Synthetic aperture interferometry: High-resolution optical measurement over an exceptionally large field of view

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Introduction

Aim: To emulate Coherence Scanning Interferometry (CSI) over a large area
CSI Output

Light Source

Beam Splitter

Mirau Interferometer

Sample

CCD
Plane wave illumination/observation pairs

Illuminate with a plane wave ....

Wave Vectors

$k = k_o - k_i$

... Measure phase and amplitude of observed plane wave components
The illumination wave vectors are restricted ......

- Wave vectors must pass through the objective lens (or condenser)
- For a mono-chromatic system wave vectors must lie on Ewald sphere
.. and the observation wave vectors are restricted

- Wave vectors must pass through the objective lens
- For a mono-chromatic light wave vectors must lie on Ewald sphere
Mono-chromatic, multiple illumination directions

This is the **transfer function** of quasi-monochromatic coherence scanning interferometry
1. Multi-Camera/Source Coherent Imager Concept

- 225 coherent imagers (15 x 15)
- 225 reference beams required (one per CI)
- 225 object beam positions (configurable)
- 3 optical wavelengths
- Specimen size up to 100 x 100mm
- Stand-off 180mm
- Illumination fibre launch NA > 0.5
Coherent Imager: BS Configuration

- Simple optical design
- Lower cost
- Enabling technology
Focussed Ion Beam (FIB) Fibre

Ceramic ferrule

Silver coating

125 μm Pinhole

1 μm

SM fibre

125 μm
Side-Launch FIB Fibre Design

- Reference fibre
- CMOS sensor
- Aperture
- Single-mode optical fibre (SM600)
- Silver coating
- Pinhole
- 125 μm
- 45°
- High NA
Object Reconstruction

CI → Object

Illumination → d≈8.5 cm

NA=0.54
**Fibre Launch & Distribution**

Lightech LT1100 1×16

Laser

- 785nm $\lambda_1$
- 850nm $\lambda_2$
- 852nm $\lambda_3$

Thorlabs LP785-SAV50
50mW pigtailed laser diode

Obj beam launch

Ref beam launch
RPi Cluster

Loughborough University

#InspiringWinners since 1909
The Calibration Problem

• The **cameras** need to be positioned sufficiently well to identify the plane waves, $k_0$, and place them in angular space
  - Rotation tolerance is of the order of the angular resolution
  - Position tolerances is of the order of the aperture size

• The **sources** need to be positioned sufficiently well to identify the plane waves, $k_i$, and place them in angular space
  - Position tolerances are of the order of the aperture size

• The **phase** of the plane waves component $k_0 - k_i$ must be defined to better than $\pi/2$
  - Phase needs to be “locked” at various positions in object space

$$k = k_0 - k_i$$
Calibration
SAI – Phase Locking with Active Target

Image at the object plane

Guide Star

Coherent Imager
2x High NA Fibre Sources
Scanning Source SAI

Object Fibre

Reference Fibre
Conclusions

• The SAI concept as first proposed works!
  • Compact cameras can be made the required standard using;
    • Beam-splitter cubes and FIB-etched fibres or
    • No beam-splitter and novel side launch fibres

• The position of the cameras and source fibres can be found to the required tolerances using a novel method which we call differential trilateration and a novel chrome on glass calibration plate
Conclusions

- Raspberry Pi cameras characterised (IR performance, 6 bit resolution and 2 FPS)
- Raspberry Pi boards have sufficient capacity to record the 675 video frames required.

- We have developed a novel “spotlight method” to reconstruct fringes in a region (or multiple regions) that are the size of the native camera resolution (approx. 100µm)
- Raspberry Pi boards process holograms locally and pass only 8 Bytes of data per region
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Questions?