Extended Range Coherent Imaging

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LMCT platform for long-range coherent imaging is based on CAPEOS Technology

- CAPEOS = Combined Active Passive EO System
- CAPEOS features:
  - Wide area coherent imaging
    - Fine detail, 3D, turbulence mitigation
    - Aperture synthesis
    - Photon-limited detection
    - COTS cameras and sources
    - and more…..
Motivation for CAPEOS

- Large aperture imaging system based on segmented or modular optics have been demonstrated
- CAPEOS offers significant SWAP savings

JWST

Features:
- Passive
- Segmented Primary
- Common Secondary

STAR-9, MMTT

Features:
- Passive
- Segmented Primary
- Separate Secondaries
- Optical Combiner

CAPEOS

Features:
- Active, Coherent
- Passive (Single Aperture)
- Modular Design
- Digital Processing
- 3D Imaging
CAPEOS Overview

- Image plane detection using COTS FPA
- Standard passive imaging mode
  - Atmospheric compensation using “dewarp-and-add” correction
- Coherent active detection mode is based on digital holography (DH)
  - Uses standard MOPA (master oscillator, power amplifier) pulsed laser
  - Coherent detection allows low illumination power levels
  - Atmospheric compensation using autofocus algorithms
  - High-resolution 3D imaging
- New method for multi-function imaging systems
CAPEOS Active Coherent Imaging

1) Intensity Data

2) FFT of Intensity

3) Complex Valued Image

4) FFT to pupil

5) Apply aberration, compute sharpness, maximize

6) Final Image

Maximize Sharpness $\Sigma (Intensity)^p$ by adding phase (48 Zernikes)

Processing similar to SAR autofocus
Fiber-based CAPEOS Hardware

- CAPEOS hardware provides advanced capability in small package
- Further SWAP reductions readily achievable
- Eyesafe, > 1 kHz PRF
Multi-Aperture CAPEOS Image Formation Processing

Exit Pupil → Detector Array → FFT → Pupil (Digital) → Synthesized Pupil → FFT → Synthesized Image
Multi-Aperture Technical Approach

1. Target flood illuminated: coherent images recorded by sub-apertures

2. Image reconstructed using digital imaging methods

Aberrated Pupil

Aberrated Image

Digitally Corrected Image
3D Image Formation

- Sensor operation based on high-speed Fourier processing
- Range > 1 km, moving object (vehicle running)
- Processing similar to IFSAR

Coherent Image

Close-Up Photograph of Target

\[ \lambda_1 \text{ Image} \rightarrow \lambda_2 \text{ Image} \rightarrow \text{Phase Difference} \rightarrow \text{3D Image} \]

Raw
Example CAPEOS Active Images

- Active 2D and 3D images shown with close-up reference images
- 3D images are color-encoded and not unwrapped

Target 100 m

Target 1.5 Km

Target 5 Km

Close-Up

2D Active

3D Color Encoded

Facial imaging with 1 mm, 3D resolution at 100 m

One inch 3D bars well-resolved at 1.5 Km

Imaging with Extended FOV
CAPEOS Summary

• LM is making great progress on CAPEOS for long-range coherent imaging
  – Fine-resolution 2D, 3D imaging
  – Coherent system allows low illumination powers
  – Allows advanced imaging functions
    • Synthesis for fine resolution, 3D, Vibration, Polarization

• Applicable to several missions