Center of Multidisciplinary Research Excellence in Cyber-Physical Infrastructure Systems (MECIS)

The University of Texas Rio Grande Valley

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# Development and Testing of a Prototype Erbium-Doped Lithium Tantalate Based Sensor for Infrastructure Crack Detection and Measurement

National Science Foundation

NSF Award No. 2112650

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## Abstract

The development of a novel sensor for detecting and characterizing cracks in infrastructure, particularly suited for deployment in Unmanned Aerial Vehicles (UAVs) is presented. The sensor utilizes a sophisticated setup involving laser triangulation and nanoparticles, with a focus on leveraging Erbium-doped Lithium Tantalate nanoparticles. This research presents a significant step forward in advancing infrastructure health monitoring through innovative sensor technologies embedded within UAVs.


## Introduction & Background

- Monitoring infrastructure such as bridges, roads, and railways is essential for public safety and economic stability
  - Traditional inspections are manual, time-consuming, and prone to low accuracy from human error
- UAVs now offer scalable, efficient, and safer alternatives, capable of collecting high-resolution data
- Recent advances in near-infrared (NIR) laser sensing, particularly using optical properties from lithium tantalate nanoparticles doped with erbium, enhance accuracy and performance in various conditions
- This study is about the development of a UAV-mounted sensor using these materials to improve crack detection and surface mapping, aiming to boost reliability and cost-effectiveness in infrastructure maintenance

*Figure 1: Infrastructure anomaly examples (Source: anavision.com)*

## Methodology

- Near infrared light (980nm) of a laser beam reflects off surface to be received by the LiTaO3-Er nanoparticles causing emission of1550nm wavelength light to the photodiode
- Constant velocity is necessary while scanning for data reduction of resistance readings over time
- By means of laser triangulation, a 5° angle is used between photodiode and laser diode
- Simplified 3D printed PETG crack samples were profiled for initial sensor characterization
- Distance between sensor and profiled surface were varied to analyze sensing distance threshold

