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

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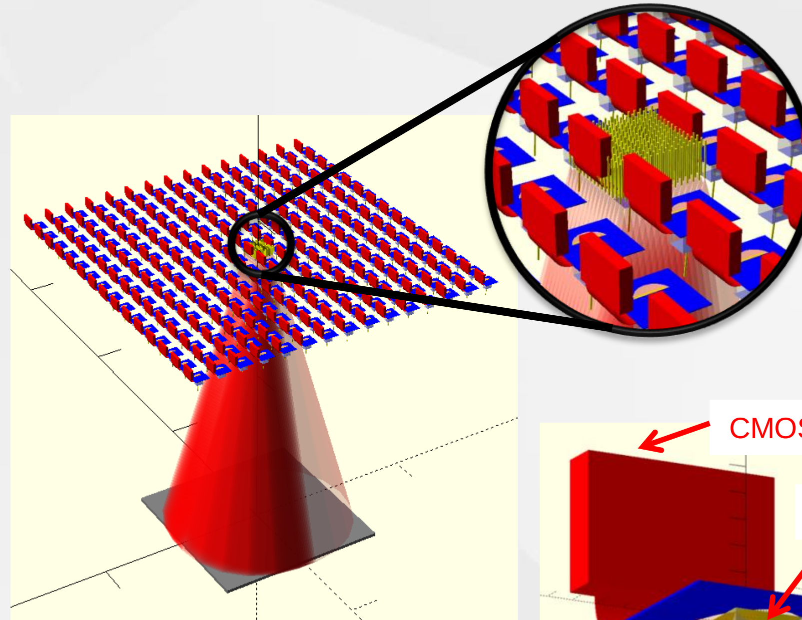
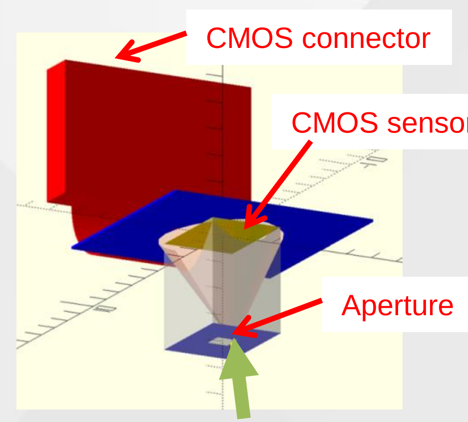
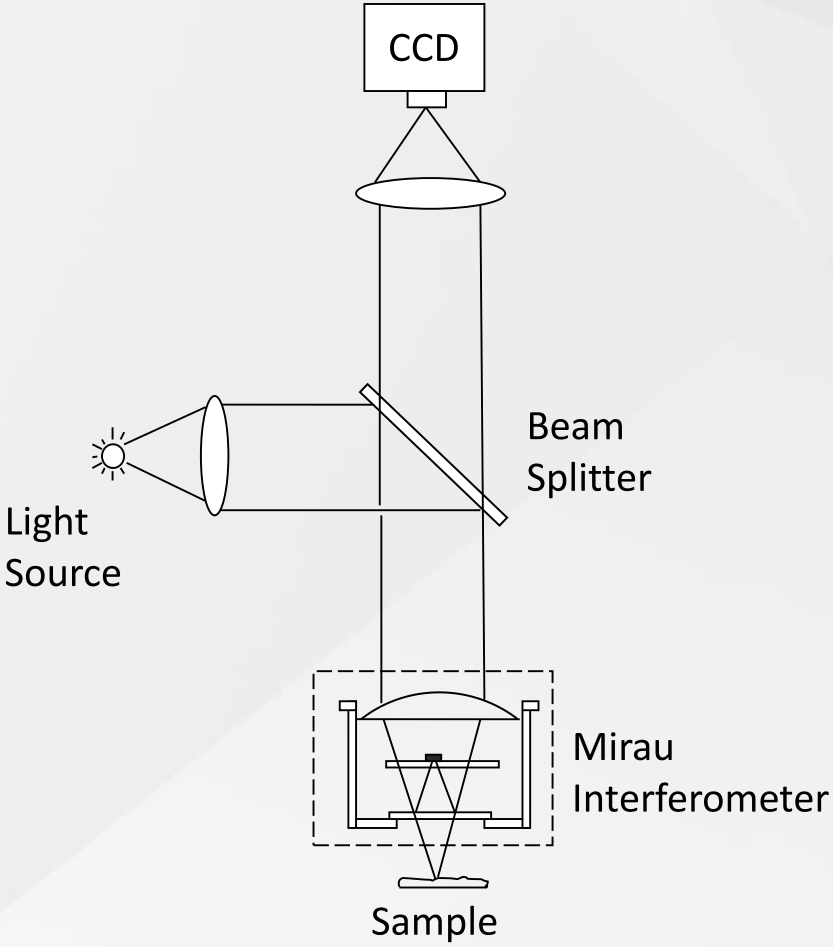
Introduction

