Three-dimensional Phase Imaging with Near Infrared Synchrotron Beam Using Phase-Retrieval Algorithm

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SUMMARY

- Near-infrared (NIR) synchrotron beam has been extracted and used for three-dimensional (3D) phase imaging.
- A pinhole was inserted in the path of the fork shaped NIR synchrotron beam and the Airy diffraction pattern was aligned with biochemical samples
- The diffracted intensity distribution was captured using an image sensor sensitive to NIR.
- A phase retrieval algorithm was used to estimate the 3D phase distribution from the recorded intensity distribution

EXPERIMENT

Optical configuration of the IRM system

- IR beam extracted from the storage ring using a gold-coated mirror with a central slit has a fork shaped intensity distribution, which is focused using a Schwarzschild condenser on the sample[1]
- After passing through the sample, the beam is refocused by a Schwarzschild IR reflecting objective
- The beam then is collected by an MCT detector used for imaging in the single pixel scanning mode
- Visible light is also aligned collinearly with the synchrotron-IR beam for alignment of the sample during beam alignment in the microscope

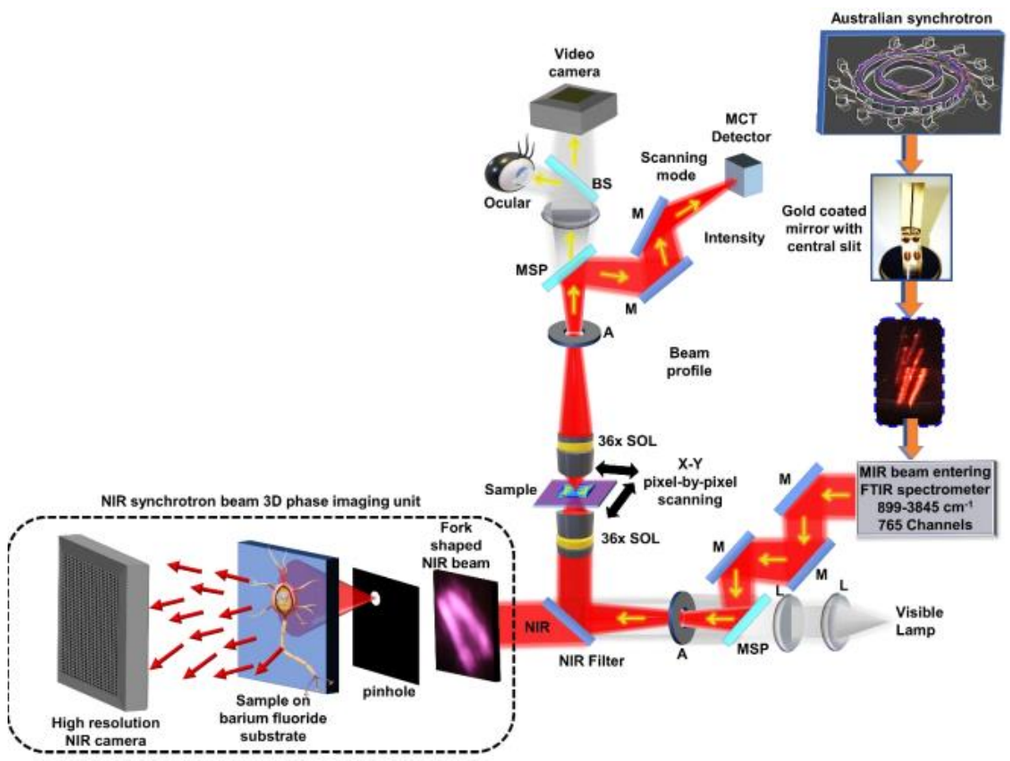

Figure 1: Schematic of the Australian synchrotron's IRM system and the attached synchrotron NIR phase imaging module (shown in the dotted line box). [4]

Attached NIR phase imaging module

- The high frequency filter is used to remove high-frequency components and extract the NIR beam.
- For getting a uniform intensity distribution, a pinhole was aligned with the maximum intensity region NIR beam and the Airy diffraction pattern was used to illuminate the biochemical sample.
- The phase information was extracted from this recorded intensity distribution using the phase-retrieval algorithm [5-7].