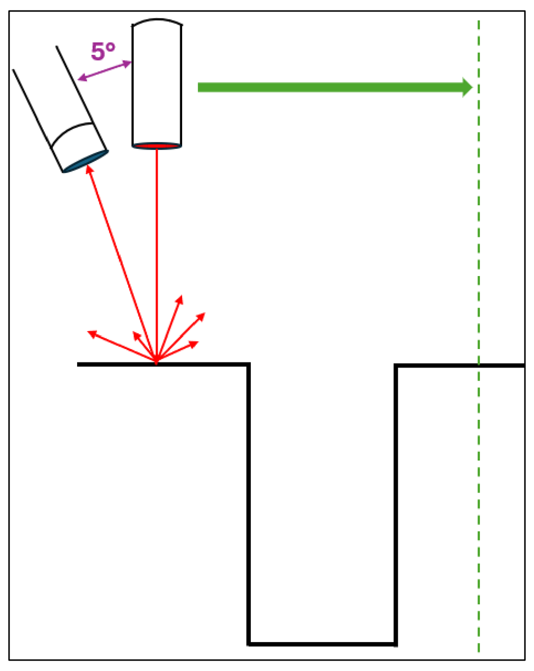


*Figure 2: Surface profiling technique*

## Data and Results

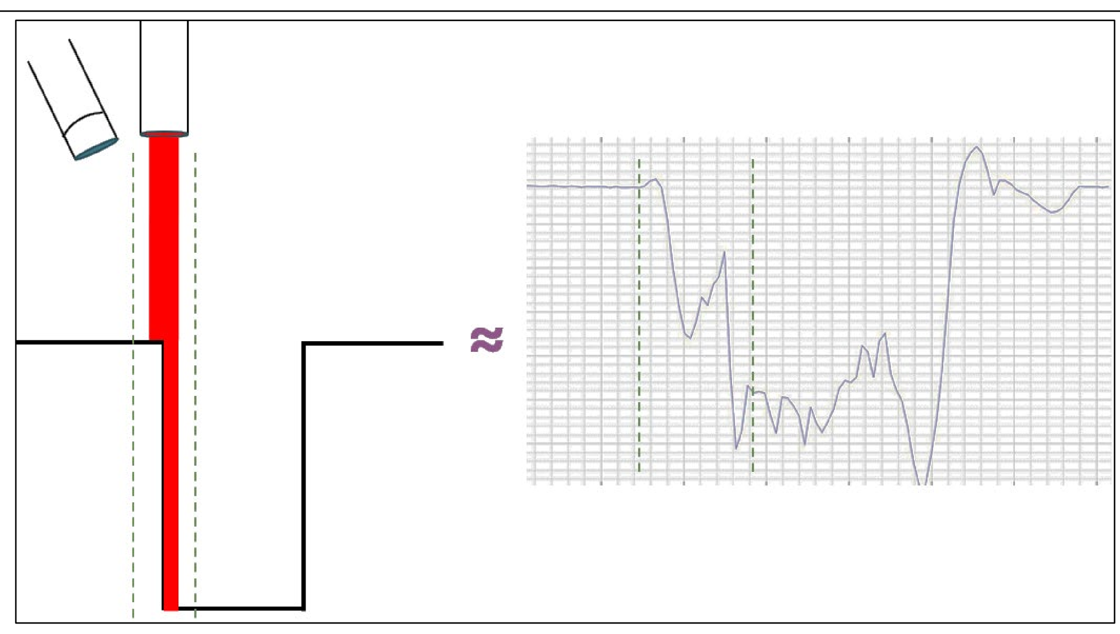


*Figure 3: Surface edge phenomenon*


*Figure 4: Surface profile data*

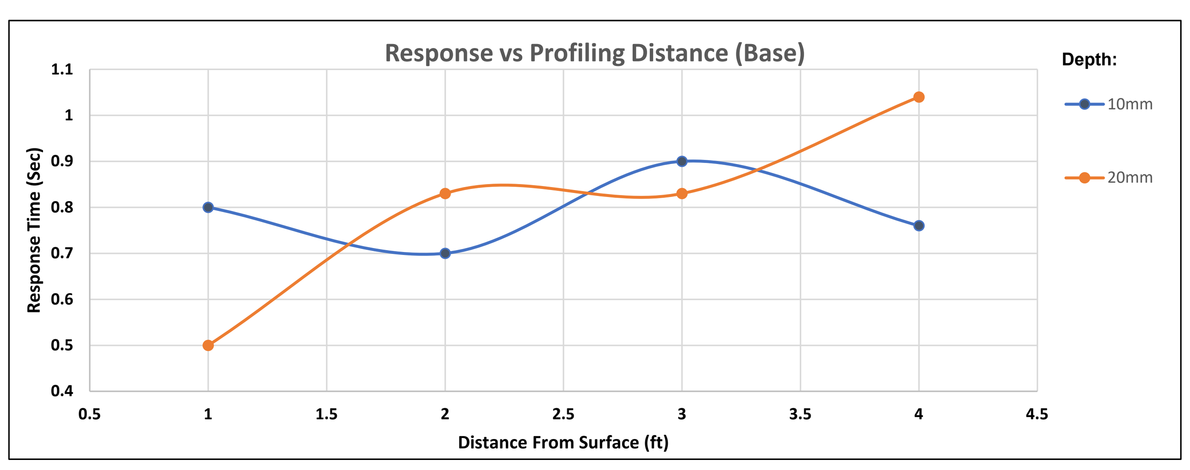


*Figure 5: Response vs Profiling Dist. (Base Sensor)*

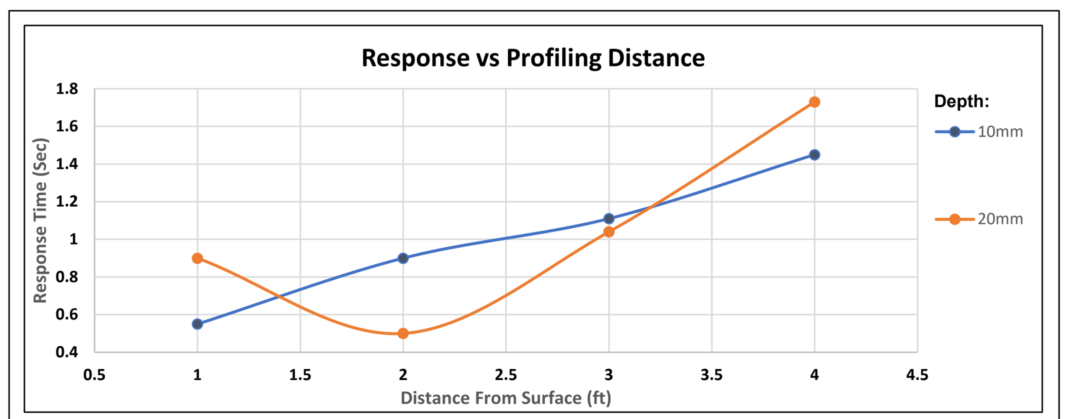


*Figure 6: Response vs Profiling Dist. (LiTaO3)*

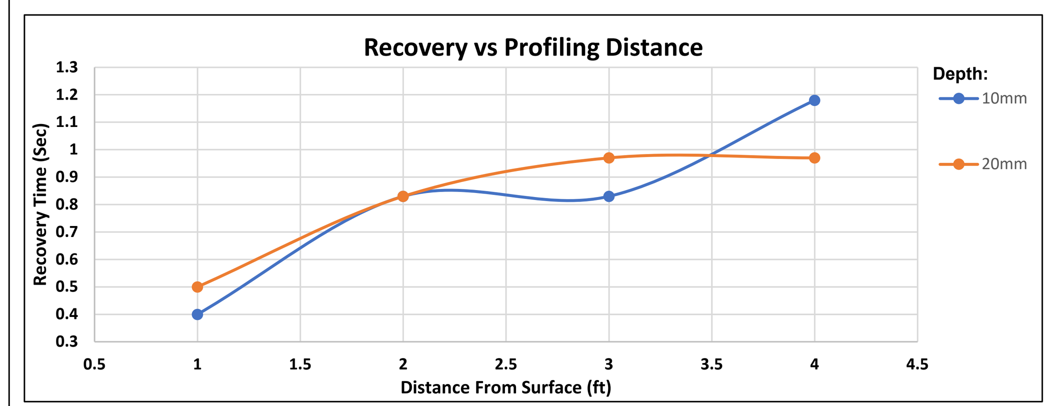


*Figure 7: Recovery vs Profiling Dist. (LiTaO3)*

## Conclusions & Future Work

- Sensor demonstrated increased recovery & response time as distance away from scanned surface grew
- Width of cracks were calculated at a 2% error by testing at a constant velocity to analyze the time taken to cross the crack
- Depth values are determined by resistance readings from photodiode
- Different surface materials are to be evaluated based on infrastructure
- Implementing a smaller laser diameter proves to be favorable for cracks with shorter widths for accurate profiling at a proper laser-to-width resolution
- More complex crack geometries will be evaluated to emulate anomalies expected to be found in infrastructure


## Acknowledgments

The authors would like to acknowledge funding provided by the National Science Foundation CREST Center for Multidisciplinary Research Excellence in Cyber-Physical Infrastructure Systems (MECIS) under NSF Award No 2112650.


## References


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8th Annual STEM Ed Conference, South Padre Island, Texas. February 13 – 15, 2025