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SHRINKING DIMENSIONS LEAD TO WORLD'S FASTEST TRANSISTOR

New technology promises faster communications, sharper radar, and electronics in the infrared

(Santa Barbara, Calif.) Mark Rodwell, professor of electrical and computer engineering, and his group of researchers at the University of California, Santa Barbara, together with a team at NASA's Jet Propulsion Lab in Pasadena, have developed a record-breaking high-speed transistor.

The bipolar transistor, unveiled in June at the semiconductor Device Research Conference held in Santa Barbara, can amplify signals at frequencies as high as 1 terahertz (THz), a trillion cycles per second.

"Surpassing the 1 THz mark is a milestone," said Rodwell. "This transistor is three-and-a-half times faster than previous bipolar transistors, and about twice as fast as the fastest field-effect transistor (FETs)."

The new bipolar transistor begins an era when transistor electronics operate at the boundaries of the far infrared. Infrared radiation lies at frequencies between roughly 0.3 THz and 500 THz, higher than the frequencies of radio waves and microwaves, but lower than the frequencies of visible light. Far infrared is between 0.3 THz and 3 THz.

The infrared frequencies have been beyond the reach of transistors, while lasers work best at the highest infrared frequencies and beyond: visible light. With this new transistor, it should be possible to build amplifiers and other important circuits, which can operate over the lowest frequencies within the infrared bands.

The vast frequency band of infrared waves offers enormous capacity for wireless voice and data communications. The very lowest infrared frequencies are low enough that, unlike light, the waves penetrate through smoke, fog, and rain, but high enough that, unlike microwaves, infrared radar would provide a sharp TV-like image. This is important for landing airplanes in foul weather and for military uses.

Because gases emit with distinct signatures in the low THz range, the far infrared is also important for radio astronomy, planetary science, and for measuring ozone in the earth's upper atmosphere.

Several features produce the transistor's high performance. As with many of the fastest transistors, the UCSB/JPL device is made from indium gallium arsenide, a semiconductor in which electrons move with particularly high speed. Electron-beam lithography was used to make the very small device.

Finally, and unique to the UCSB/JPL effort, a "flip-chip" process allowed both the top and bottom surfaces of the semiconductor layers to be accessed during fabrication of the device. This allowed the transistor to be shaped precisely so as to remove unwanted semiconductor from places where it degraded the transistor's performance. Led by Rodwell, the UCSB team included graduate students Qinghung (Michelle) Lee, Dino Mensa, James Guthrie, Shrinivasan Jaganathan, Thomas Mathew and Sundararajan Krishnan, and post-doctoral researcher Yoram Betser.

The work is a collaboration with Susie Martin and Peter Smith, scientists at JPL's Center for Space Microelectronics Technology. The Office of Naval Research supported the UCSB team.

"It will not happen quickly," said Rodwell, "but we can see logical ways to further increase the frequency range to about 3 THz. Meanwhile, we must show the scientific community that we can use the transistor to build circuits that generate and detect far infrared radiation.

"And we must transition the technology to build much larger and more complex chips that do many more of the functions typical of modern electronics-functions well beyond simply generating and detecting signals."

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