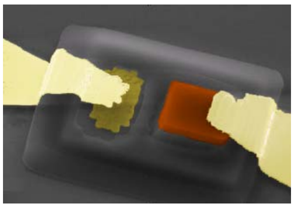
Fully Ballistic p-i-n diode-based photomixers



Scanning electron beam image (false color) of a p-i-n diode-based photomixer.

Image: S. Preu

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A photomixer device generates an AC photocurrent by absorbing the intensity beating of two slightly detuned (by the desired THz-frequency) laser beams. This (THz)-current can be fed into an antenna which emits the THz-radiation. The device has to be optimized with respect to the extremely high frequency. In particular, the capacitance of the device must be minimized since an RC roll-off results from the antenna (R)-device (C) system. Furthermore, the intrinsic "speed" has to be maximized by reducing the transit time of the optically generated charge carriers through the intrinsic layer. We demonstrated that a p-i-n diode shows ballistic electron motion under optimum field conditions and intrinsic layer lengths: For sufficiently low kinetic energy below the threshold of very efficient sidevalley scattering process, the electron motion is only perturbed by weak scatters such as phonons. We develop fully ballistic p-i-n diodes (FB-PIN) for efficient Terahertz generation where we optimize the intrinsic layer structure for best transport performance with transit-time 3 dB corner frequencies in the range of 1 THz.

The n-i-pn-i-p superlattice photomixer

Together with the University of Erlangen-Nuremberg and the University of California, Santa Barbara, we develop a device concept for efficient generation of THz-radiation in photomixers, the **n-i-pn-i-p superlattice photomixer**. Several (N) ballistically operated p-i-n diodes are connected in series which reduces the device capacitance, $C=C_{pin}/N$. Therefore, the individual diode can be optimized with respect to the ballistic operation, while the capacitance can be *independently* optimized by the choice of the number of periods, N. A band structure is depicted in Fig. 1.

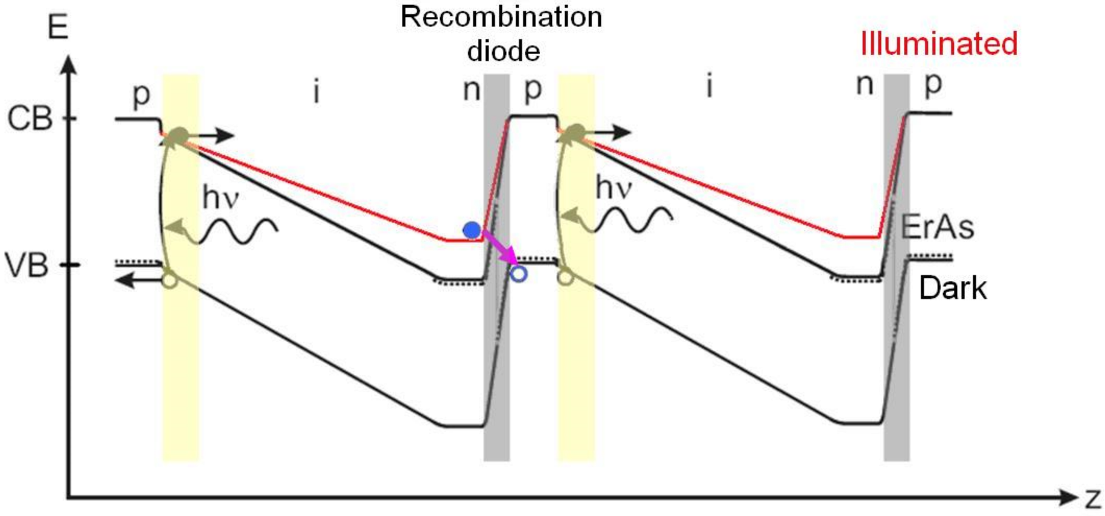

Fig. 1: Band structure of a n-i-pn-i-p superlattice photomixer. Several p-i-n diodes are connected in series to reduce the device capacitance. A low-resistance interconnect between subsequent p-i-n diodes is formed by ErAs-enhanced recombination diodes (gray area). Under illumination (red graph), a small forward bias with respect to the recombination diode increases the recombination current, which results in a slight reduction of the built-in field. It can be recovered by a small external bias. In order to improve the internal response-time of the diode, the absorption region (yellow) is confined close to the p-contact to allow for ballistic electron transport only. Holes remain stationary
[link to paper].

The concept has been demonstrated at both 850 nm and the very attractive telecom range at 1550 nm. We have built a setup for CW photomixing at 1550 nm for testing processed In(Al)GaAs based photomixers and for pursuing THz applications. A power spectrum is illustrated in Fig. 1. The current work focuses on the improvement of the devices, including band gap engineering, thermal optimization and processing. We also work on photomixer arrays for further increasing the THz power.

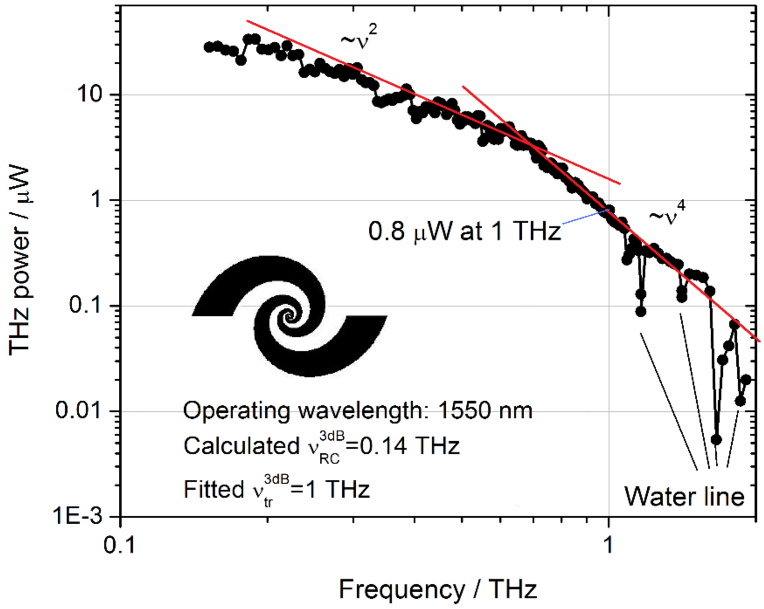

Fig. 2: Continuous-wave power spectrum of a three period n-i-pn-i-p superlattice photomixer at 1550 nm attached to a logarithmic spiral antenna [link to paper].