The University of Texas Rio Grande Valley
Center for Multidisciplinary Research Excellence in Cyber-Physical Infrastructure Systems (MECIS)

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

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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

- A Thorlabs L980P200 laser diode emits 980 nm wavelength light to a surface.
- The reflected light causes a LiTaO3-Er pellet to emit wavelengths of 1550 nm which are measured by a FGA21 photodiode.
- Voltage was recorded using a NI USB-6008 in conjunction with LabView
- Samples that were profiled were 3D printed to understand profiling of basic crack geometries
- A NEMA 23 stepper motor translated the sensor across the photodiode at constant velocities
- Distance between sensor and surface being profiled were varied to analyze sensing distance threshold

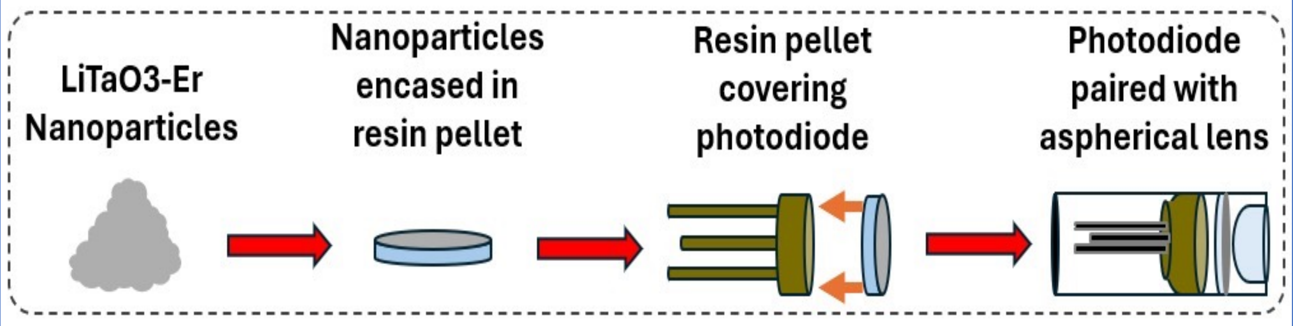

Figure 2: Implementation of LiTaO3-Er nanoparticles on photodiode

Data and Results

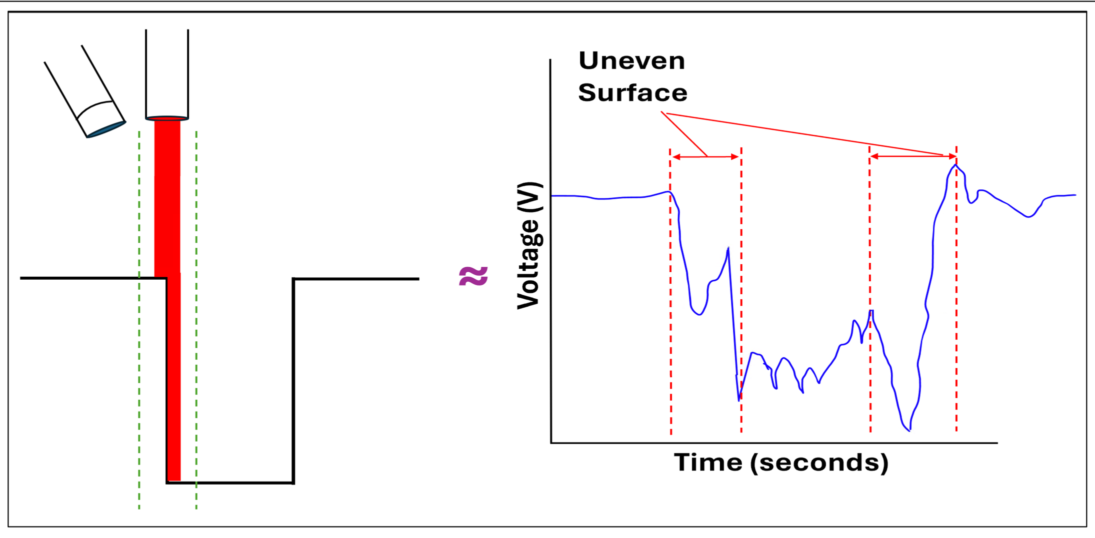

Figure 3: Voltage reading through an edge of 90 degrees

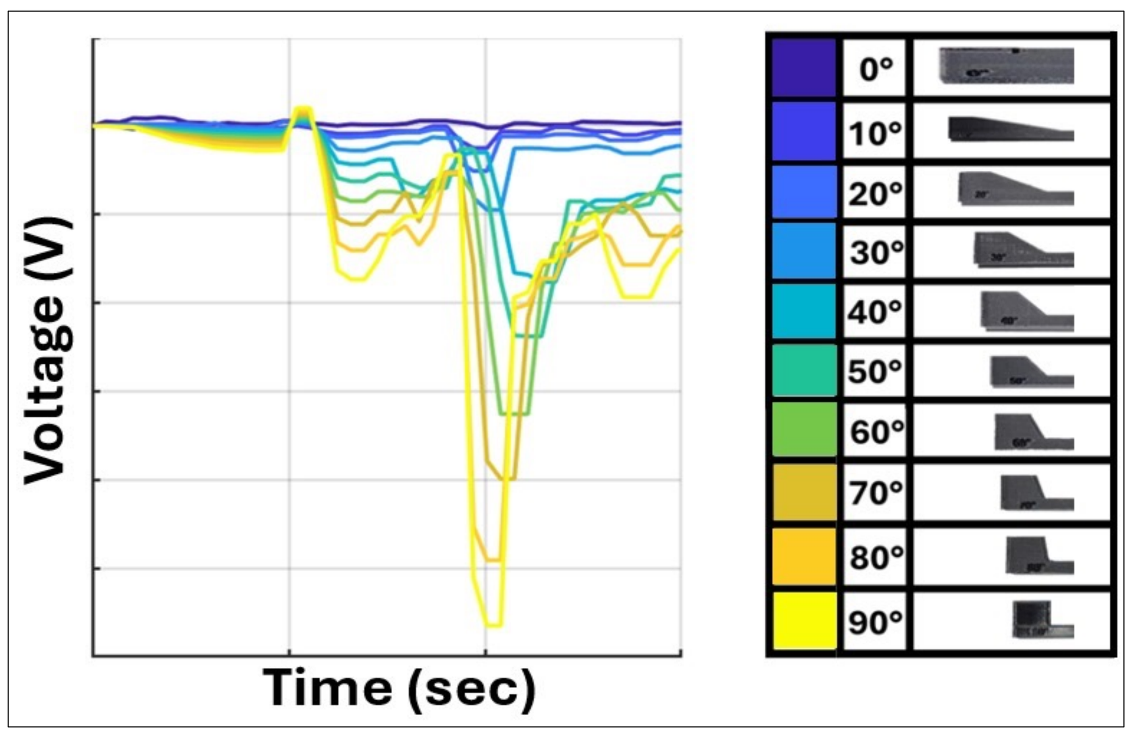

Figure 4: Profiles of edges at different pitches

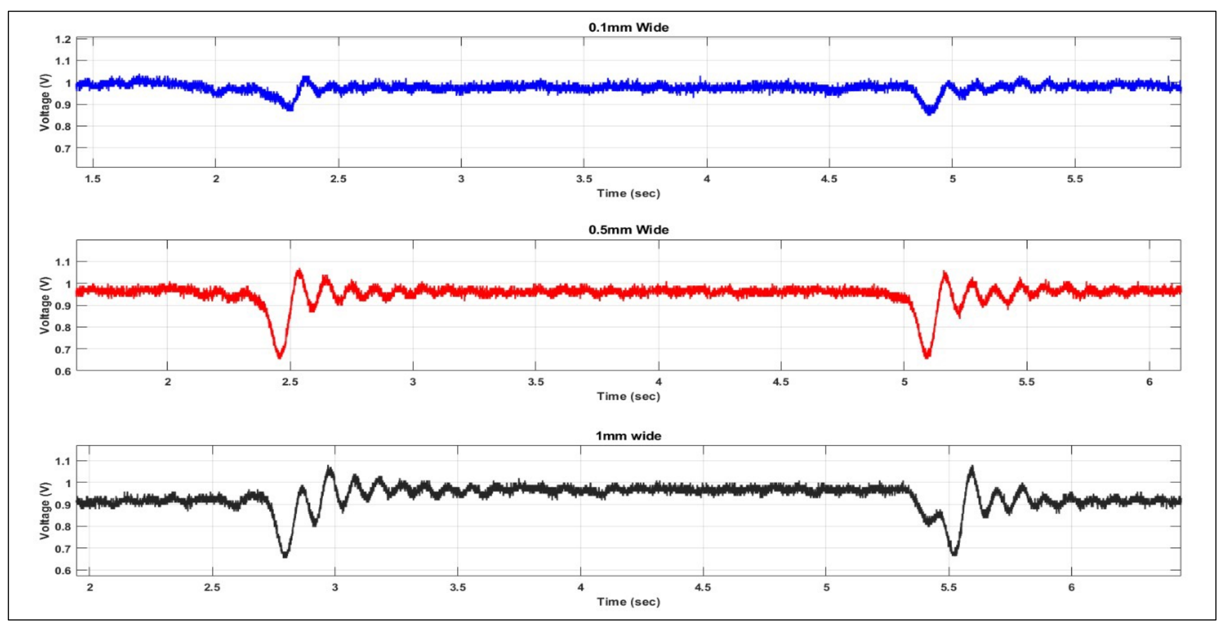

Figure 5: Profiles of cracks of different widths

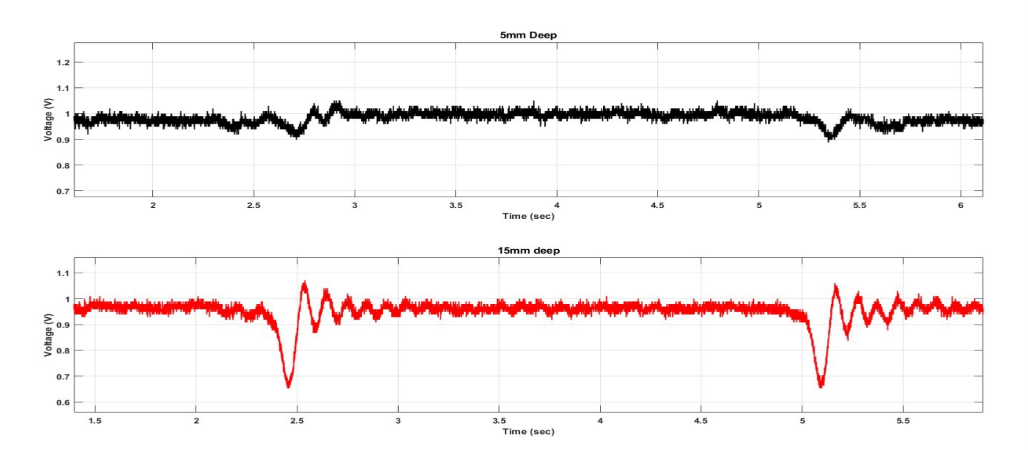

Figure 6: Profiles of cracks of different depths

Conclusions & Future Work

- Signal behavior of entering a crack was determined to be affected by the pitch of the wall between different leveled surfaces
- 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 were determined from the repeatability of voltages in each sample
- 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

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References

[1] Hobosyan, M. A., Carvajal, A. P., Srivastava, B. B., Zakia, T., Uddin, M. J., Martirosyan, K. S., ... & Dimakis, N. (2023). Computational and experimental study on undoped and Er-doped lithium tantalate nanofluorescent probes. Materials Today Communications, 106503.

[2] Feroz, S., & Abu Dabous, S. (2021). Uav-based remote sensing applications for bridge condition assessment. Remote Sensing, 13(9), 1809.

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