



Extended Range Coherent Imaging

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

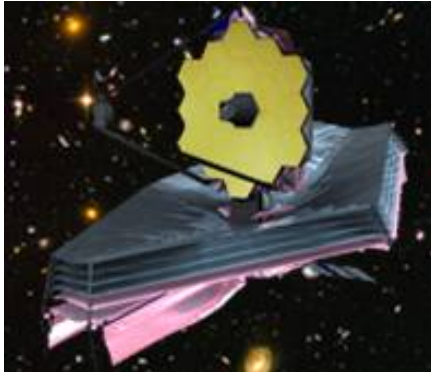
- **CAPEOS = Combined Active Passive EO System**
- **CAPEOS features:**
 - **Wide area coherent imaging**
 - **Fine detail, 3D, turbulence mitigation**
 - **Aperture synthesis**
 - **Photon-limited detection**
 - **COTS cameras and sources**
 - **and more.....**

Motivation for CAPEOS



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

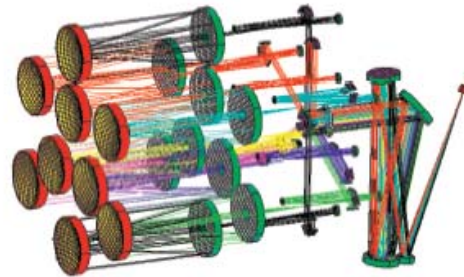
JWST



Features:

- Passive
- Segmented Primary
- Common Secondary

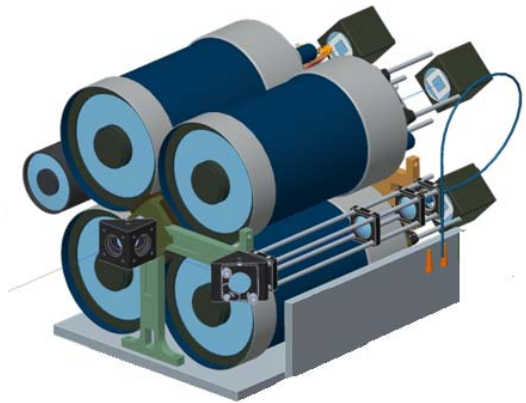
STAR-9, MMTT



Features:

- Passive
- Segmented Primary
- Separate Secondaries
- Optical Combiner

CAPEOS



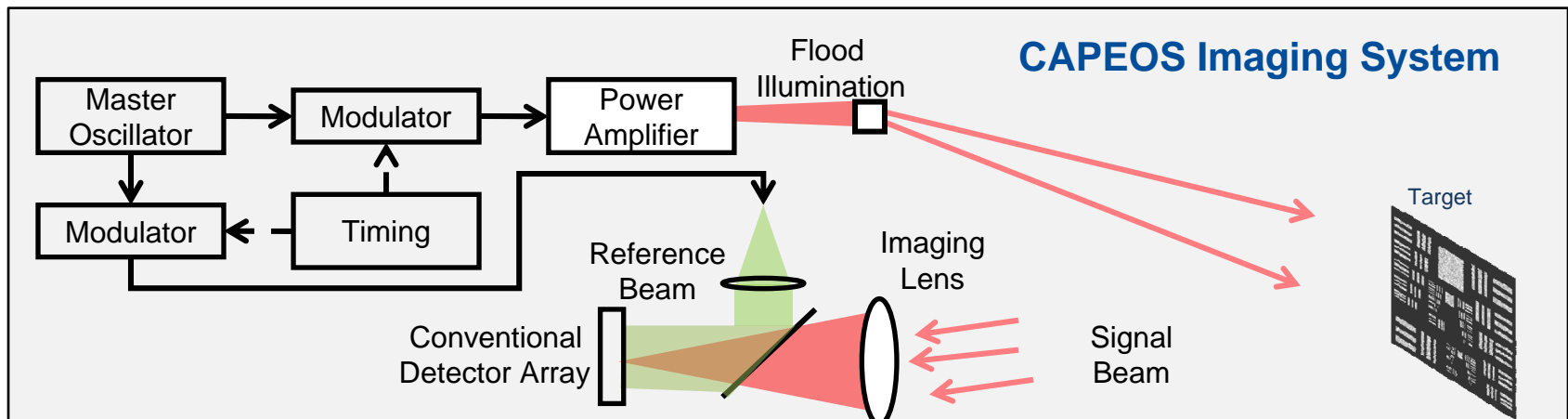
Features:

