Scene Reconstruction via Coherency Imaging

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Abstract

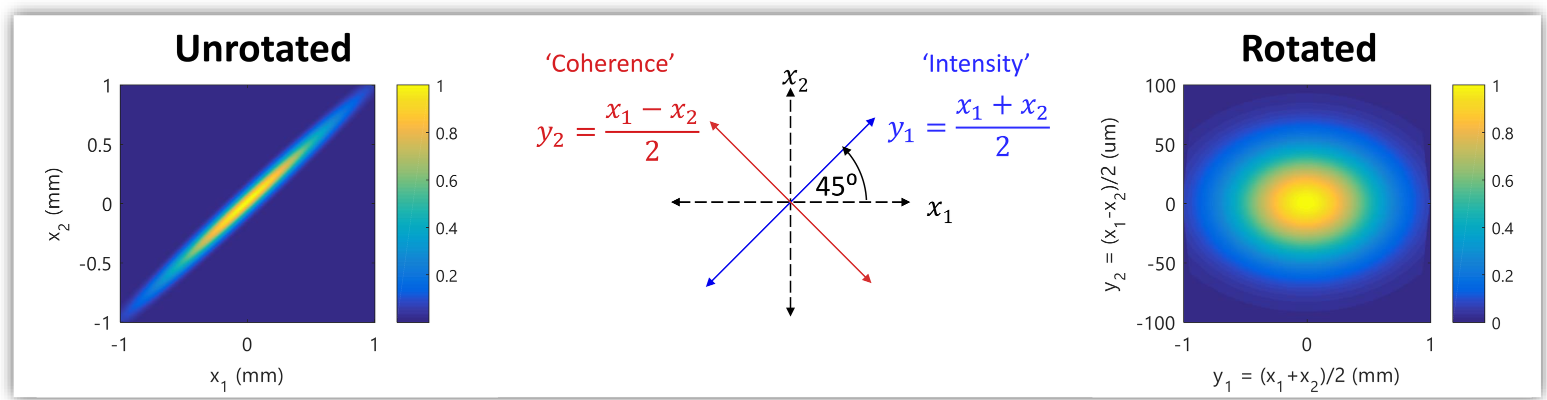
We implement numerical back-propagation of an experimentally obtained spatial complex coherence function to estimate both the axial and transverse positions of 1D objects. The measurement of the coherence function of partially coherent light is performed using dynamical double slits implemented via a digital micromirror device.

