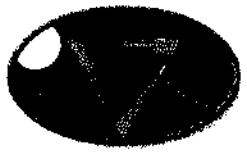
Liquid Crystal-based Beam Steering Device Development for NASA Applications

John Pouch, Hung Nguyen, and Felix Miranda
NASA Glenn Research Center, Cleveland, OH

Philip Bos, Oleg Lavrentovich, and Xinghua Wang
Liquid Crystal Institute, Kent State University, Kent, OH

The NASA Computing, Information and Communications Technology (CICT) Program is supporting the development of liquid crystal-based beam steering devices. The device would use inexpensive, light-weight, optical components, and it would have the following capabilities: electronic beam scanning to angles above 1 milliradian, and sub-microradian beam pointing accuracy. In order to correct for the imperfections resulting from the space-deployable optics, the technique of wave-front correction would be implemented. Hence, the output beam quality would be maintained. The potential applications could include satellite tracking, near-Earth inter-satellite communications, deep-space communications, and optical phased array systems. The status of the beam steering device development based on the liquid crystal technology and its relationship to prospective NASA mission scenarios will be described.

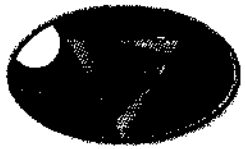


Space Communications Project

Liquid Crystal-Based Beam Steering Device Development for NASA Applications

John Pouch, Hung Nguyen, and Felix Miranda
NASA Glenn Research Center, Cleveland, OH

Philip Bos, Oleg Lavrentovich, and
Xinghua Wang
Liquid Crystal Institute, Kent State University, Kent, OH

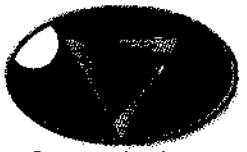


Space Communications Project

NASA Headquarters, Washington, DC:
Mr. Sean O'Keefe, NASA Administrator

NASA Glenn Research Center, Cleveland, OH:
Center Director: Dr. Julian Earls
Research and Technology Directorate: Dr. Jih-Fen Lei, Director
Communications Technology Division: Dr. Dan Williams, Chief
Antenna, Microwave, and Optical Systems Branch: Dr. Felix Miranda, Chief

Liquid Crystal Institute, Kent State University, Kent, OH
Professor Philip Bos
Professor Oleg Lavrentovich
Xinghua Wang



Space Communications Project

Funding by the Computing, Information and Communications Technology (CICT) Program

-- Space Communications Project Manager (CICT): Dr. Kul Bhasin

-- Level III Project Manager (CICT): Mr. Larry Wald

Background

• NASA Research Announcement, "Advanced Cross Enterprise Technology Development for NASA Missions," issued in CY 1999.

Thrust Area: High Rate Data Delivery

-- Precise optical beam pointing (suppressing of the effects of spacecraft platform vibrations)

sub-microradian steering accuracy

several milliradians of overall steering range

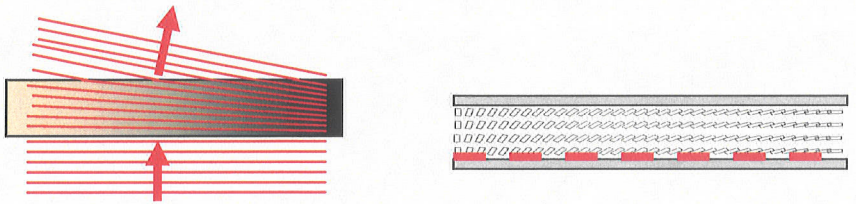
-- High accuracy (near diffraction limited), low cost, and thermally stable optical telescopes

-- Support two or more NASA Enterprises

Space Communications Project

Overview:

The project is focused on non-mechanical, low-cost, light-weight, low-power beam steering with wave-front control.



A gradient in the index of refraction is achieved with a liquid crystal device (source: Liquid Crystal Institute, Kent State University, Kent, OH).

Space Communications Project

Performance aspects:

- Design for 1.5 micron wavelength operation
- Testing at helium-neon wavelength
- Non-mechanical beam steering
- Scanning range ~ milliradians
- Beam pointing accuracy ~ submicroradian
- Wave-front correction capability
- Low weight, low cost, low power consumption
- Use of COTS technology, e.g., liquid crystal on silicon (LCOS) components

Space Communications Project

Additional characteristics:

- High output efficiency (89% or better) measured for steering device
- Accurate steering: to (1/10) x beam divergence
- An 8-inch parabolic reflector with distortions was corrected

  -- Before correction: 34 wavelengths of aberration peak-to-valley at 0.6328 microns

  -- After correction: (1/10) wavelength of aberration peak-to-valley
- A beam steering device (currently at Technology Readiness Level 3*) has been delivered to the NASA Glenn Research Center. It demonstrates wave-front correction, target tracking, beam shaping, and beam splitting into two and four beams (independent movement). This is the second of two working devices that have been sent to NASA for evaluation.