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

CAPEOS Overview



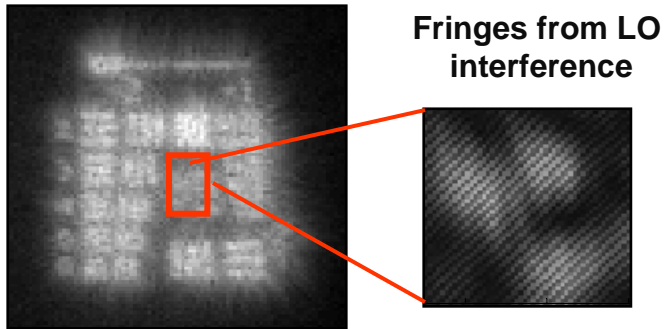
- Image plane detection using COTS FPA
- Standard passive imaging mode
 - Atmospheric compensation using “dewarp-and-add” correction
- Coherent active detection mode is based on digital holography (DH)
 - Uses standard MOPA (master oscillator, power amplifier) pulsed laser
 - Coherent detection allows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



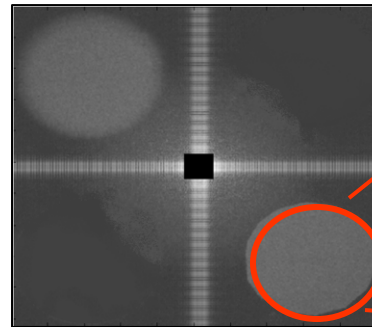
CAPEOS Active Coherent Imaging



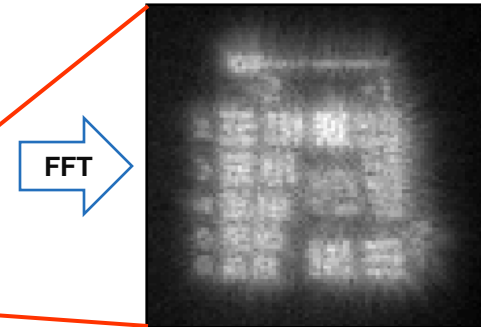
