High-frequency transistors achieve record efficiency at 100 volts

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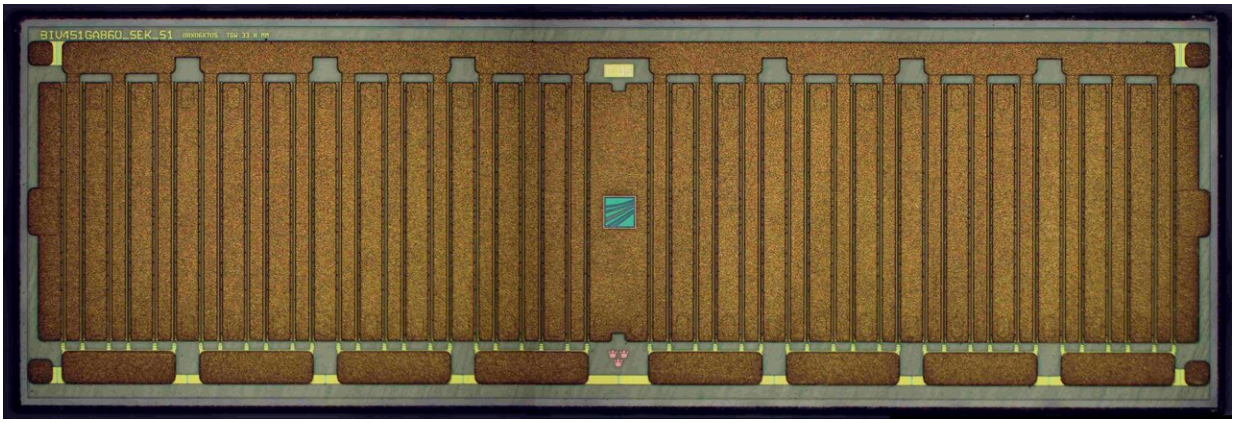


A 100 V gallium nitride power transistor with an output power of 600 W at a frequency of 1.0 GHz. Credit: Fraunhofer IAF

Researchers at the Fraunhofer Institute for Applied Solid State Physics IAF have succeeded in significantly increasing the output power of their GaN-based high-frequency transistors for the frequency range from 1–2 GHz: They were able to double the operating voltage of the devices from 50 volts to 100 volts, thus achieving a power-added efficiency of 77.3 percent. This technology allows the development of highly efficient amplifiers with even higher power, as required for applications in the fields of plasma generation, industrial heating, communications and radar technologies.

The power density of transistors is one of the most important criteria for their use in high-power applications in the GHz range. It determines the size of amplifier modules and thus largely the system complexity—both of which are decisive for the manufacturing costs and the required use of resources.

There are several ways to increase the power density of transistors. Researchers at Fraunhofer IAF have chosen the path of increasing the operating voltage: By scaling the transistor design vertically and laterally, they have succeeded, for the first time in Europe, in realizing high-frequency transistors suitable for applications at an operating voltage of 100 volts. These devices based on the semiconductor gallium nitride (GaN) are characterized by significantly increased power density at frequencies in the GHz range.

