Avalanche photodiode breaks performance record for LiDAR receivers

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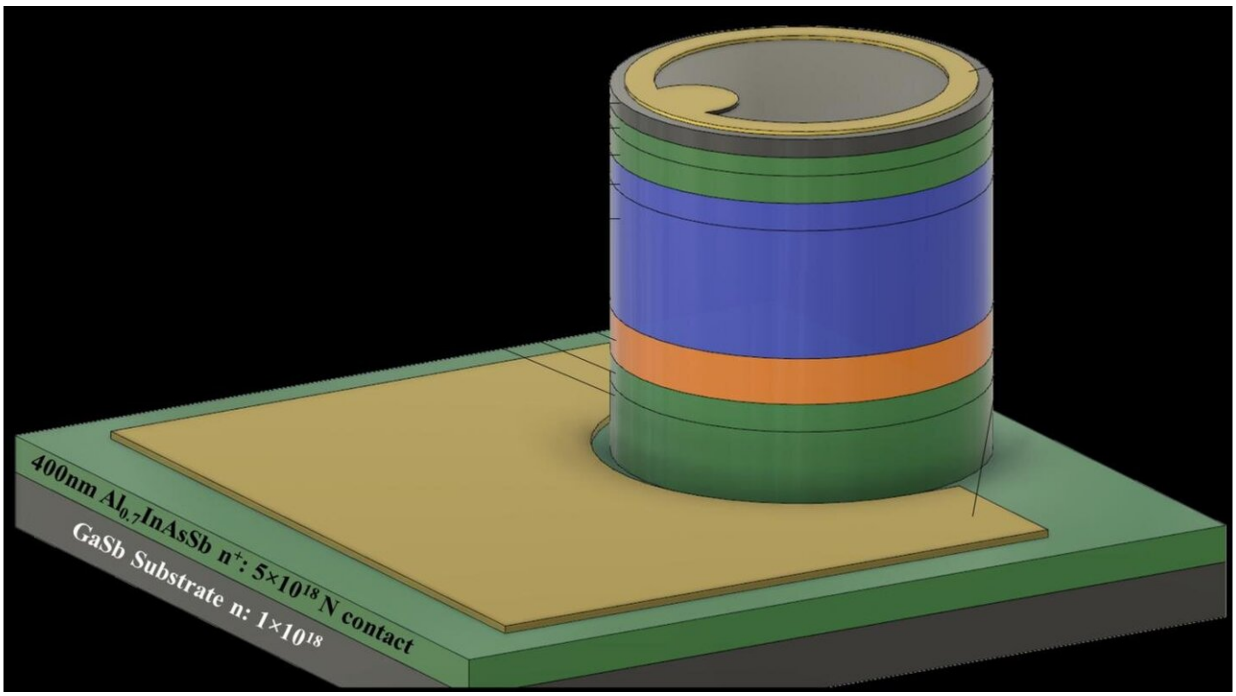

Epitaxial cross section of the avalanche photodiode design. Doping concentrations are given in cm^{-3} Credit: Joe C. Campbell

Electrical and computer engineers at the University of Virginia and University of Texas-Austin have developed an avalanche photodiode that achieved record performance and has the potential to transform next generation night-vision imaging and Light Detection and Ranging (LiDAR) receivers. For LiDAR, the team's low-noise, two-micrometer avalanche photodiode enables higher-power operation that is eye-safe.

The peer reviewed paper, "Low-noise high-temperature AlInAsSb/GaSb avalanche photodiodes for 2-µm applications," was published May 18, 2020, in *Nature Photonics*, a monthly journal of the best research from all areas of light generation, manipulation and detection.

This breakthrough comes from a long-standing collaboration between Joe C. Campbell, Lucien Carr III Professor of electrical and computer engineering at UVA, and Seth R. Bank, Cullen Trust Professor at UT-Austin. Andrew H. Jones, a 2020 Ph.D. graduate advised by Campbell, and Stephen D. March, a Ph.D. student in Bank's research group, contributed to the research. The team's work was funded by the Defense Advanced Research Projects Agency and the Army Research Office.

The team used the novel optical and electrical characteristics of a digital alloy created in Bank's Laboratory for Advanced Semiconductor Epitaxy. Bank employed molecular beam epitaxy to grow the alloy, composed of aluminum, indium, arsenic and antimony. The alloy combines long-wavelength sensitivity, ultra-low noise, and the design flexibility that is needed to achieve low dark currents, which is not available with existing low-noise avalanche photodiode materials technologies.

"Our ability to control the crystal growth process down to the single atom-scale enables us to synthesize crystals that are forbidden in nature, as well as design them to simultaneously possess the ideal combination of fundamental material properties necessary for efficient photodetection," Bank said.

The team's avalanche photodiode is an ideal solution for compact, high-sensitivity LiDAR receivers. Many LiDAR applications, such as robotics, autonomous vehicles, wide-area surveillance and terrain mapping, require high-resolution sensors that can detect greatly attenuated optical signals reflected from distant objects. Eye safety has limited the adoption of these next-generation LiDAR systems, however, because the requisite higher laser power poses an increased risk of eye damage.

"The 2-micrometer window is ideal for LiDAR systems because it is considered eye-safe and extends the detection reach." Campbell said. "I can envision our avalanche photodiode impacting numerous key technologies that benefit from high sensitivity detectors."

This work is being transferred to IQE for foundry services and Lockheed Martin to develop photodiode arrays with readout circuitry. Future work at the two universities will concentrate on achieving low-noise operation at near-room temperatures, extending the operating wavelengths further into the infrared, and pushing the sensitivity to the single photon level.

More information: Andrew H. Jones et al, Low-noise high-temperature AlInAsSb/GaSb avalanche photodiodes for 2-μm applications, *Nature Photonics* (2020). DOI: 10.1038/s41566-020-0637-6

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