Characterization of InGaAs Self-Mixing Detectors for Amplitude-Modulated LADAR

Mike Gerhold[1], Keith Aliberti[2], Hongen Shen[2], Peter Rishabh Mehandru[3], Soohwan Jang[3], and Fan Ren[3]

1. U.S Army Research Office, Research Triangle Park, NC 27709-2211
2. U. S. Army Research Laboratory, Adelphi, MD 20783
3. Department of Chemical Engineering, University of Florida, Gainesville, FL 32611

LADAR Systems utilize laser light for the detection of object speed, altitude, direction and range. Military interest in LADAR has been ongoing for a number of years, particularly for target identification and range determination. In general, there are two types of ranging techniques used in LADAR to measure the time delay from the sensor to the target. One technique measures the time delay using short pulses of laser light: this technique requires the use of high-bandwidth receivers. The other technique measures the time delay using modulation waveforms impressed on continuous-wave (cw) lasers: this technique requires suitable-bandwidth receivers. Both techniques can be implemented using direct detection or optically coherent receivers.

The U.S. Army Research Laboratory (ARL) is developing low-cost LADAR Systems that utilize diode-laser transmitters. Diode lasers cost significantly less than solid state lasers and are more electrically efficient. Pulsed diode lasers suffer from limited peak power capability due to damage at the output laser facet that, in a typical pulse operation, limit the amount of total energy that can be focused onto a target. Low-cost cw laser diodes, however, with optical power levels in the low Watts, are available commercially. With this in mind, ARL began investigating a unique, optically incoherent, LADAR architecture that uses frequency-modulated, continuous-wave (FM/cw) radar principles. In this architecture, transmit and receive radar antennas are replaced by an intensity-modulated cw semiconductor laser diode and an optical receiver, respectively.

LADAR operation in the infrared, mainly 1.55 μm, would help render the system eye-safe. For this application, InGaAs-based MSM-PD OEMs are necessary. Unfortunately, the Schottky barrier height on InGaAs is quite low (~0.1-0.2 eV) leading to high dark current and, hence, low signal-to-noise ratio. To reduce dark current, the Schottky barrier height must be "enhanced". Typically, this is accomplished by growing (e.g. via molecular beam epitaxy) high-band-gap, lattice-matched InP or InAlAs Schottky enhancement layers (SELs) on top of the InGaAs layer. Photodetectors using Schottky enhancement layers (SELs) have been shown to yield low dark current, high responsivity, and high bandwidth.

In this talk, various device designs and processing schemes of InGaAs based 1.55 μm inter-digitated metal-semiconductor-metal (MSM) photo-detectors will be presented. A simple circuit model was employed to explain the mixing results. Another more comprehensive semiconductor device model coupled with electromagnetic optics was used to simulated the dc and pulse responses of the MSM devices and good agreements with the experimental results were obtained. The simulations helped understand the nature of so called "knee" in the photo dc IV characteristics of the MSM photodetector. As a results of simulation, a thinner SEL structure were utilize and the mixing characteristics were greatly improved.