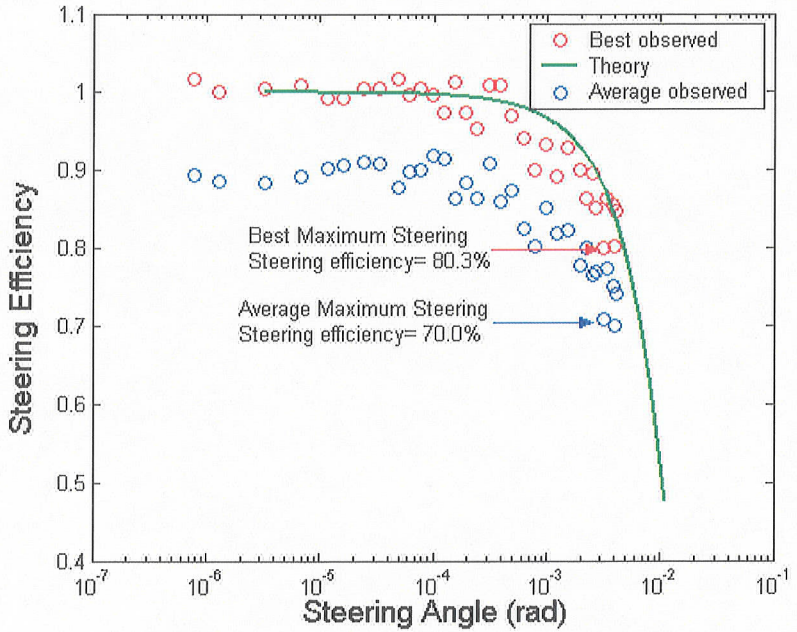
* "Analytical and experimental critical function and/or characteristic proof-of-concept" (source: NASA).

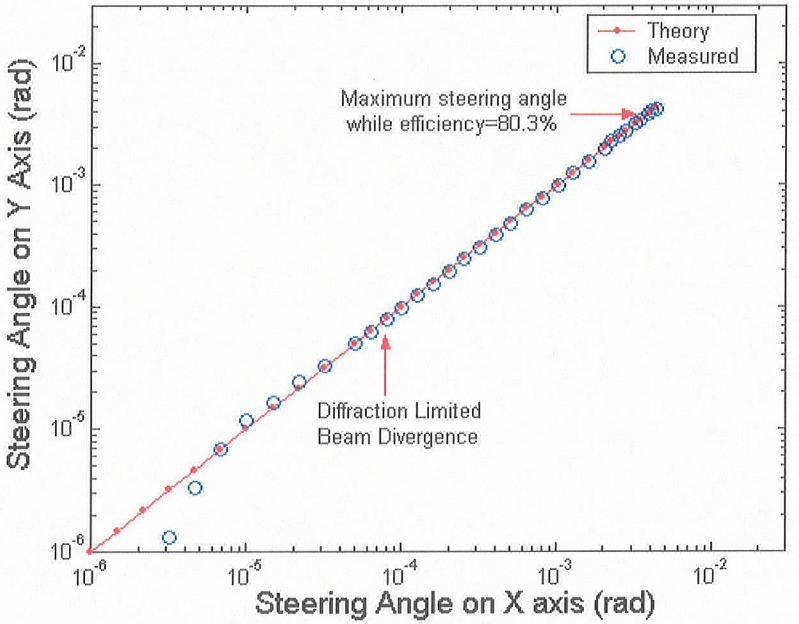
Two-dimensional LCOS optical phased array (OPA) steering efficiency and accuracy

Steering range: ± 4 mrad (± 0.23°) along x- and y-axes

Steering accuracy: 10 μrad (1/10 diffraction limited beam divergence)

Steering efficiency: > 80%



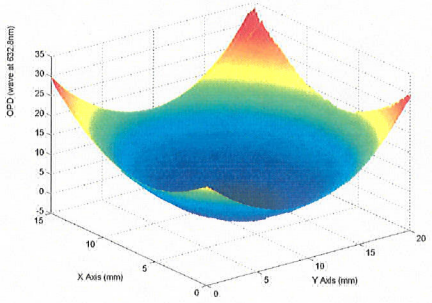


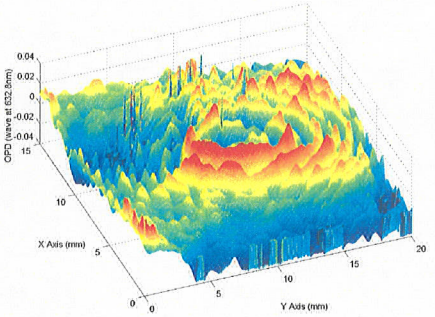
Source: Liquid Crystal Institute, Kent State University, Kent, OH.