Coherence versus Intensity

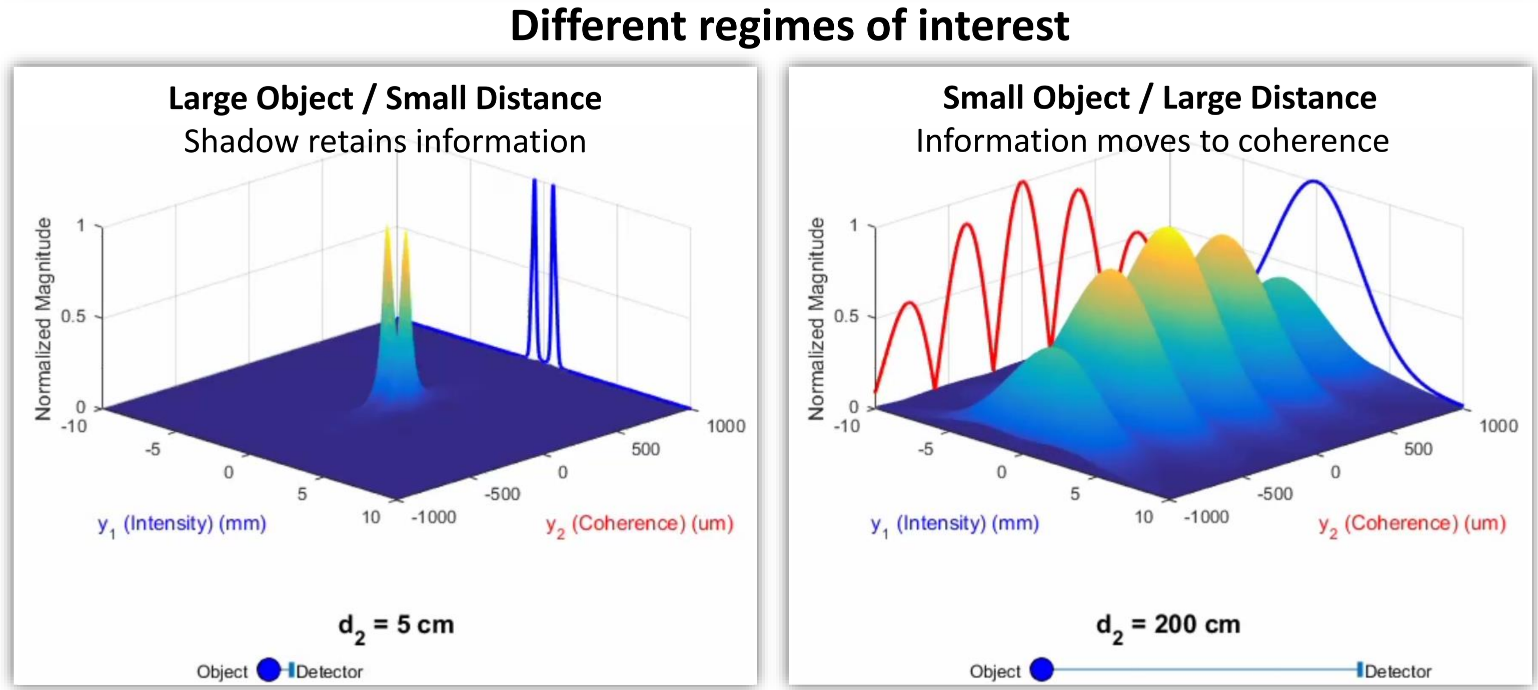
Two-point field correlation: $G^{(1)}(x_1,x_2)=\langle E(x_1)E^*(x_2)\rangle$ **Intensity:** $I(x)=G^{(1)}(x,x)$

Normalized correlation: $g^{(1)}(x_1,x_2)=\frac{\langle E(x_1)E^*(x_2)\rangle}{\sqrt{I(x_1)I(x_2)}}$