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

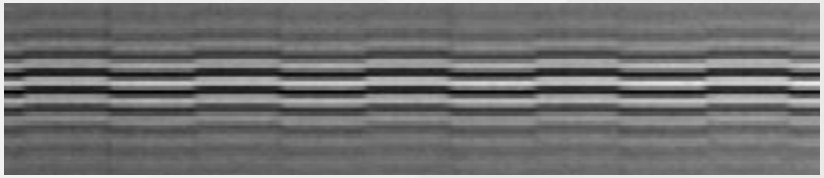




CSI Output

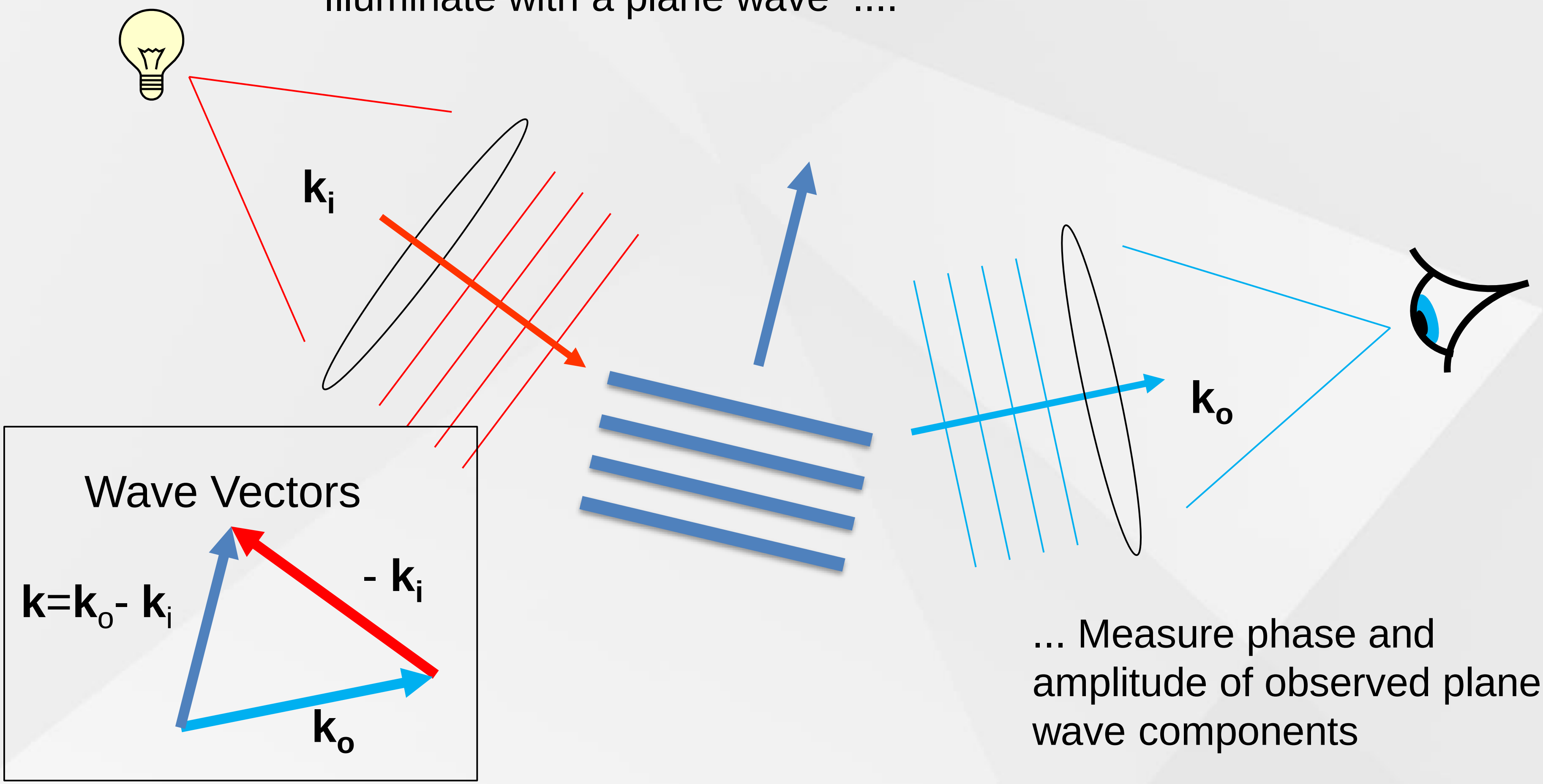


CCD
Beam
Splitter
Light
Source
Mirau
Interferometer
Sample



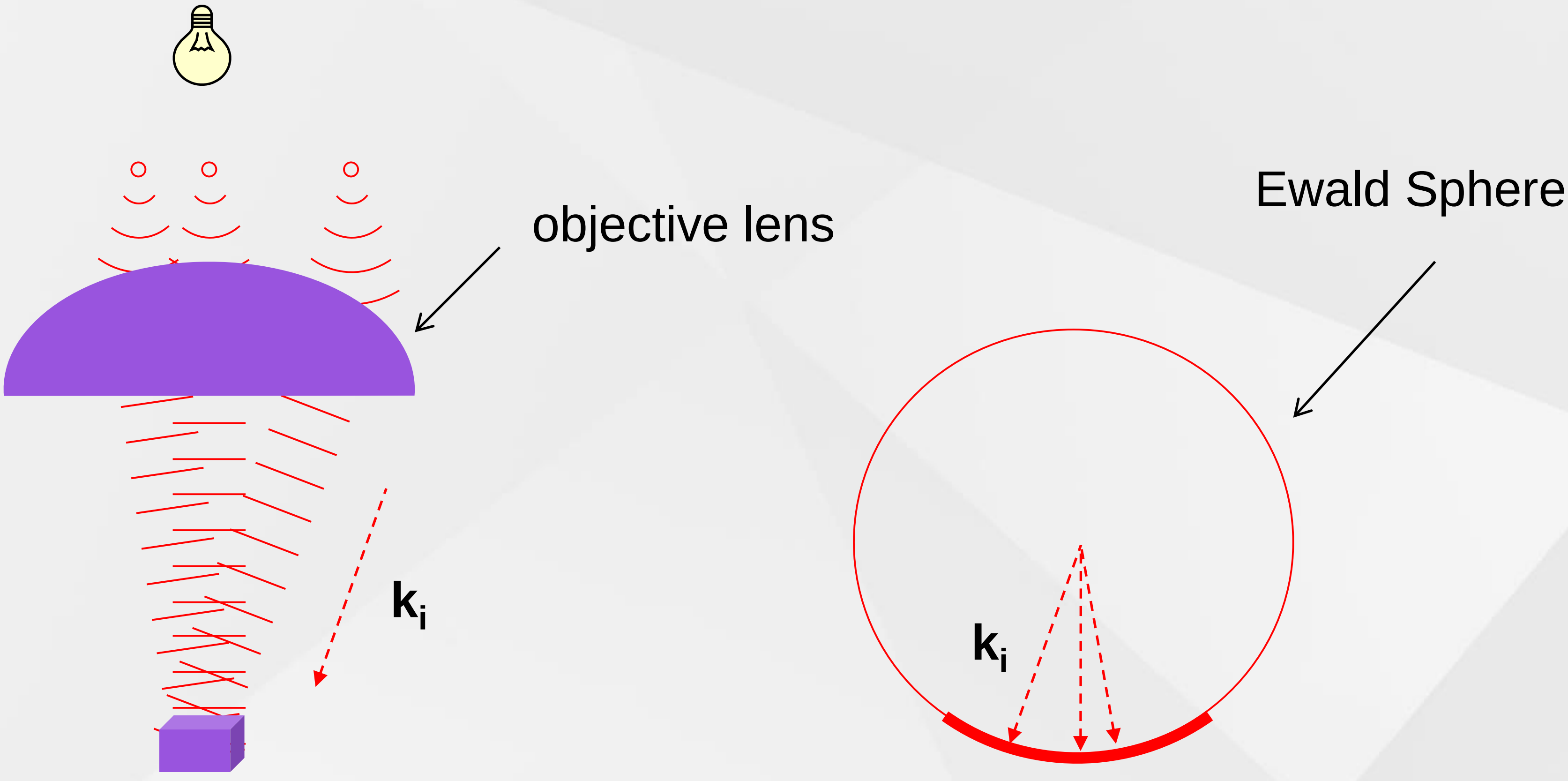
Plane wave illumination/observation pairs

Illuminate with a plane wave ....



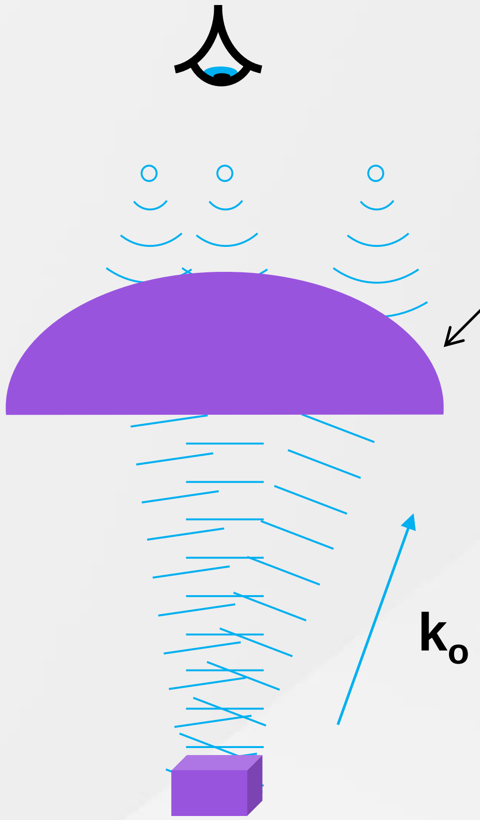
... Measure phase and amplitude of observed plane wave components

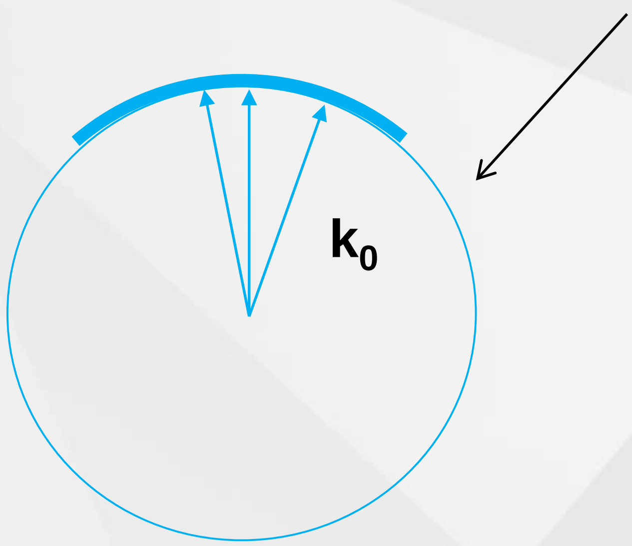
The illumination wave vectors are restricted .....



