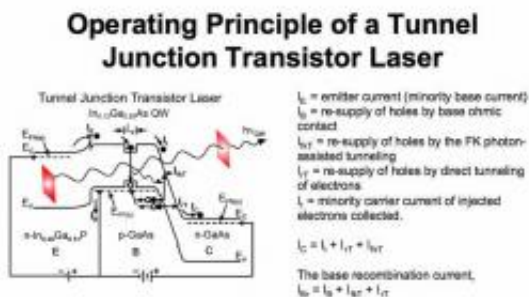


High-speed signal mixer demonstrates capabilities of transistor laser

March 19 2009, By James E. Kloeppel



Operating principle of a tunnel-junction transistor laser.

(PhysOrg.com) -- Scientists at the University of Illinois have successfully demonstrated a microwave signal mixer made from a tunnel-junction transistor laser. Development of the device brings researchers a big step closer to higher speed electronics and higher performance electrical and optical integrated circuits.

The mixing device accepts two electrical inputs and produces an [optical signal](#) that was measured at frequencies of up to 22.7 gigahertz. The frequency range was limited by the bandwidth of the detector employed in the measurements, not by the transistor device.

"In addition to the usual current-modulation capability, the [tunnel](#)

[junction](#) provides an enhanced means for voltage-controlled modulation of the photon output of the [transistor laser](#),” said Nick Holonyak Jr., a John Bardeen Chair Professor of Electrical and Computer Engineering and Physics at the U. of I. “This offers new capabilities and a much greater sensitivity for unique signal-mixing and signal-processing applications.”

To make the device, the researchers first placed a quantum well inside the base region of a transistor laser. Then they created a tunnel junction within the collector region. They describe the fabrication and operation of the mixing device in the March 13 issue of the journal [Applied Physics Letters](#).

“Within the transistor laser, the tunneling process occurs predominantly through a process called photon-assisted absorption,” said Milton Feng, the Holonyak Chair Professor of Electrical and Computer Engineering.

The tunneling process begins in the quantum well, where [electrons](#) and holes combine and generate [photons](#), Feng said. Those photons are then reabsorbed to create new pairs of electrons and holes used for voltage modulation.

“The tunnel junction makes it possible to annihilate an electron in the quantum well, and then tunnel an electron out to the collector by the tunnel contact,” Feng said.

The transistor output is sensitive to third-terminal [voltage control](#) because of the electrons tunneling from the base to the collector, which also creates an efficient supply of holes to the quantum well for recombination.

“This is a new type of transistor,” said Holonyak, who also is a professor in the university’s Center for Advanced Study, one of the highest forms

of campus recognition. “We are using the photon internally to modify the electrical operation and make the transistor itself a different device with additional properties.”

High-speed signal mixing, for example, is made possible by the nonlinear coupling of the internal optical field to the base electron-hole recombination, minority carrier emitter-to-collector transport, and the base-to-collector electron tunneling at the collector junction, the researchers report.

The sensitivity of the tunnel-junction transistor laser to voltage control enables the device to be directly modulated by both current and voltage. This flexibility facilitates the design of new nonlinear signal processing devices for improved optical power output.

“The metamorphosis of the transistor is not yet complete,” Holonyak said. “We’re still working on it, and the transistor is still changing.”

Co-authors of the paper are graduate research assistant and lead author Han Wui Then, graduate student Hsin-Yu Wu and senior research scientist Gabriel Walter.

Provided by University of Illinois at Urbana-Champaign ([news](#) : [web](#))

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