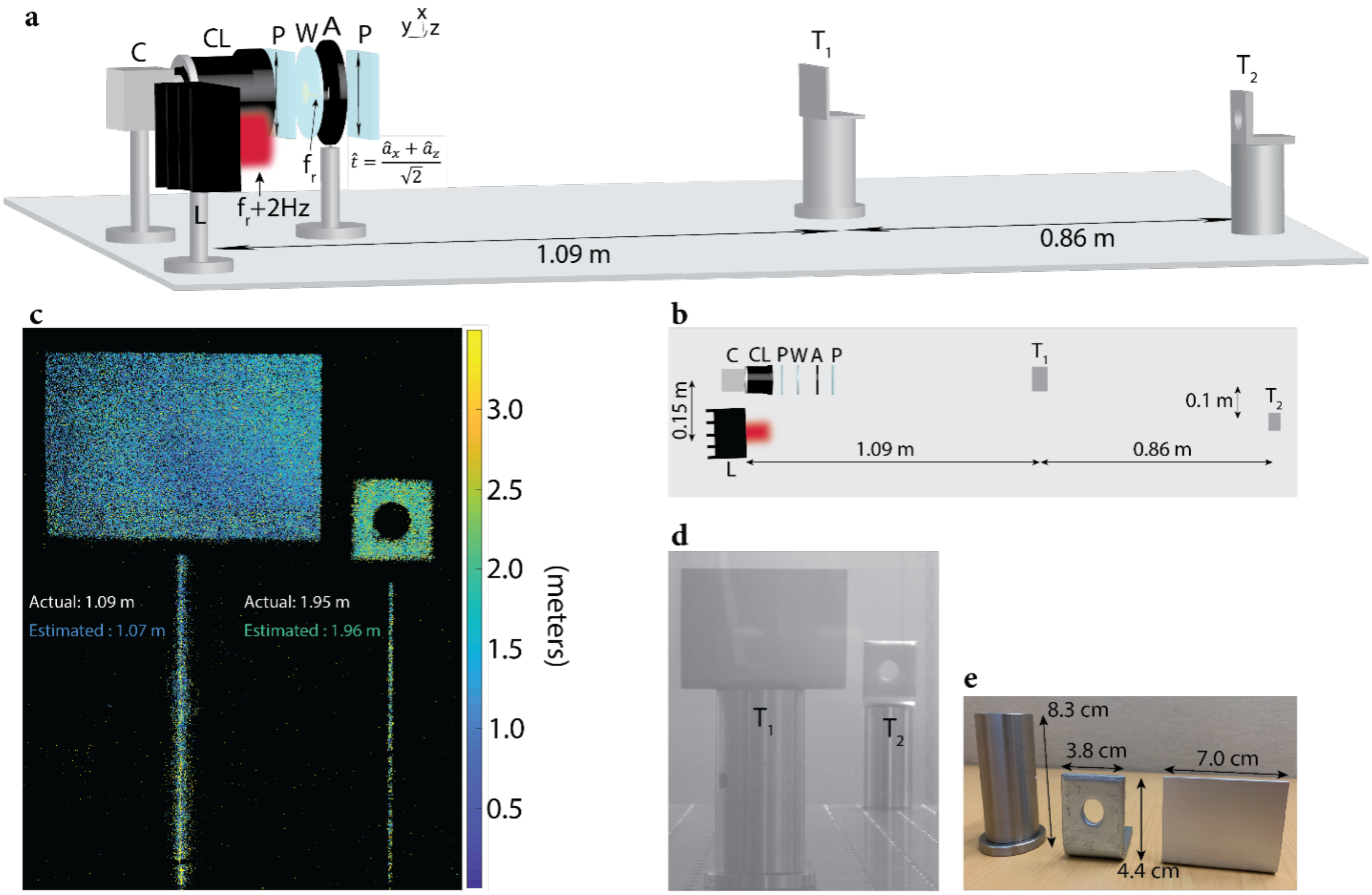
Docket #: S18-072

Full Field Imaging System Captures Position for Autonomous Vehicles and Tracking

Stanford engineers have developed an optical modulator to enable low-cost and high spatial-resolution time-of-flight imaging and LiDAR with low-cost standard image sensors. This technology supports real-time, wide field of view detection and could help imaging systems detect object features across scientific instrumentation, indoor tracking and autonomous vehicle applications. The Stanford design features a wide aperture, high acceptance angle, low required drive voltages and high operating frequency. It relies on the photoelastic effect and makes use of mechanical resonance to improve efficiency. The modulator can be used to enable efficient and low-cost per-pixel optical ranging. As a whole, the new optical imaging system employs standard CMOS image sensors that can determine the 3D position of objects with high spatial resolution, operating up to mid-range distances (30 m to 50 m). An LED light source (instead of a laser) illuminates the scene with an intensity-modulated beam which is reflected back and detected using a standard CMOS image sensor integrated with a resonant optical intensity modulator. The change in phase of the reflected light is used infer the distance of targets in the scene.

Stanford News Article "Stanford engineers enable simple cameras to see in 3D"



3D imaging demonstration using the proposed system. a) Schematic of the imaging system. **b)** Bird's eye view of the imaging system. **c)** Reconstructed depth map captured by the imaging system. **d)** Ambient image captured by the camera. **e)** The dimensions of the targets used for the imaging demonstration.

Stage of Development

As recently reported in *Nature Communications*, the researchers have demonstrated a new resonant free-space intensity modulator that modulates light from visible and up to near-infrared wavelengths at megahertz frequencies with **record efficiency**. The modulator can find immediate use in applications requiring free-space beams to be intensity-modulated with low RF power at megahertz frequencies over centimeter-square-scale apertures. **It could enable low-cost and high spatial-resolution ToF imaging and LiDAR with low-cost standard image sensors**.

Applications

- **3D Optical Image Sensing** for situational awareness, imaging and possibly localization in end user application such as:

  - autonomous vehicles
  - indoor tracking
  - robotics
  - scientific instruments

Advantages

- **Captures depth in real time** with high spatial resolution of 3D scenes
- **Relies on standard CMOS image sensors**
- **Simple design:**
  - no beam splitters or separation/combination of the beams
  - incoherent intensity modulated light from LED rather than a coherent laser, avoiding effects related to speckle

Publications

- Atalar, Okan, et al. "Longitudinal piezoelectric resonant photoelastic modulator for efficient intensity modulation at megahertz frequencies." *Nature communications* 13.1 (2022): 1-8.
- Atalar, Okan, et al. "Time-of-flight imaging based on resonant photoelastic modulation." Applied Optics 58.9 (2019): 2235-2247.
- Andrew Myers. Stanford engineers enable simple cameras to see in 3D. *Stanford Report* (2022).

Patents

- Published Application: 20210109223
- Issued: 12,019,160 (USA)

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