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

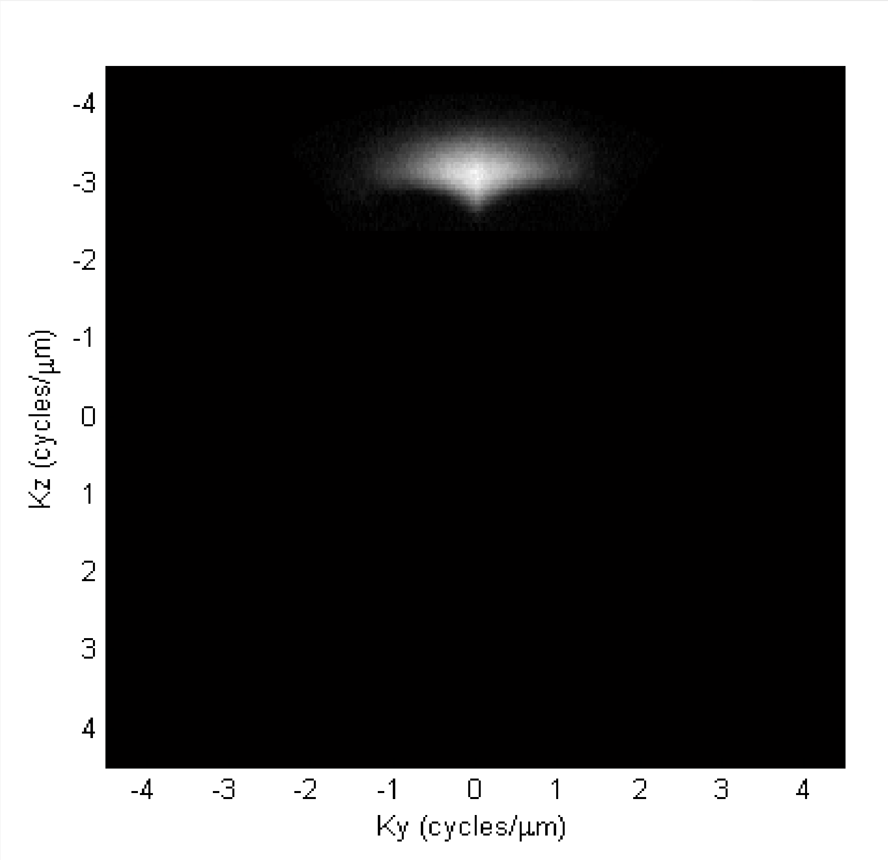
.. and the observation wave vectors are restricted

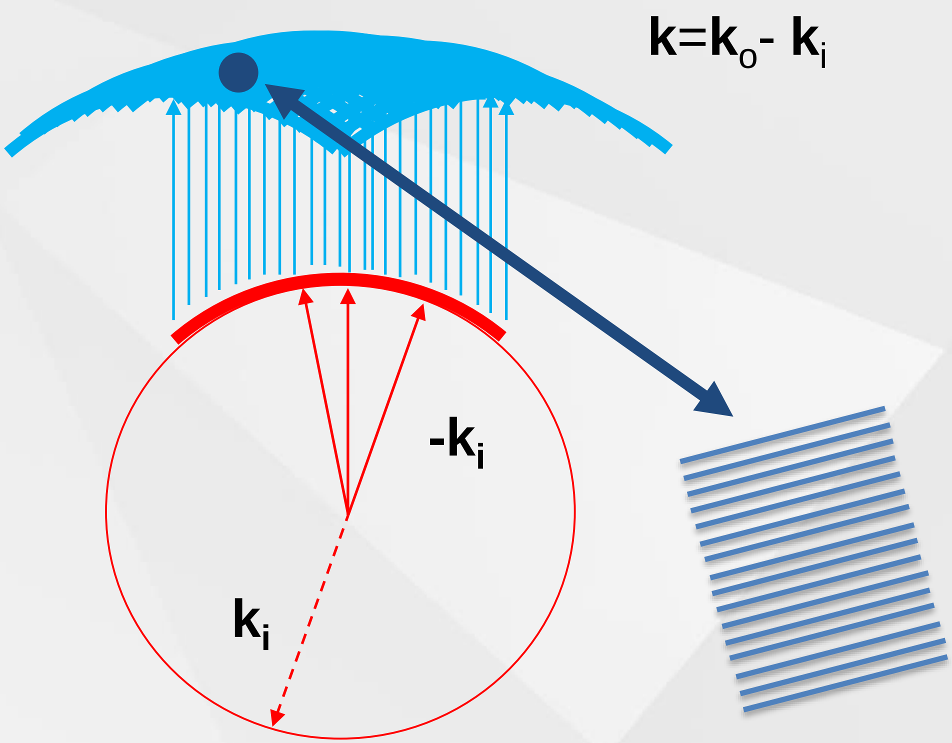




- Wave vectors must pass through the objective lens
- For a mono-chromatic light wave vectors must lie on Ewald sphere

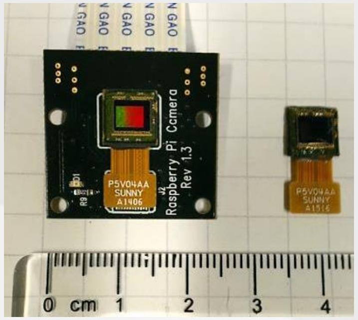
Mono-chromatic, multiple illumination directions



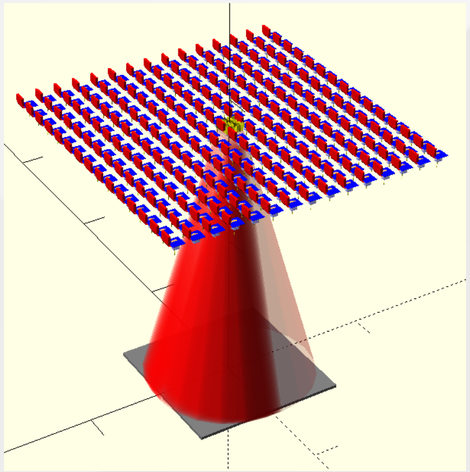


This is the **transfer function** of quasi-monochromatic coherence scanning interferometry

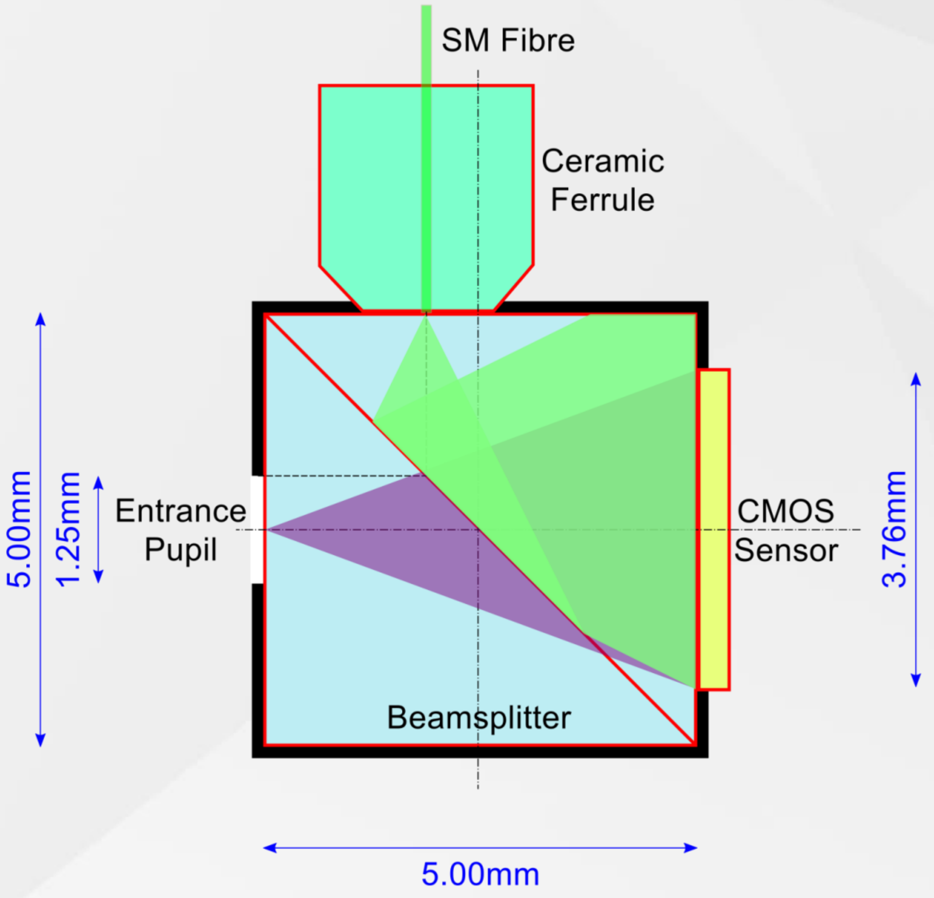
1. Multi-Camera/Source Coherent Imager Concept