Rotated coordinate system

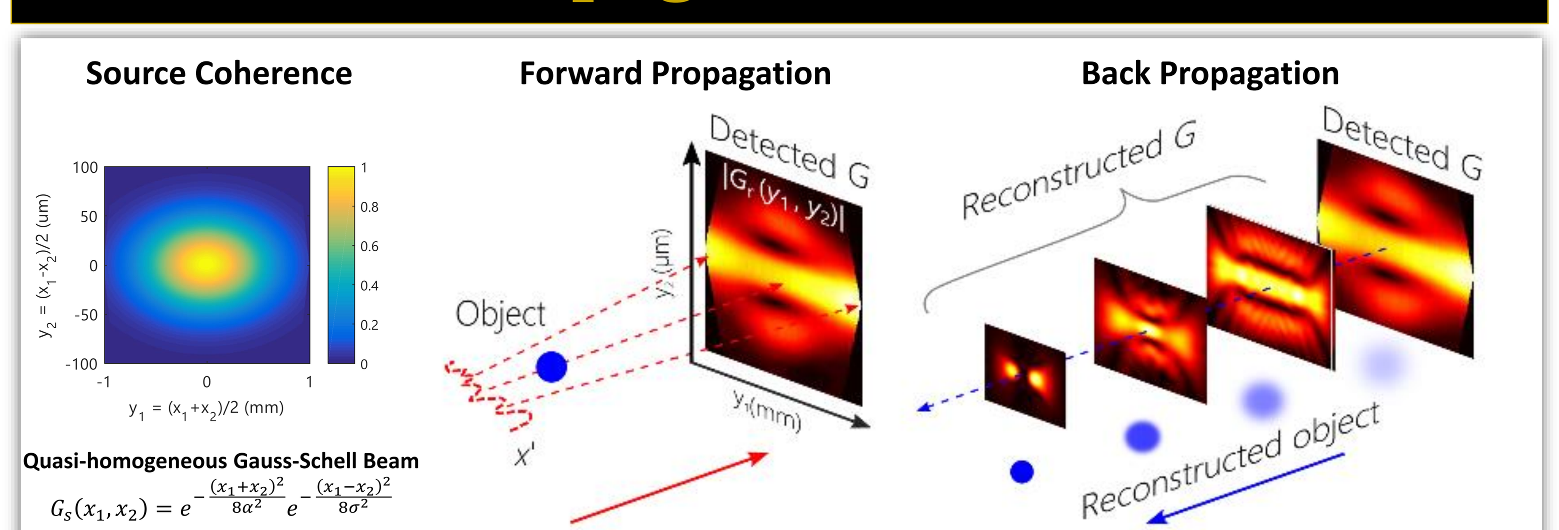


Different regimes of interest



Source is located behind the object
d_2: distance between object and detector
Object width = 1 mm
Object position $(x,z)=(0,0)$
Source beam width (uniform) = 2 mm
Source coherence FWHM width = 75 μm