1) Intensity Data



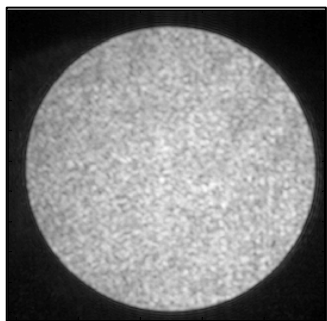
2) FFT of Intensity



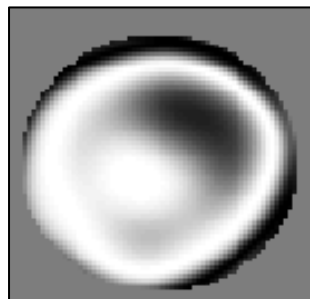
3) Complex Valued Image



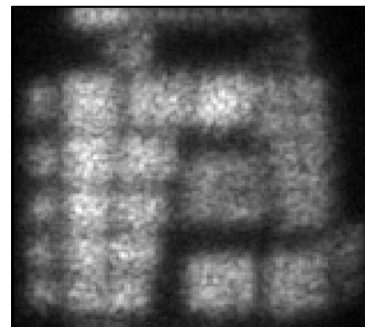
4) FFT to pupil



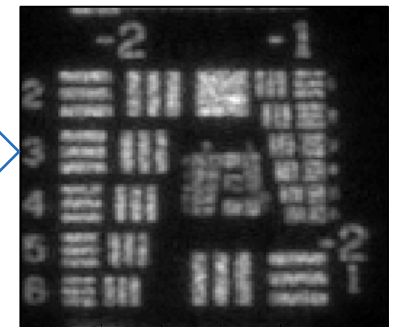
+



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



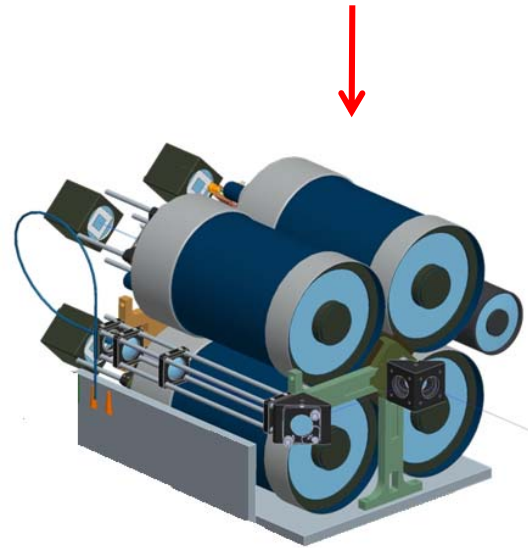
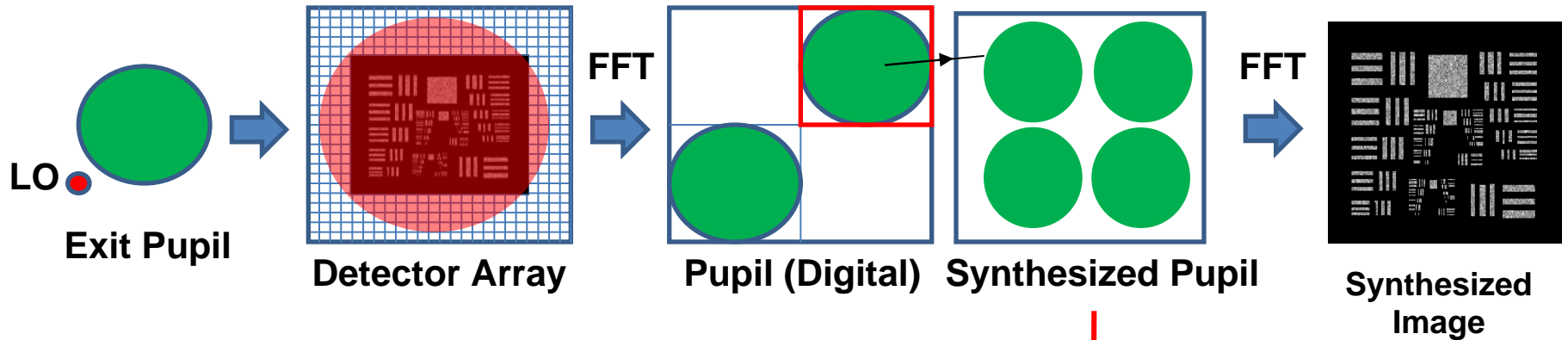
COTS Telescope

COTS Camera

LO insertion

Fiber Amplifier

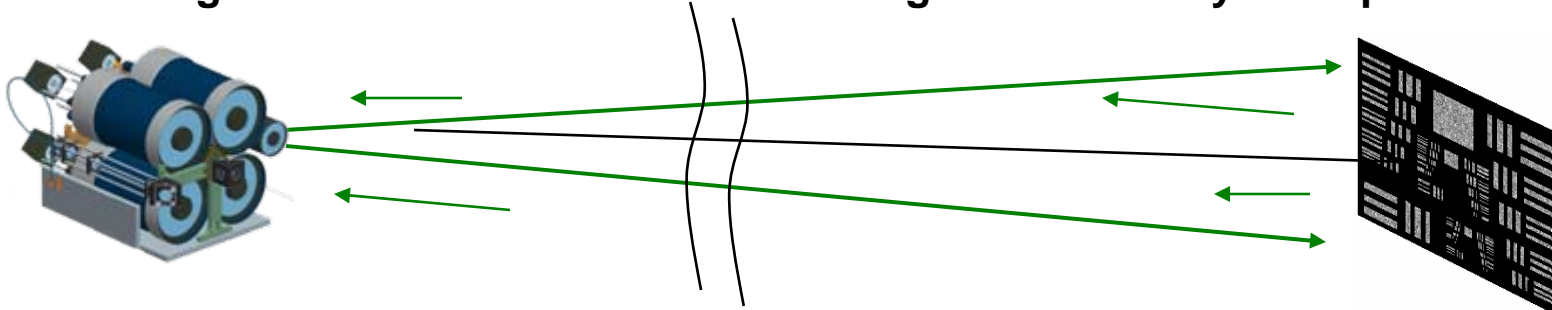
Multi-Aperture CAPEOS Image Formation Processing