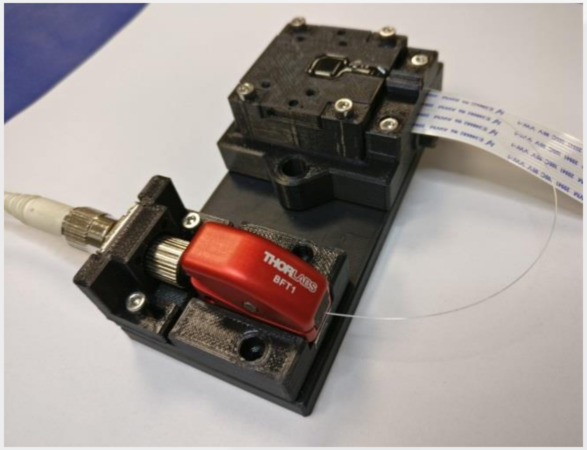
- 225 coherent imagers (15 x 15)
- 225 reference beams required (one per CI)
- 225 object beam positions (configurable)
- 3 optical wavelengths
- Specimen size up to 100 x 100mm
- Stand-off 180mm
- Illumination fibre launch NA > 0.5



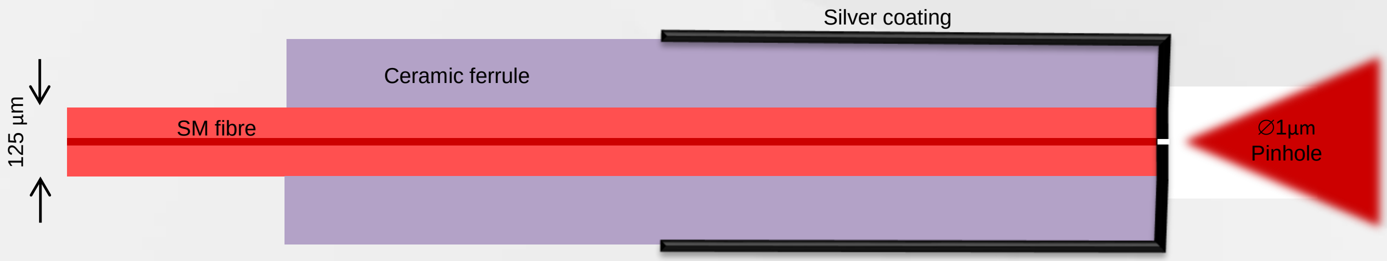
Coherent Imager: BS Configuration

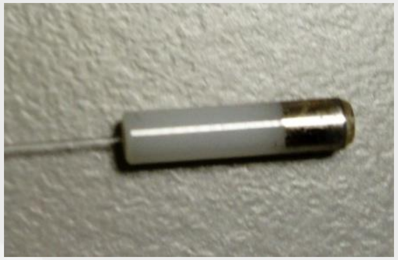


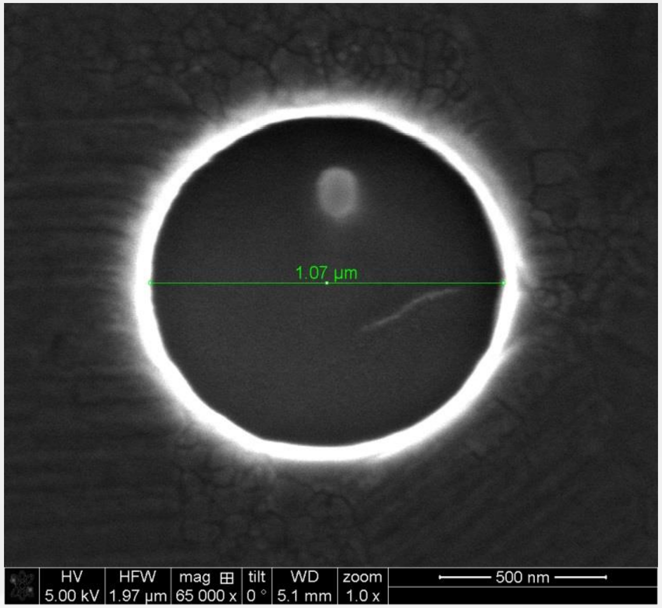
- Simple optical design
- Lower cost
- **Enabling technology**

