The proliferation of small satellites and multi-satellite networks creates a necessity for accurate satellite tracking and ranging as well as high-speed, low energy communications. This project seeks to:  
- Characterize the performance of microelectromechanical (MEMS) mirrors for tracking applications.  
- Evaluate the feasibility of a low-power optical tracking system operating on the principle of a modulated laser beam for use in optical communications, ranging, and high-precision time transfer.

Preliminary work focused on the characterization of commercially available MEMS mirror assemblies to determine their angular precision, linearity, and bandwidth. Subsequently, a two-axis mirror was implemented in a bench-top feedback-controlled tracking system and optimized for low power and fast response time. The system was then configured to track a detector at a range of 20 meters and demonstrated robust tracking despite a signal to background ratio of -15db due to high levels of ambient lighting.

Abstract

The beam is subsequently allowed to diverge with a half-angle of 12 milliradians before striking a 1mm² silicon photodiode connected to a 1GHz transimpedance amplifier.

Operating Principle

- To track a target, the steering mirror is modulated to sweep a laser beam across the target’s photodetector.  
- Detector output is sent to a lock-in amplifier and decoded to a DC signal corresponding to the pointing error.  
- Error signal is passed to an integrator which sets the DC bias on the mirror modulation to center the laser on the target.  
- Since a lock-in is not sensitive to frequencies other than the reference, the laser can be simultaneously modulated and steered in both axes when appropriate modulation frequencies are utilized.

Long-range tracking

Essentially identical except:  
- Reduced beam divergence (2.5 milliradian half-angle)  
- Lower modulation amplitude (6 milliradians peak-to-peak)  
- Photodiode is battery powered (due to layout constraints)

Results

- Low-frequency square wave error summed into the mirror bias.  
- At 20W detector illumination, optimal settling times of 200ms obtained for a 10 milliradian-equivalent step.  
- Configuring the system to respond more rapidly is possible but sacrifices tracking robustness and increased noise susceptibility.

Conclusions

- Robust, low power, tracking was demonstrated with <1mW of detected power and a signal-to-background ratio of -15db.  
- Tracking response rates were found to exceed requirements for most communications systems.  
- MEMS mirrors possess sufficient linearity, bandwidth, and pointing repeatability to be well suited for optical tracking applications.

Further work

- Although one-way tracking has been successfully implemented, the ultimate goal is to create a two-way system in which each node is able to communicate its detector readings to the other via the tracking beam, thus allowing for isolated devices to locate each other and communicate.
- Algorithms need to be implemented in order to reestablish a tracking lock in the event that one is interrupted and to initially locate a detector and lock to it without manual steering.