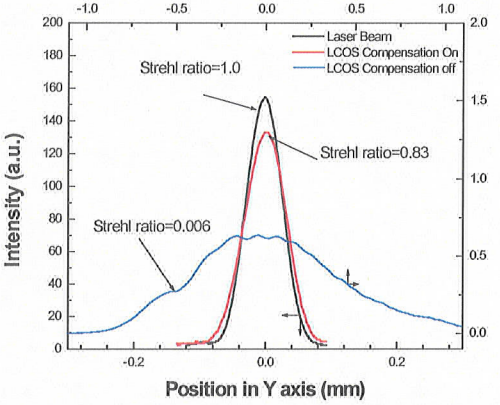
High-resolution wave-front control in large optical components

Space Communications Project

Wavefront aberration introduced by the primary mirror of an 8-inch telescope



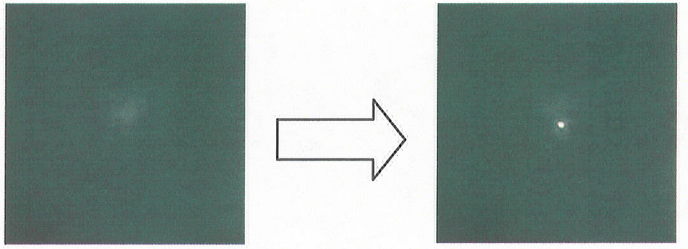




Before correction:

34 wavelengths of aberration peak-to-valley

Strehl ratio 0.006



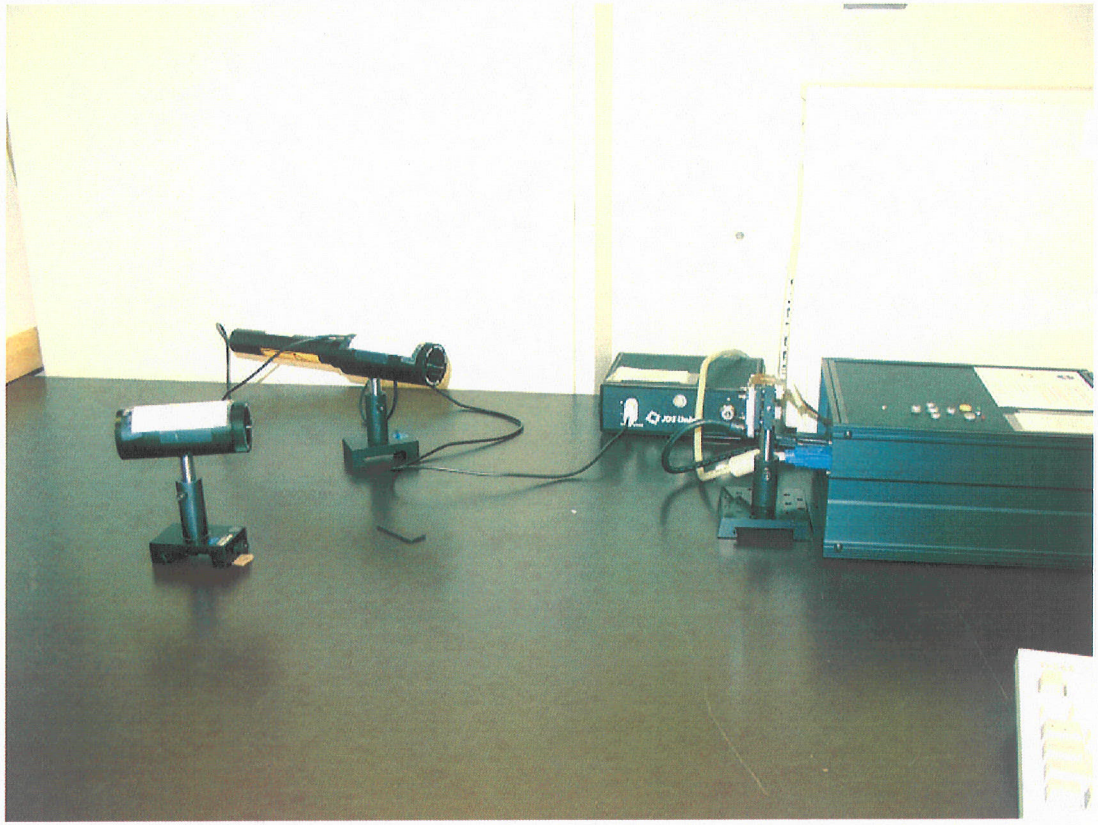
After correction:

1/10 wavelength of aberration peak-to-valley

Strehl ratio=0.83

Diffraction limit attained

Source: Liquid Crystal Institute, Kent State University, Kent, OH.



Optical beam steering device at the NASA Glenn Research Center, Cleveland, OH (source: Liquid Crystal Institute, Kent State University, Kent, OH).

Space Communications Project

President George Bush's Space Vision announced on January 14, 2004.

- Complete International Space Station
- Return to the Moon
- Travel to Mars and beyond
- Build Crew Exploration Vehicle

Liquid crystal optical beam steering technology development supports the following NASA Offices: Exploration Systems, Earth Science, and Space Science.

Applications:

- Submicroradian beam pointing technology. Scanning range ~ milliradians; in situ wave-front correction; low cost, compact design, low weight, low power consumption
- OPA systems (communications and spectroscopy)
- Precision tracking of robotic systems, landers, spacecraft, and astronauts (Moon/Mars)
- Optical communications systems in support of robots, landers, spacecraft constellations, and astronauts (Moon/Mars).
- Low-cost elements for advanced, large-aperture, optical telescopes (orbiting/deployed on the Moon)
- Strategic mining operations (planetary systems)