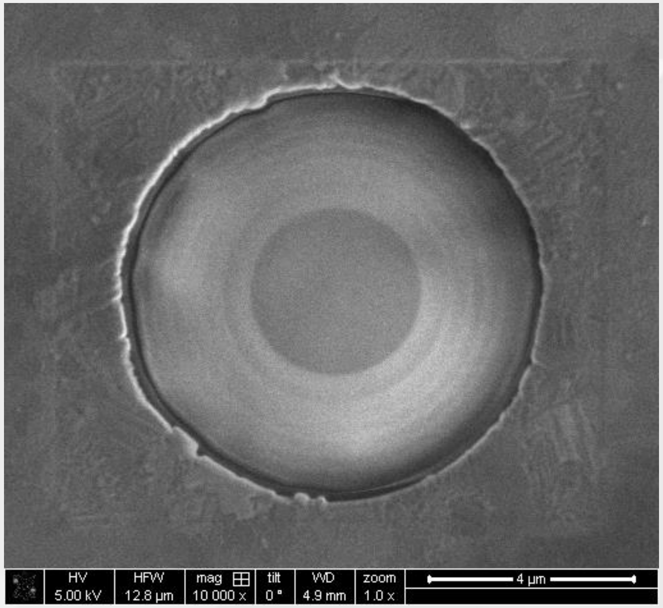


Focussed Ion Beam (FIB) Fibre

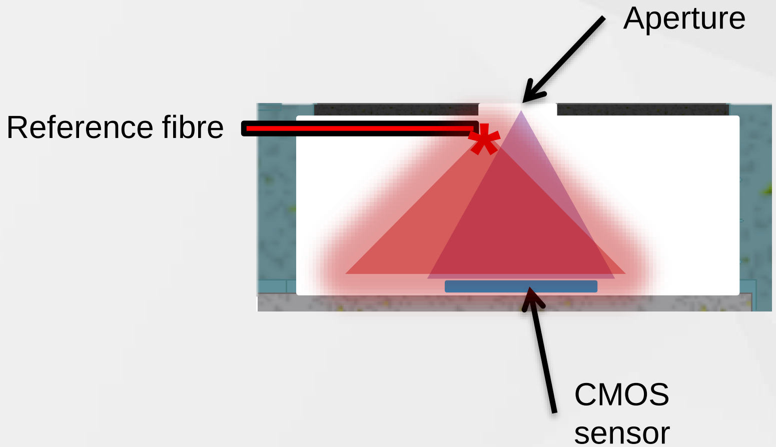


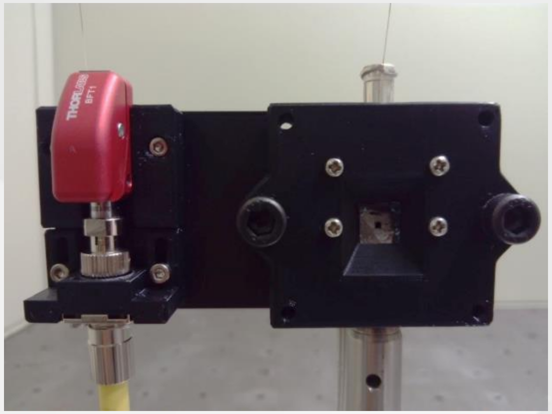


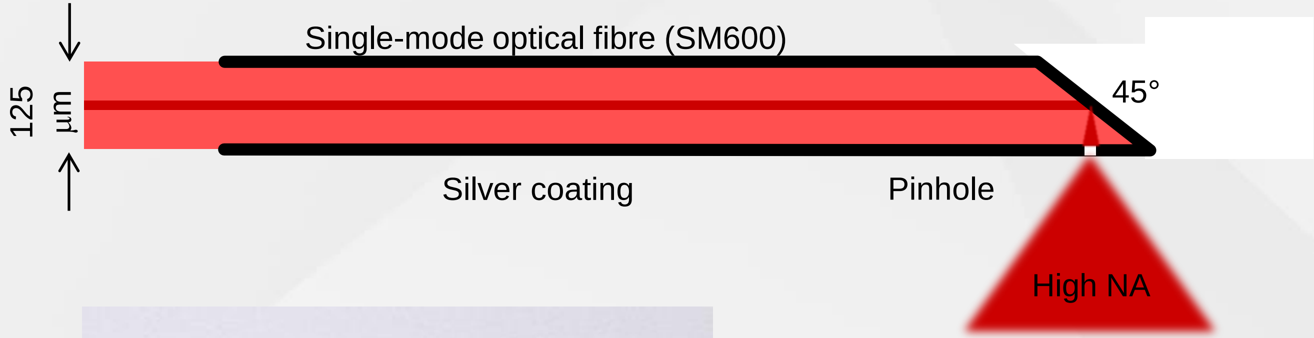




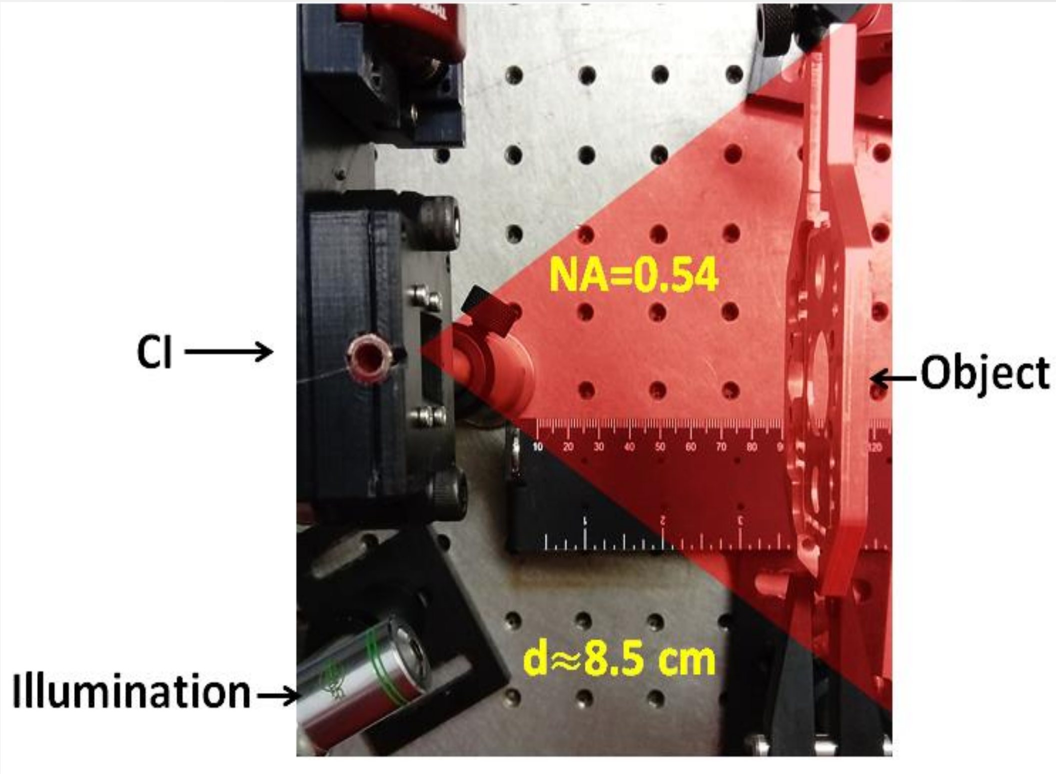
Side-Launch FIB Fibre Design

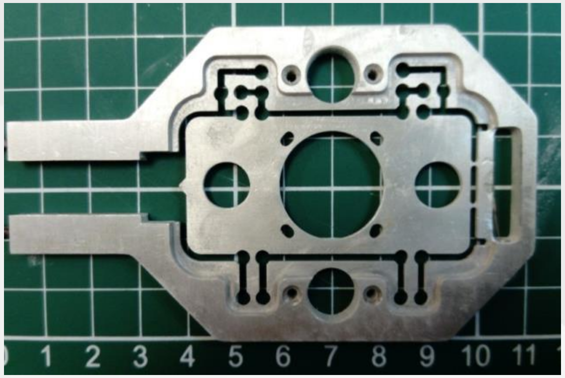


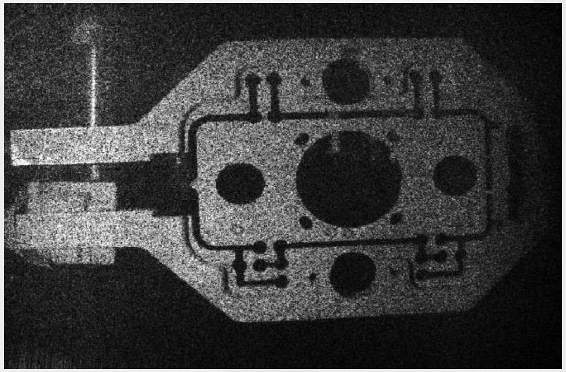




Object Reconstruction







Fibre Launch & Distribution

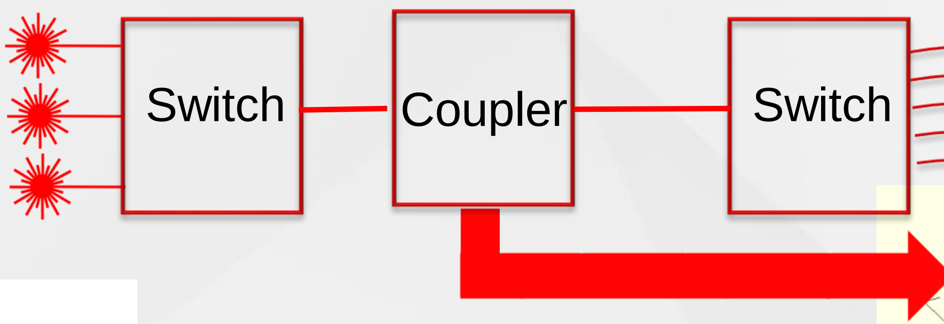
Lightech LT1100 1×16

Laser

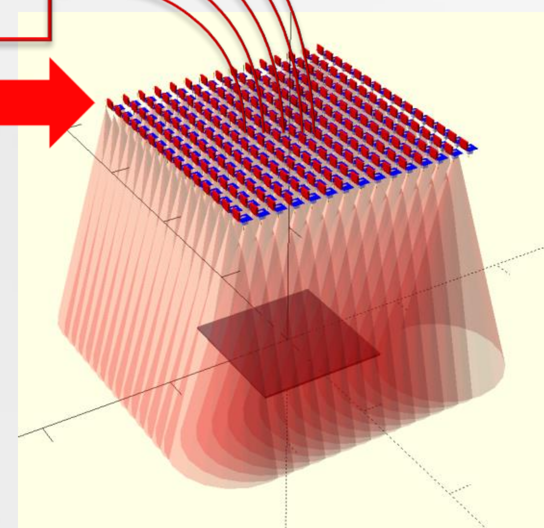
