

2026-2027 UCSB Capstone Project

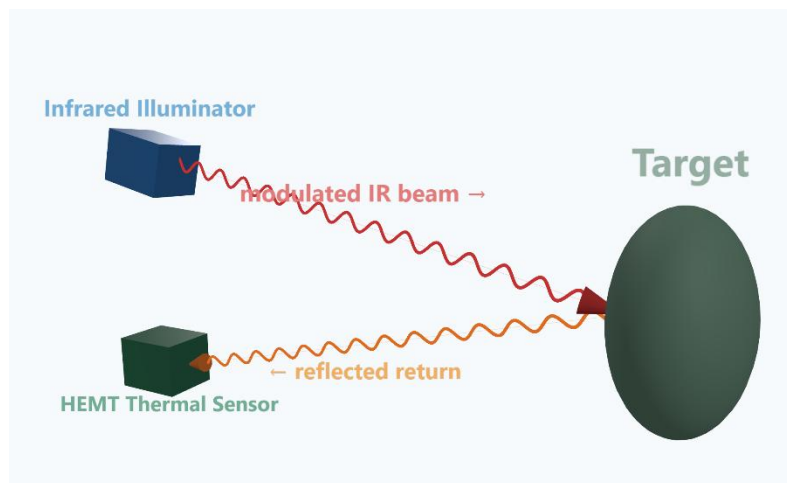
Frequency-domain LiDAR imaging using a nitride HEMT thermal transducer

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Background: Infrared cameras capture images of the infrared spectrum, which is electromagnetic radiation with wavelengths longer than visible light. Natural and synthetic objects emit infrared radiation whenever they are above absolute zero, so infrared imaging is widely used in industrial, scientific, military, commercial, and medical applications. Thermal imaging in the mid-wavelength (3–5 μm) and long-wavelength (8–12 μm) bands is of particular interest because sensors can *passively* image objects with no illumination at all.

LiDAR (Light Detection and Ranging) is the active counterpart: the scene is illuminated with a modulated light source, and the returned signal is used to measure range. Doing this in the long-wave infrared (LWIR) is attractive because of good atmospheric transmission and low solar background, and because the same aperture can provide both 3-D range and a thermal image.

The hard part is the receiver, and this project explores a new approach and alternative to conventional photodetectors: a nitride high electron mobility transistor (HEMT) connected to a thermal transducer element, such that incoming infrared energy changes the transistor's gate condition. The HEMT is placed in an oscillator circuit, so the detected return signal shows up as **phase delay** that can be measured in the **frequency domain** rather than a small change in voltage or current.



Problem Statement: Performance depends on a set of competing design trades that need to be characterized and understood for this architecture:

- **Thermal isolation vs. speed.** Better thermal isolation of the thermal transducer element gives more sensitivity but a slower response, which limits the modulation rate and range resolution.

- **HEMT self-heating.** The transistor is both an electrical readout device and a heat source, so bias current trades against thermal drift and stability.
- **Oscillator frequency stability for measurement.**
- **Source and link budget.** LWIR source power and modulation format vs. achievable range and frame rate.

Project Description: The objective is to design, build, and evaluate a breadboard LWIR LiDAR imaging system based on a HEMT thermal sensor element and determine whether frequency-based detection can match or beat conventional LWIR receivers — accounting for the practical realities of fabricating, packaging, and characterizing the device.

A baseline LWIR data collect will be coordinated with support from the industry team to establish phenomenology, data reduction, and quantitative performance metrics such as range accuracy, minimum detectable signal, response time, and frame rate.

Modeling and simulation will then be used to evaluate software tools and methods, optimize the sensor element and its packaging, and compare against conventional LWIR detection.

Expected tasks:

- **System/link budget model:** source power, optics, target reflectivity, and receiver noise → range and precision.
- **Thermal and MEMS modeling:** finite-element trades on thermal conductance, time constant, and mechanical stability, including MEMS isolation and package ambient.
- **Circuit design:** HEMT modeling, oscillator topology, phase-noise budget, and the frequency readout chain.
- **Fabrication and test cycles:** develop approach to integrate an LWIR source, optics, tested element, and readout circuit into a working ranging/imaging demonstrator and compare to the model.

The team will downselect and recommend a path for fabrication and characterization of an optimized design, with a stretch goal of demonstrating end-to-end LiDAR imaging ‘breadboard’ with the industry team.

This project is ideally suited for students with an interest in microfabrication, semiconductor devices, MEMS, high-frequency circuits, optics, and multiphysics modeling. Students must have some background in microfabrication and testing and have preferably taken ECE 120A and 120B.

Further Information:

- References on uncooled thermal detector figures of merit and thermal isolation design
- References on GaN HEMT high-frequency operation and oscillator design
- References on modulated LiDAR system architectures