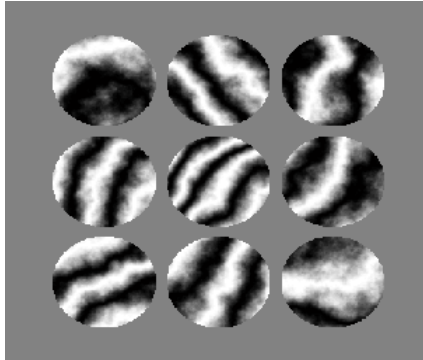
Multi-Aperture Technical Approach



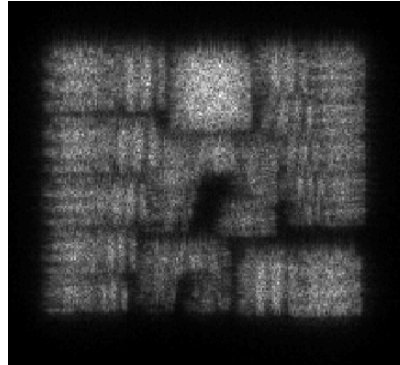
1. Target flood illuminated: coherent images recorded by sub-apertures



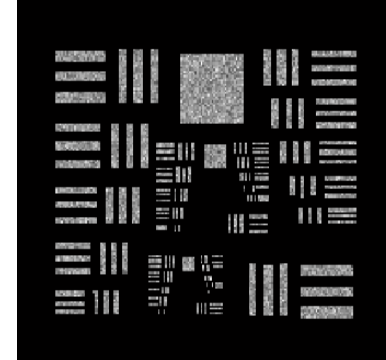
2. Image reconstructed using digital imaging methods