785nm λ_1

850nm λ_2

852nm λ_3



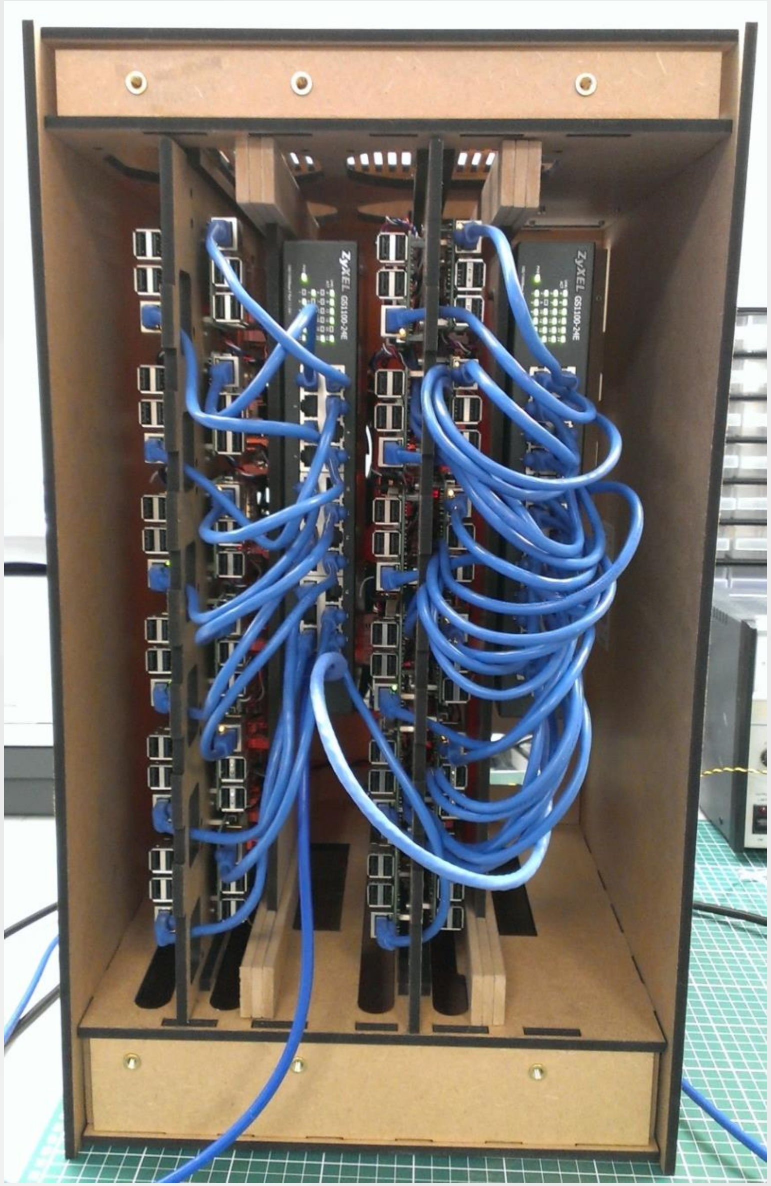
Obj beam launch



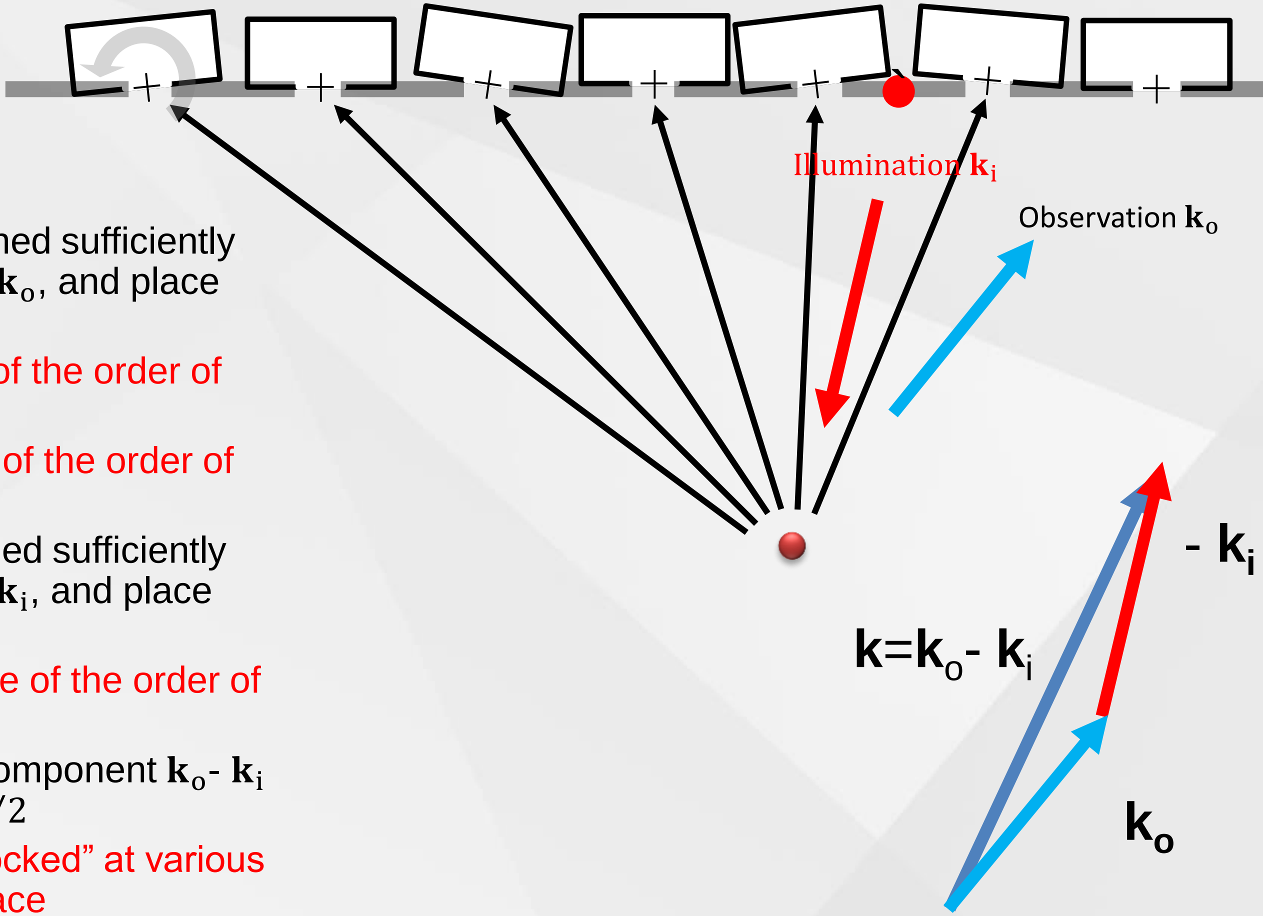
Ref beam launch

Thorlabs LP785-SAV50
50mW pigtailed laser diode

RPi Cluster

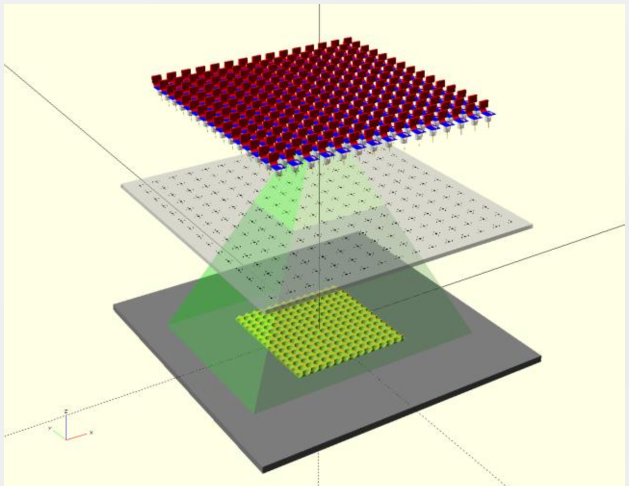


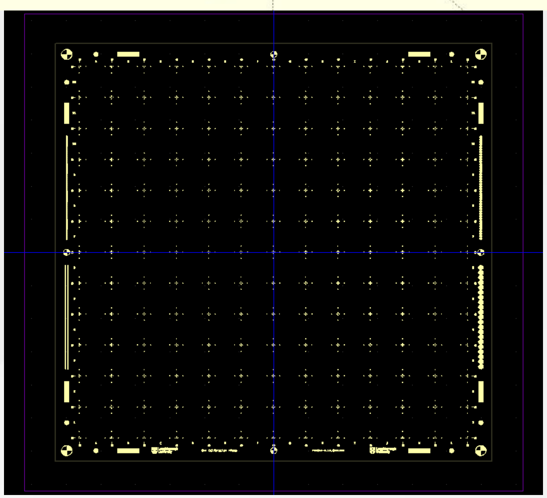
The Calibration Problem

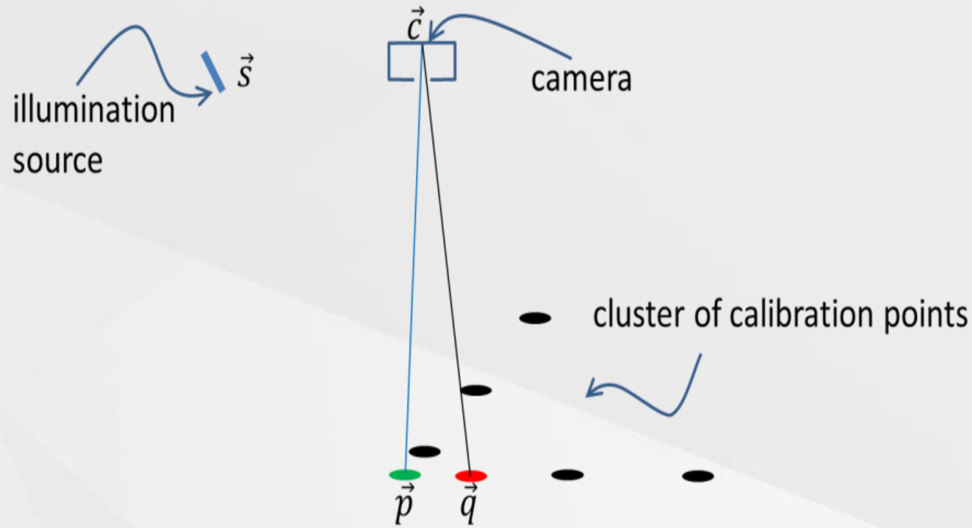


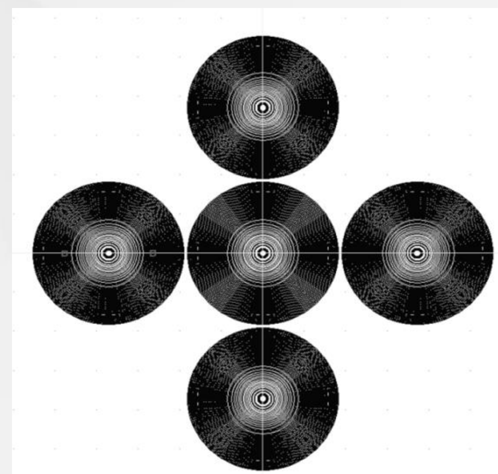
- The **cameras** need to be positioned sufficiently well to Identify the plane waves, $\mathbf{k}_o$, and place them in angular space
  - Rotation tolerance is of the order of the angular resolution
  - Position tolerances is of the order of the aperture size
- The **sources** need to be positioned sufficiently well to Identify the plane waves, $\mathbf{k}_i$, and place them in angular space
  - Position tolerances are of the order of the aperture size
- The **phase** of the plane waves component $\mathbf{k}_o$- $\mathbf{k}_i$ must be defined to better than $\pi/2$
  - Phase needs to be "locked" at various positions in object space