METHOD

- There are two planes of interest namely sample plane and sensor plane with two complex amplitudes ψ1 and ψ2 respectively with their intensities either known or measurable
- Initially, assuming phase variable is zero at detector plane, the complex amplitude ψ1 can be simply expressed as $\sqrt{Io}$ (phase = 0). The complex amplitude at specimen plane ψ2 can be obtained by convolution of ψ1 and a forward spherical propagator $S-(z) = \exp[-j2\pi \boldsymbol{R}/\lambda]$.
- The resulting complex amplitude's magnitude is replaced by the Airy intensity distribution or a constant valued matrix and the phase is retained.
- This modified complex amplitude is propagated to the sensor plane using a spherical propagator $S+(z)= \exp[j2\pi \boldsymbol{R}/\lambda]$
- The process will be repeated until estimation of phase images

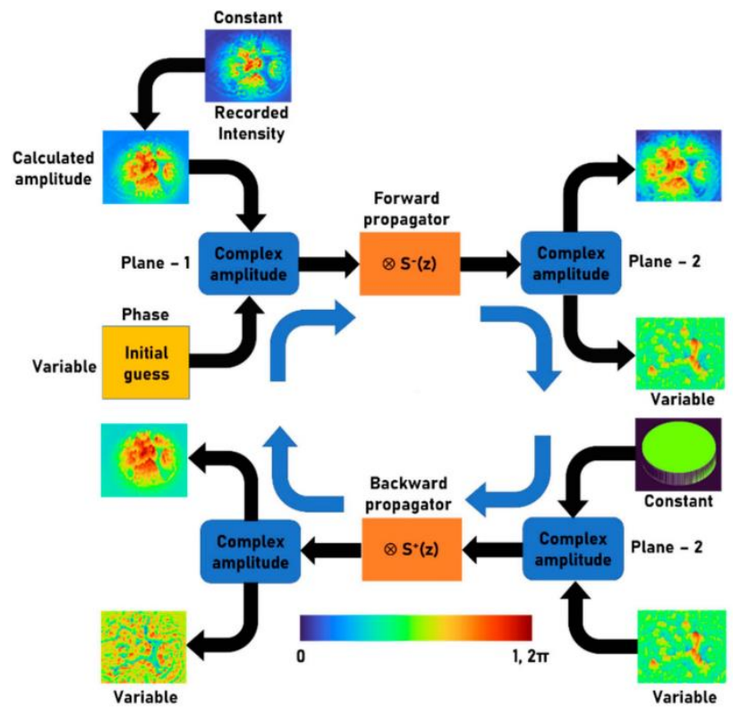

Figure 2 Schematic of the phase-retrieval algorithm[4]

RESULTS

The results obtained for two samples: randomly arranged latex beads with an average diameter of 15µm and an insect wing

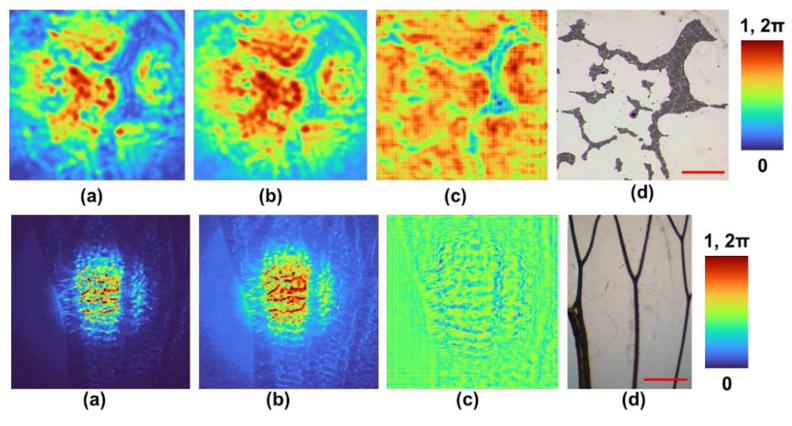

Figure 3: phase imaging results of both latex beads sample (top) and insect wing sample (bottom): **(a)** Intensity image, **(b)** amplitude image, **(c)** phase image, and **(d)** reference image of the bead samples. [4]

CONCLUSION

- A single shot, interferenceless phase imaging technique has been developed and demonstrated in the IRM system of the Australian Synchrotron for the first time.
- The phase-retrieval used in this approach has a rapid convergence of 2-4 iterations which may allow real-time phase imaging with only a slight decrease in the temporal resolution

References:

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