Laboratory measurements show record efficiency

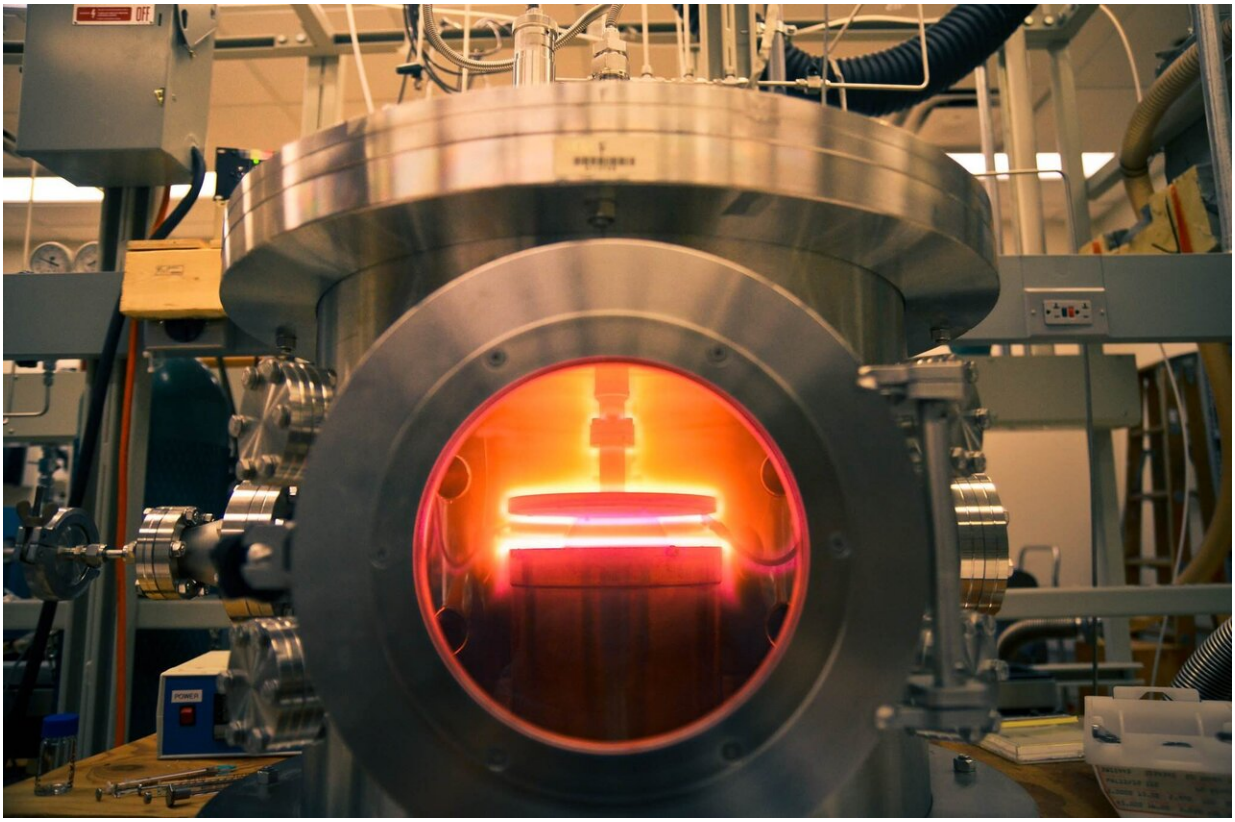
The performance of these newly developed devices for the 1–2 GHz frequency range has already been demonstrated in the laboratory: Measurements showed a power density of more than 17 W/mm and a power-addedefficiency (PAE) of 77.3 percent at a frequency of 1.0 GHz. This is the highest power-added efficiency achieved for 100 V operation in this frequency range ever reported. Tests have even shown that this technology delivers a power density in excess of 20 W/mm at 125 V. The researchers presented their results at the International Electron Devices Meeting (IEDM) in San Francisco for the first time in December 2019.

Twice the voltage for much higher power

"Increasing the operating voltage from 50 to 100 volts enables higher power densities. This means that a system can deliver more power on the

same area than what is possible with commercially available 50 V or 65 V technologies," explains Sebastian Krause from Fraunhofer IAF, one of the main developers of the technology.

On the one hand, this enables systems of the same size with higher output power. On the other hand, it is possible to create more compact and lighter systems delivering the same power, since less chip area is required to achieve the desired power level: "By doubling the operating voltage to 100V, the transistor exhibits a four times higher output impedance for a given power," says Krause. This allows the implementation of smaller and therefore less lossy matching networks, which in turn, results in higher energy efficiency of the overall system.



The 100 V technology is of great interest for high-performance applications such as plasma generators, particle accelerators and industrial microwave heating.

Usage in industrial high-power systems

"The long-term goal of our development is operation through 10GHz," explains Krause. This would make the Freiburg-based Fraunhofer Institute the first source for such 100 V GaN-based devices. This is of particular interest for high-performance applications such as particle accelerators, industrial microwave heaters, mobile-phone amplifiers, pulse- and continuous-wave radar and amplifiers for plasma generators. These systems require high output power levels while maintaining a preferably small footprint—exactly what the 100-V technology can deliver.

Particle accelerators play an important role in research, medical technology and industry. Plasma generators in the high-frequency range are used, for example, for coating processes in the production of semiconductor-based chips, data-storage media or solar cells.

Power semiconductors replace vacuum components

Another large industrial field of application is power generators for microwave heating. "In this field, industry usually works at higher frequencies, but vacuum components, e.g. magnetrons or klystrons, are predominantly used to date. Here, we are working on providing a semiconductor-based alternative. Semiconductors are much more compact and more lightweight, which enables arrangements such as phased arrays," says Krause.

For a long time, tube-based components (e.g. traveling wave tubes) have dominated electronic systems with high output power. However,

development is moving towards power semiconductors. FraunhoferIAF scientists believe that the GaN-based 100 V technology can provide an efficient alternative for increasing the power of microwave generators.

More information: S. Krause et al. High-Power-Density AlGaN/GaN Technology for 100-V Operation at L-Band Frequencies, *2019 IEEE International Electron Devices Meeting (IEDM)* (2020). DOI: 10.1109/IEDM19573.2019.8993632

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