Mid-infrared high-bandwidth PIN GeSn photodetectors monolithically grown on silicon

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A plethora of applications, such as time-resolved spectroscopy, medical optical tomography, environmental monitoring of greenhouse gases, high-resolution active light detection and ranging (LIDAR), and next-generation telecommunication systems, depend on the availability of high-speed photodetectors (PDs) operating in the MWIR spectral ranges [1]. The state-of-the-art photodetectors functioning above 2.3 µm with a bandwidth over 5 GHz are made up exclusively of In-rich InGaAs on InP, InGaAs/GaAsSb on InP, and GaInAsSb on GaSb [2], whereas group IV detectors running at 2 µm offer a bandwidth surpassing 30 GHz [3]. These devices have a low bandwidth above 2.3 µm that does not surpass 6 GHz and face cost and scalability issues. An appealing paradigm for large-scale manufacture, cost-effectiveness, and compatibility with CMOS processing is the establishment of silicon-integrated high-speed detectors.

Epitaxially grown GeSn semiconductors on silicon substrates offer a viable substitute toward silicon-integrated monolithic devices, with the added benefit of tin content control over bandgap directness and tuning [4]. In fact, GeSn has just been included into the demonstration of emitters and detectors in the 2–2.5 µm range and beyond [4-6]. This work presents all-GeSn PIN heterostructures produced on silicon substrates that result in faster, free-space photodiodes. These devices have a high bandwidth exceeding 12 GHz at a bias of 5 V, a 2.8 µm cutoff wavelength, a 0.2 A/W responsivity at room temperature, and a broadband spectral responsivity. It also describes the integration of high-bandwidth devices in ultrafast spectroscopy. Using a Fourier transform infrared (FTIR) spectrometer, the high-speed operation of GeSn PDs was utilized to reveal the pulse duration, intensity, and spectral distribution of a pulsed supercontinuum laser, achieving a temporal resolution in the picosecond range at 2.5 µm that has never been achieved before. Furthermore, a thorough examination of the GeSn PDs dark current properties is offered in order to illustrate the dominant leakage current mechanisms as a function of temperature.

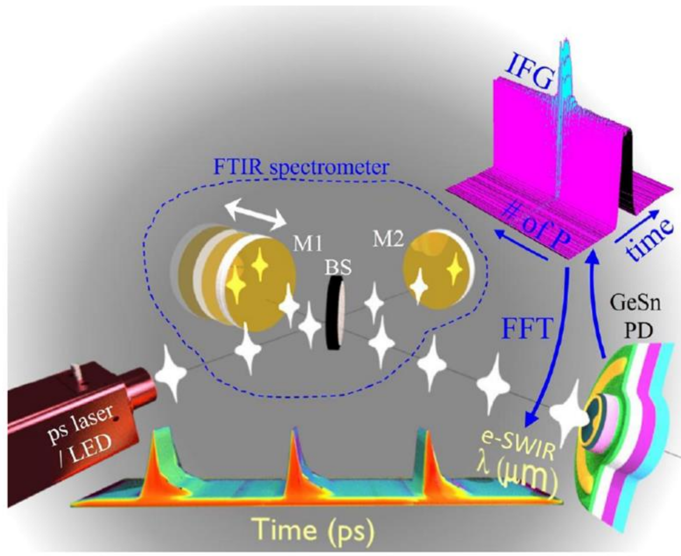

Fig. 1. Schematic depicting the high-bandwidth setup used to characterize GeSn PDs in a time-resolved spectroscopy setting.

References

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