Propagation Model

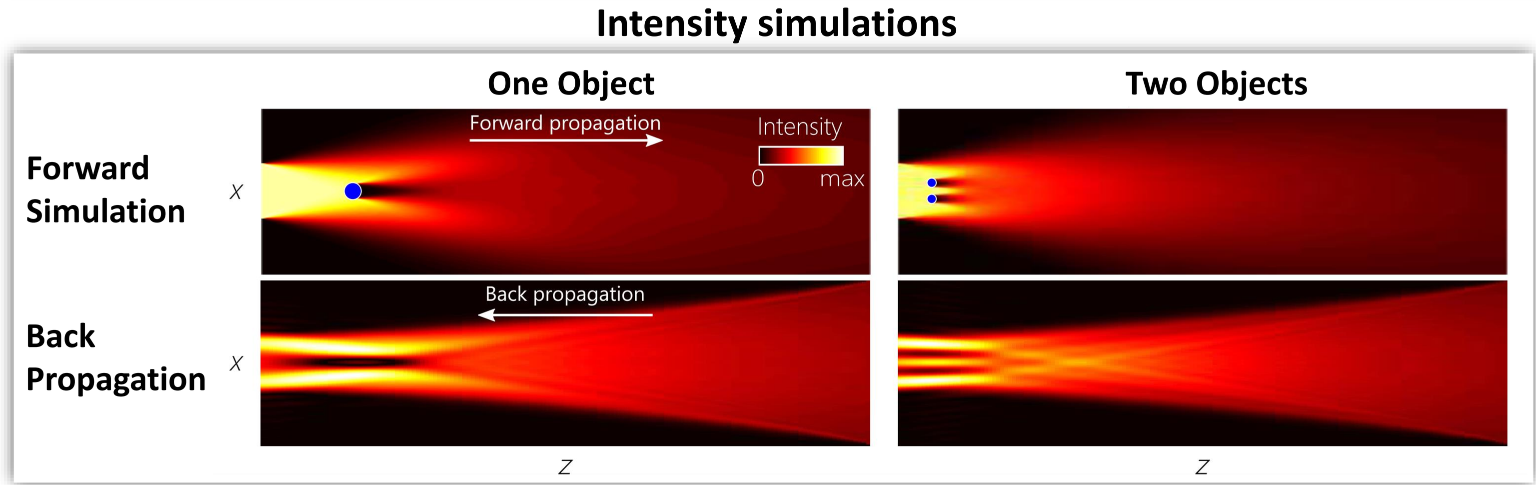


$G_s(x_1,x_2)=e^{-\frac{(x_1+x_2)^2}{8a^2}}e^{-\frac{(x_1-x_2)^2}{8\sigma^2}}$

Fresnel Transform / Inverse Fresnel Transform

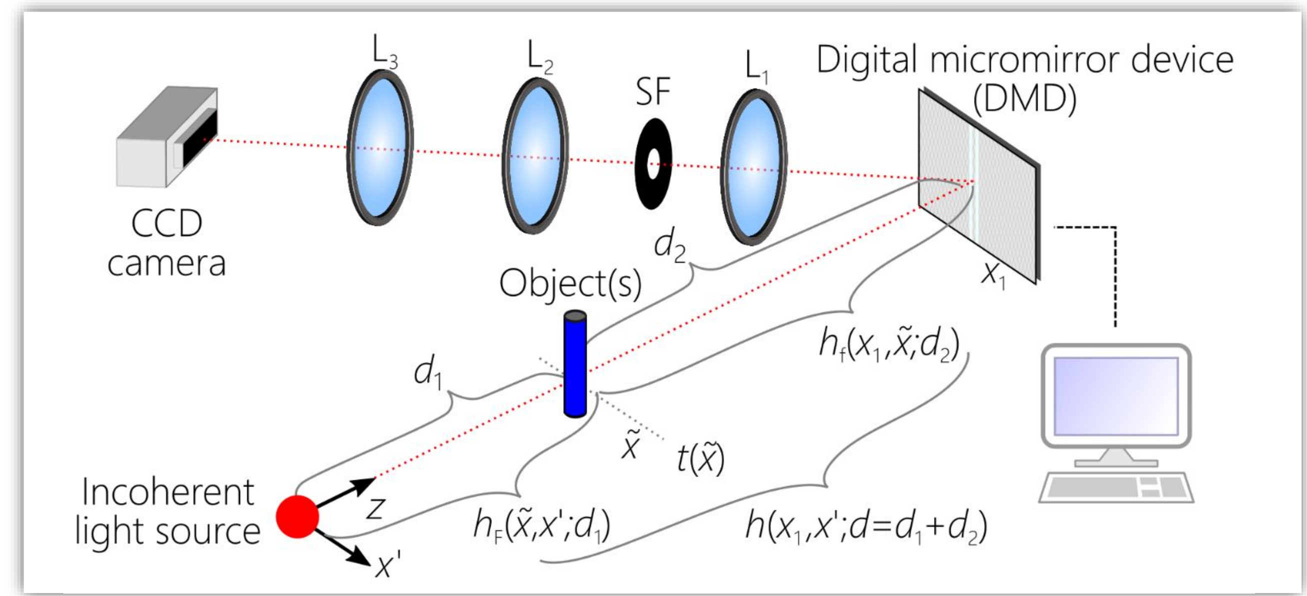
$$G_{out}(x_1',x_2')=\frac{1}{\lambda d}\iint dx_1\,dx_2\,e^{\pm i\frac{k[(x_2'-x_2)^2-(x_1'-x_1)^2]}{2d}}G_{in}(x_1,x_2)$$