Aberrated
Pupil



Aberrated
Image

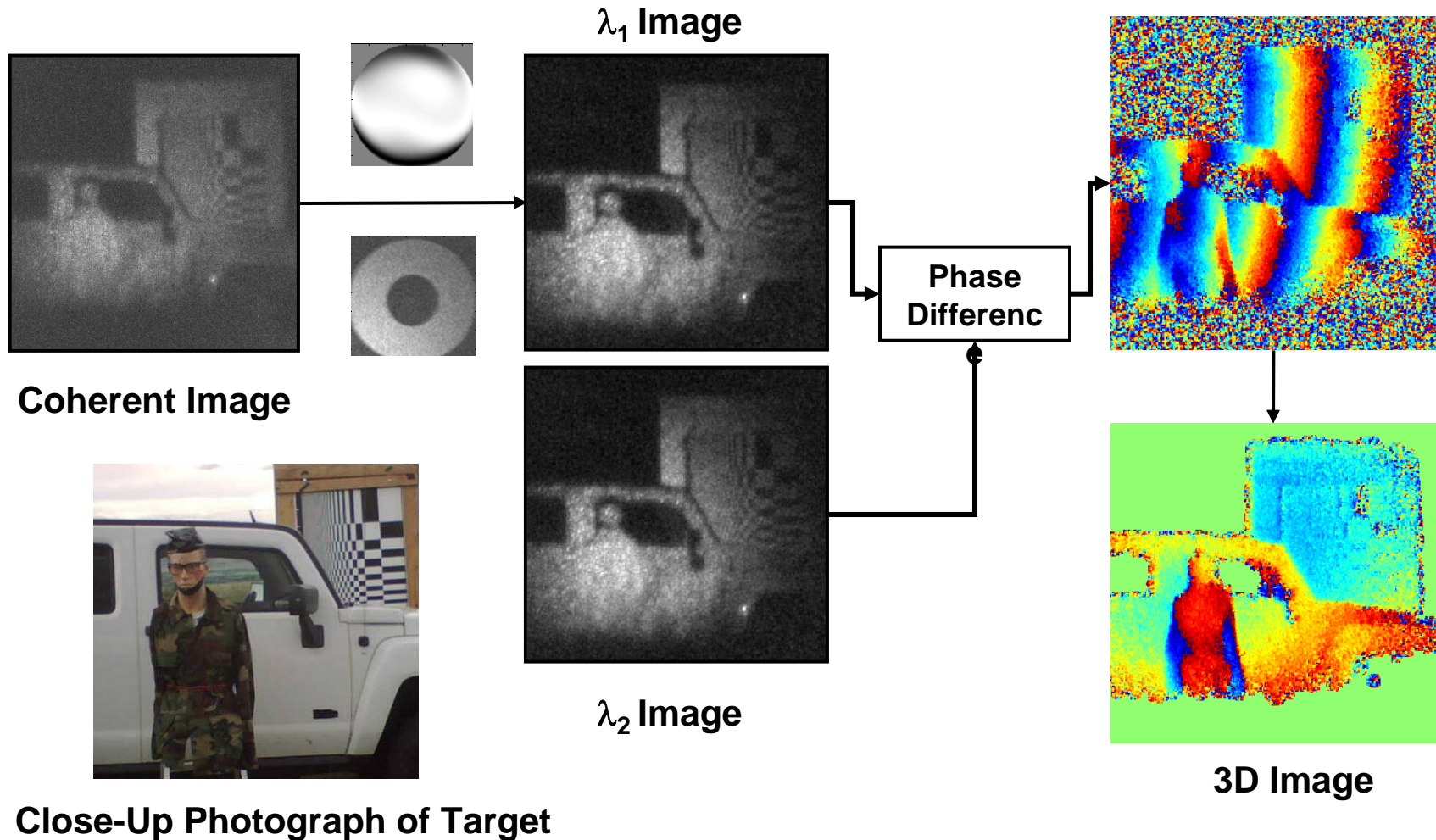


Digitally
Corrected Image

3D Image Formation



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



Example CAPEOS Active Images



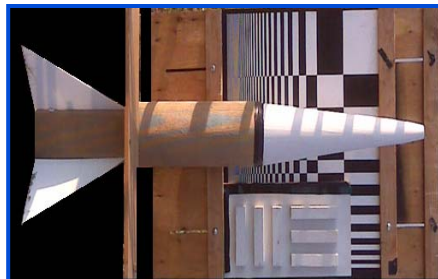
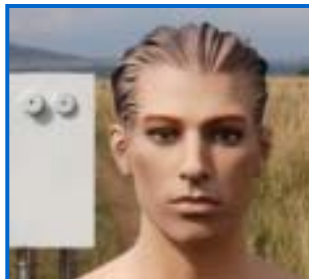
- Active 2D and 3D images shown with close-up reference images
- 3D images are color-encoded and not unwrapped

Target 100 m

Target 1.5 Km

Target 5 Km

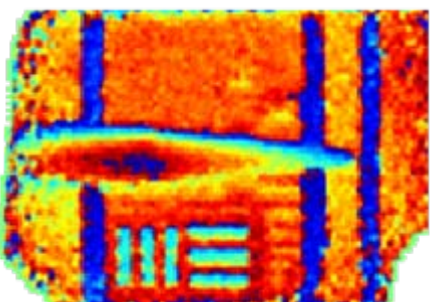
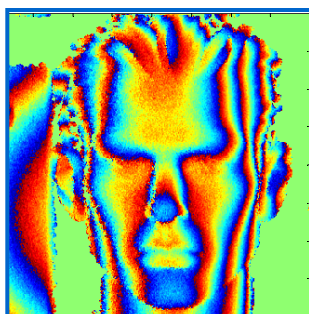
Close-Up



2D Active



3D Color Encoded



Imaging with
Extended FOV

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

One inch 3D bars well-
resolved at 1.5 Km

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**