Calibration



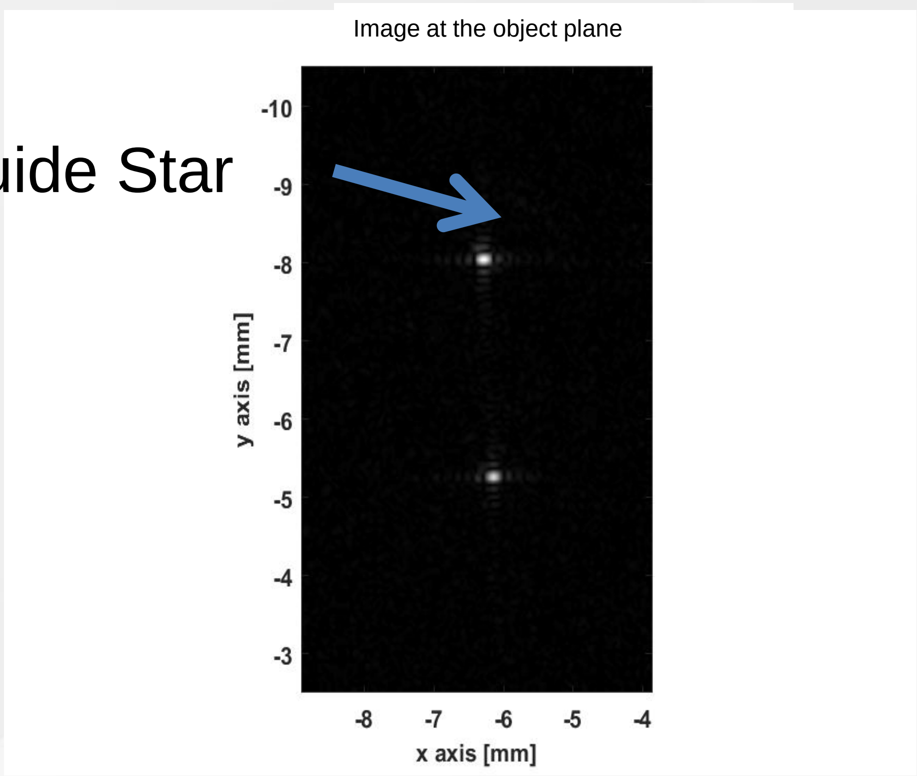


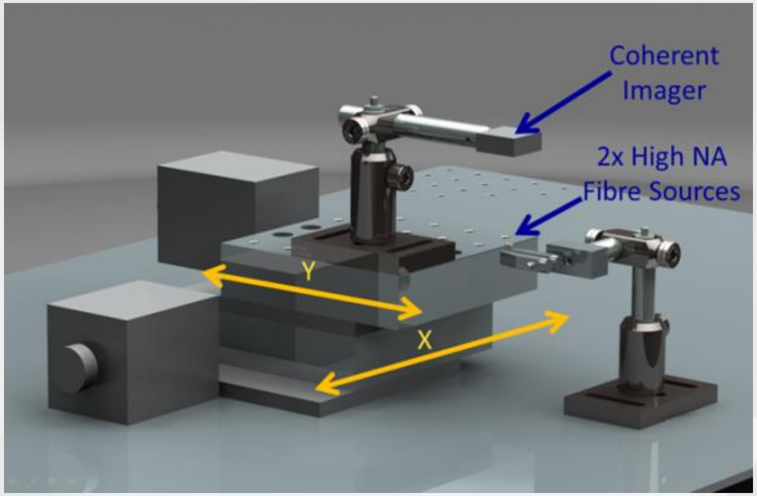


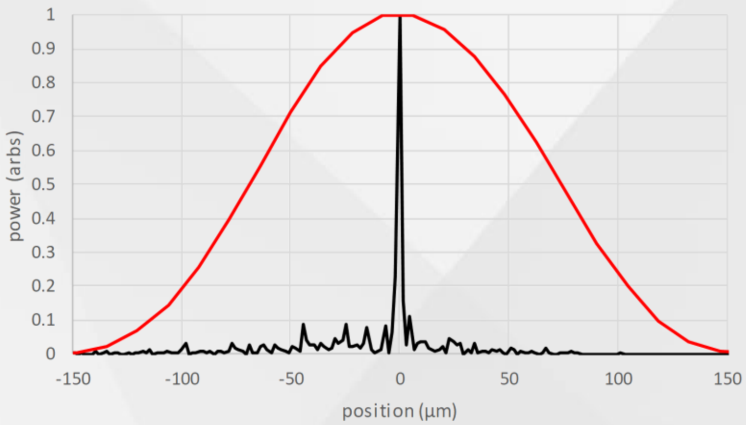


SAI – Phase Locking with Active Target

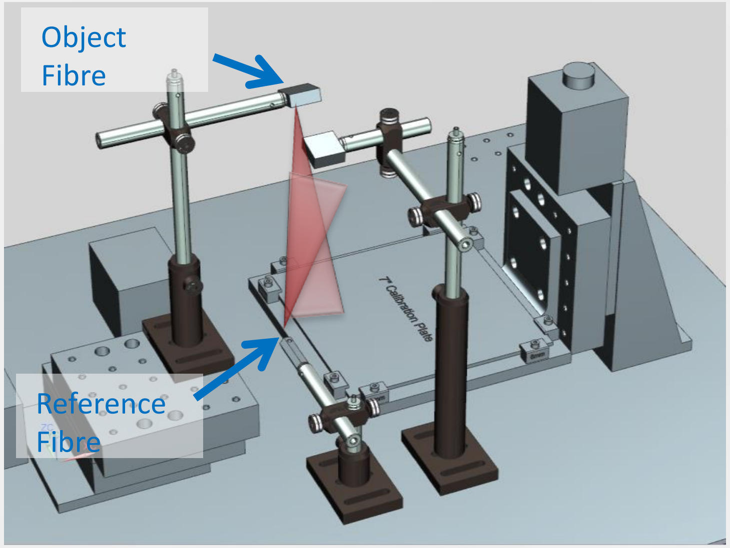
Guide Star

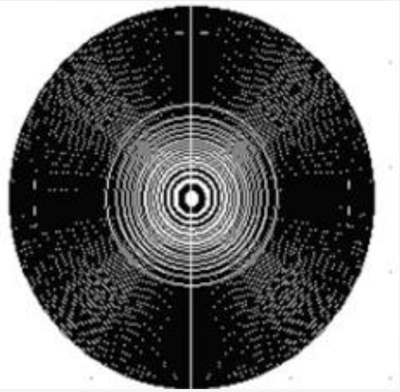


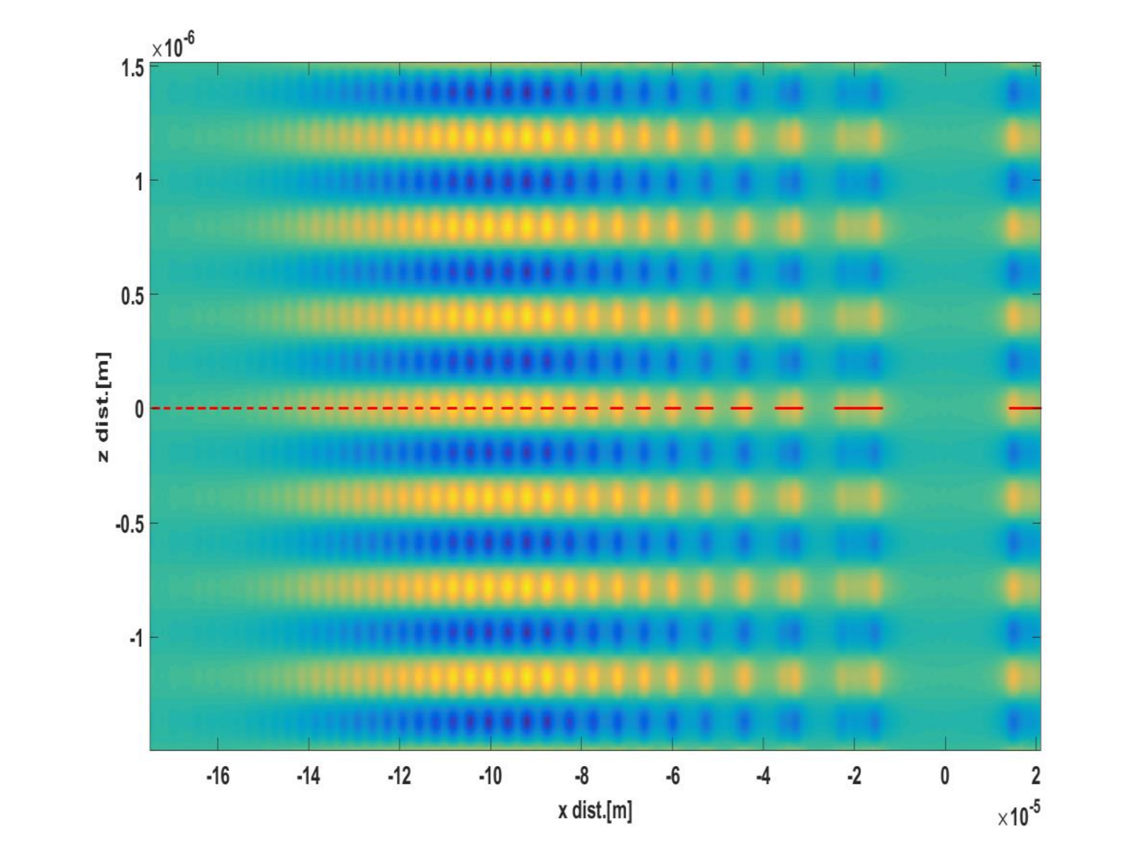




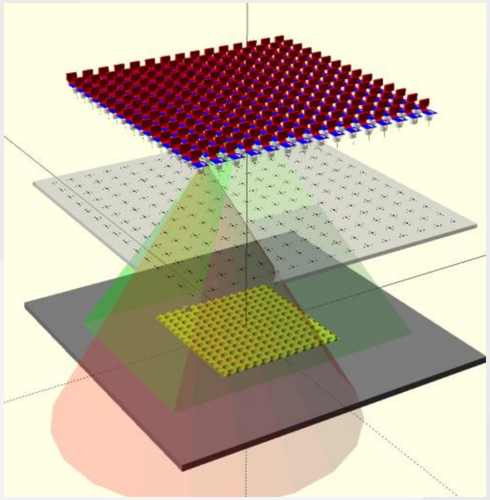
Scanning Source SAI







Conclusions

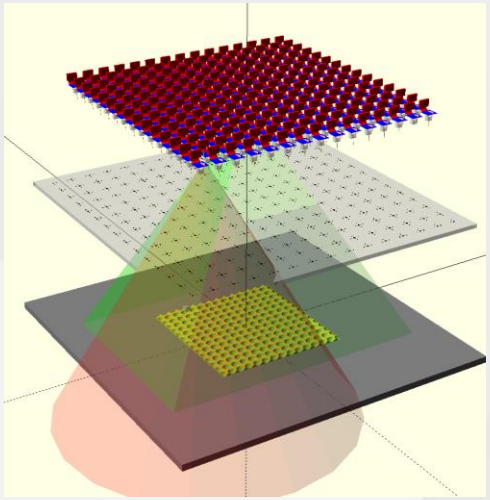


- The SPAI concept as first proposed **works!**
- Compact cameras can be made the required standard using;
    - Beam-splitter cubes and FIB-etched fibres or
    - No beam-splitter and novel side launch fibres

- 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

Acknowledgements

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Questions?