Intensity simulations

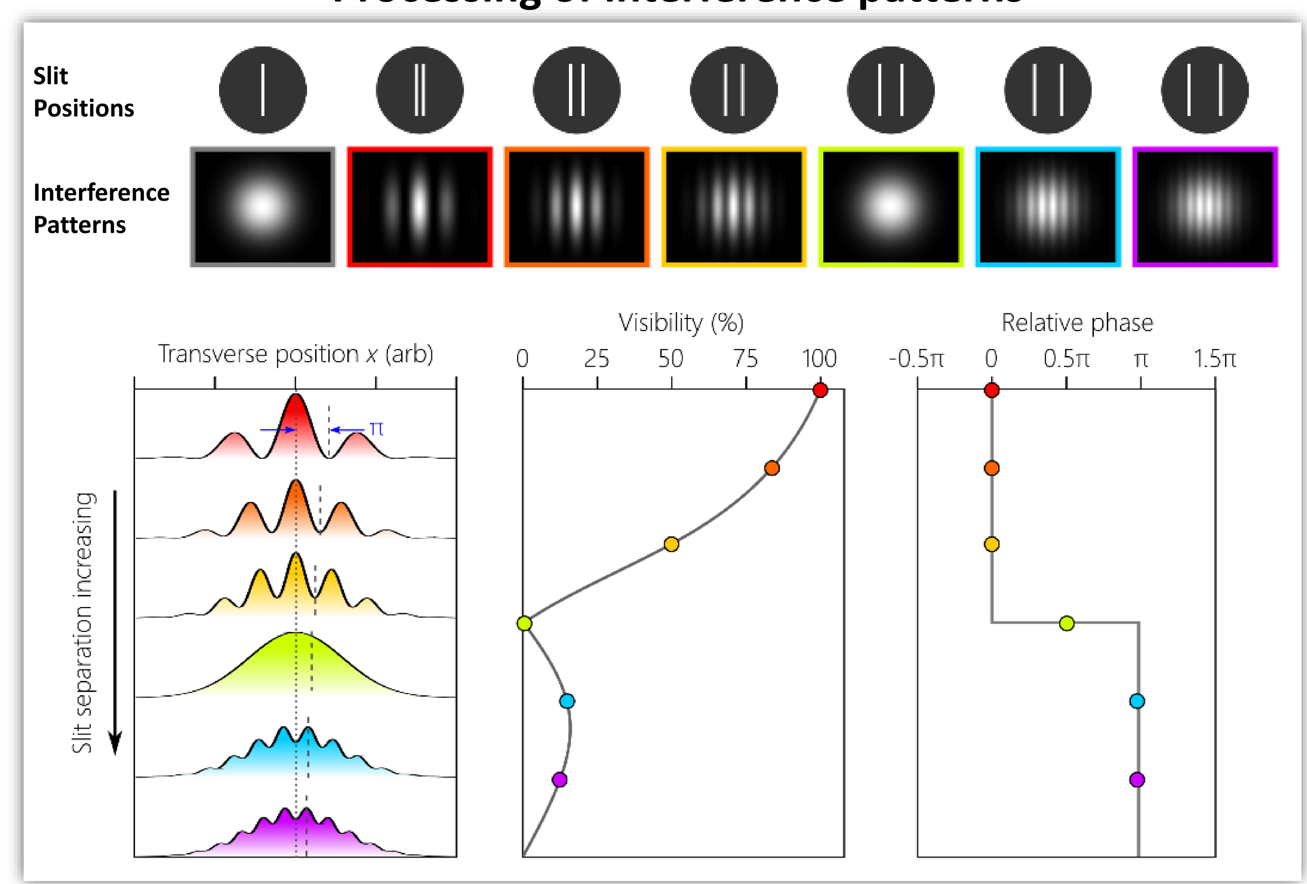


Measurement System

Double slit measurement system

