-based LEDs. This near-unity power conversion efficiency furthermore eases thermal constraints to enable miniaturization of high-performance voltage converters while simultaneously improving electromagnetic compatibility and power quality for the systems they support.

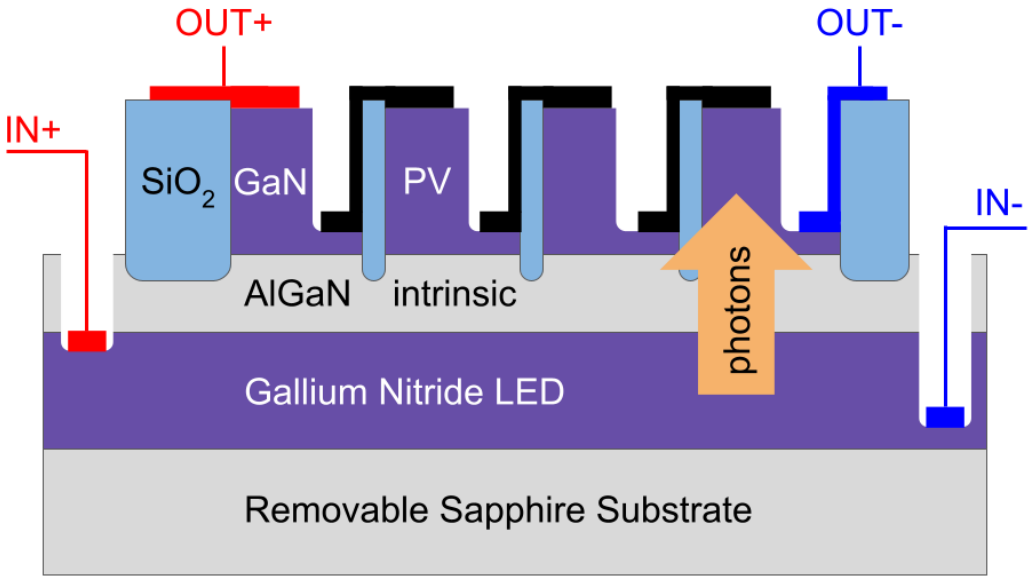

Figure description - Figure description: Diagrammatic representation of a fully fabricated GaN-based photonic transformer (cross-sectional profile view). The emitting and absorbing GaN-based diode layers are grown serially, with the electrically-insulating, optically-transparent, nearly lattice-matched AlGaN layer grown between them. Next a sequence of patterned etch steps are performed which expose contact layers and separate the PV cells (and in some cases LEDs). A patterned layer of insulating SiO2 is subsequently deposited to electrically isolate the contact traces from the PV junctions' sidewalls. Finally contacts are deposited. Optional subsequent steps (not shown) include flip-chip bonding to a CMOS circuit die and substrate removal via laser lift-off.
Image credit: https://arxiv.org/abs/2103.14728

Stage of Development

- Proof-of-concept completed. Photonic transformer constructed and physics validated via board-level implementation with discrete off-the-shelf LEDs and PV cells.
- Proof-of-concept for monolithic implementation under development.

Applications

- **Generation of high DC voltages for Single-Photon Avalanche Detectors (SPADs) and SPAD arrays**
- May be particularly useful in space-constrained applications such as mobile consumer electronic devices with SPAD-array-based LIDAR

    - May be particularly useful in other "ultra-compact" SPAD-based LIDAR systems
- **DC voltage conversion on a variety of CMOS integrated circuits**

- May be particularly useful in SWAP-limited (Size, Weight, And Power) contexts
- May be particularly useful where EMI from switching converters is undesirable or unacceptable
- **DC voltage conversion on flexible substrates including wearables**

- May be particularly useful for wearables charged by energy harvesting devices with low or inconsistent output voltages
- DC-DC converters are used in numerous applications such as **aerospace, consumer electronics, telecommunication, automotive, and medical**

Advantages

- **As compared to existing transformers:**
    - **Miniature size -** extremely small footprint compared with switching converters
    - **Low noise -** no switching noise at ouput, no EMI
    - **Higher efficiency -** much higher power conversion efficiency (approaching unity)
    - **Less waste heat** - loosens therma constraints on surrounding systems
    - **High voltage and voltage conversion ratio**
- **LED as compared to laser light sources:**
    - Simpler and less expensive to fabricate since LED does not require a cavity
    - **More robust operation** - can operate with broader operational parameters
    - **Higher ultimate efficiency**

Publications

- Zhao, Bo, Sid Assawaworrarit, Parthiban Santhanam, Meir Orenstein, and Shanhui Fan. "High-Performance Photonic Transformers for DC Voltage Conversion." *arXiv preprint arXiv:2103*.14728 (2021).

Patents

- Issued: 11,923,873 (USA)

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