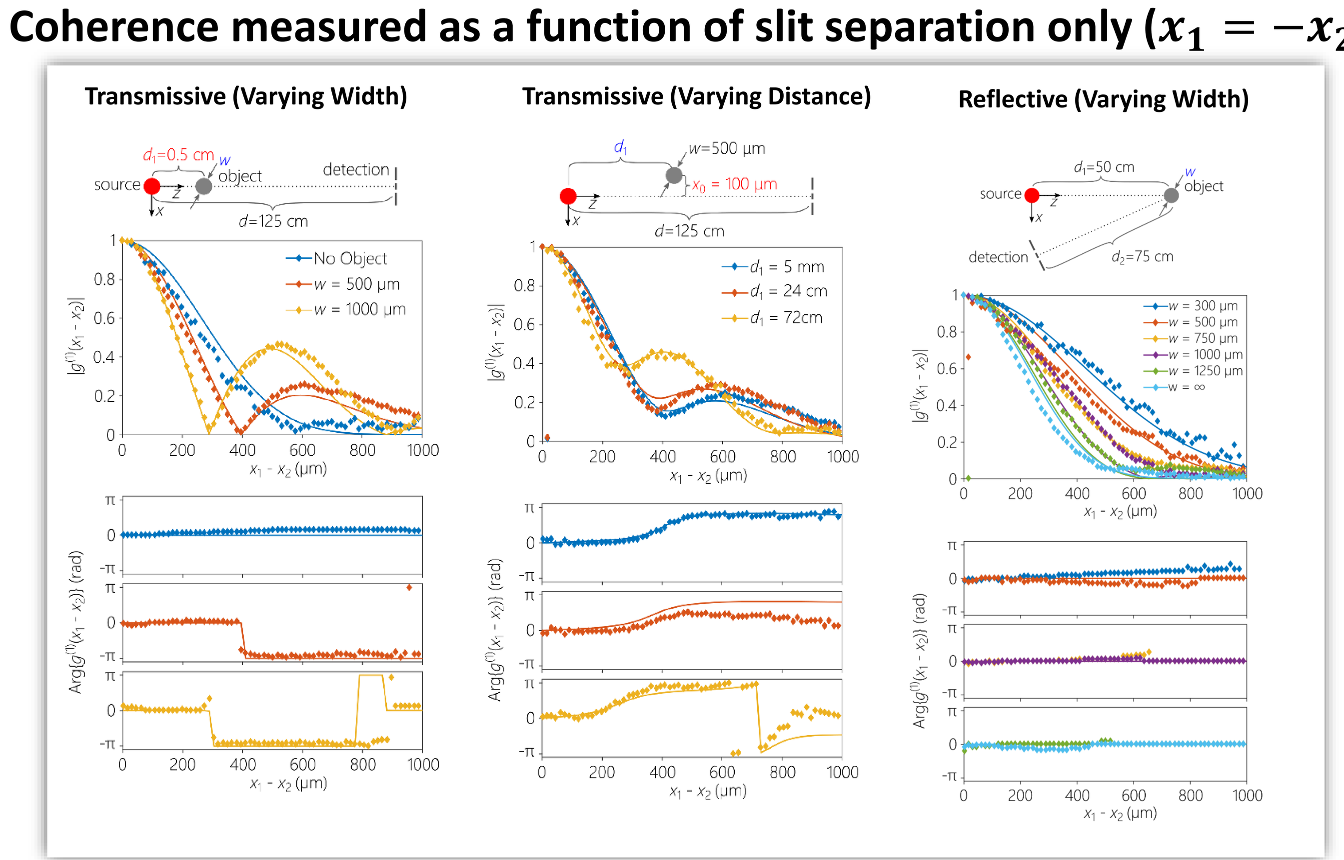


Processing of interference patterns

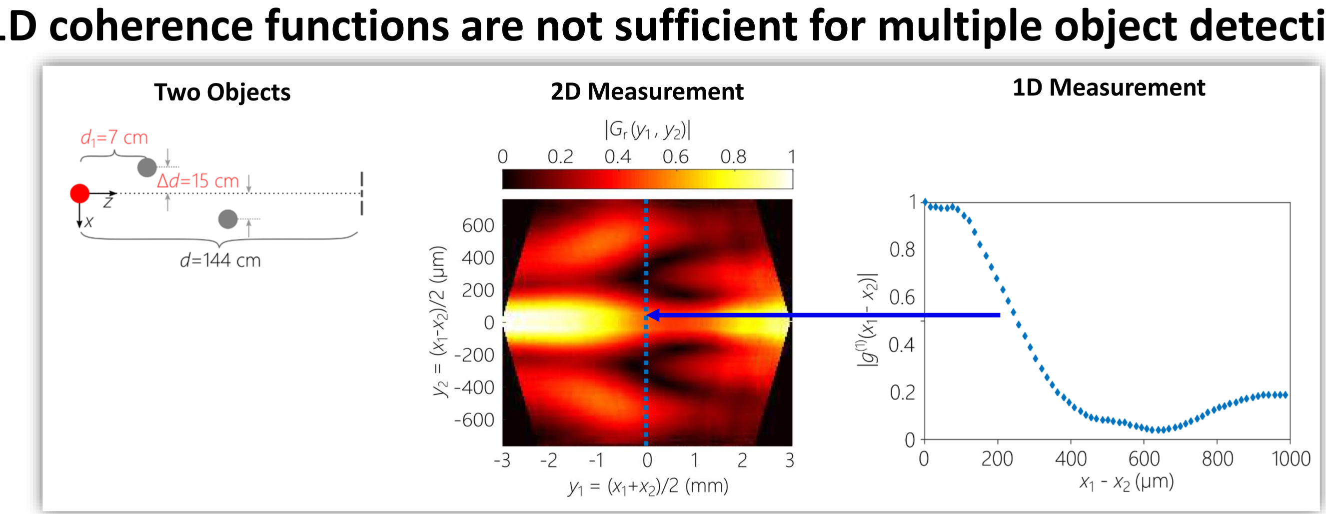


1D Coherence Results

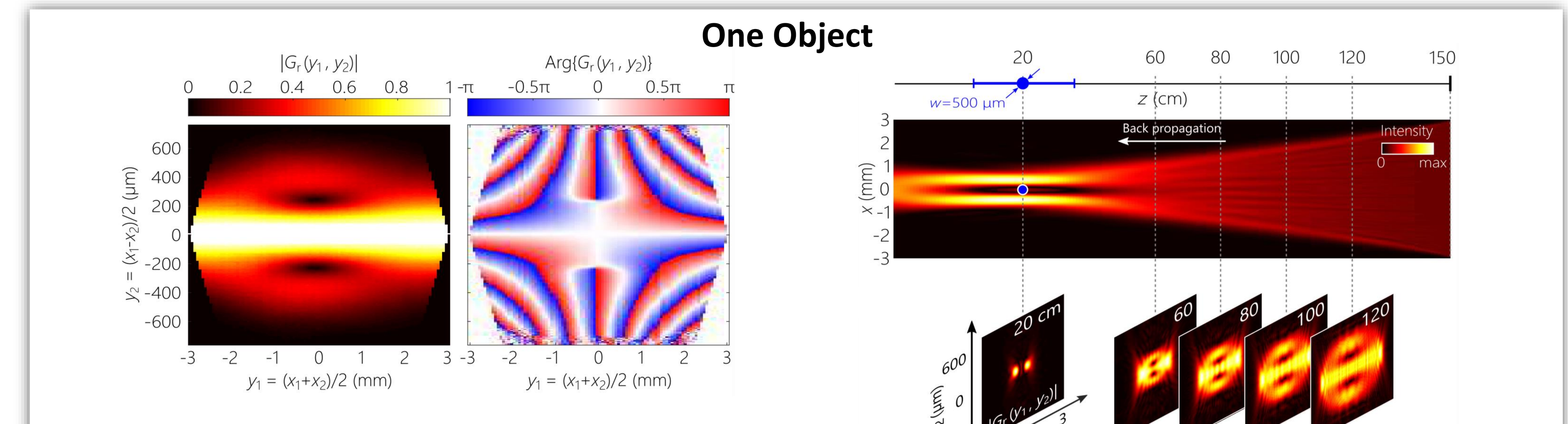
Coherence measured as a function of slit separation only $(x_1=-x_2)$



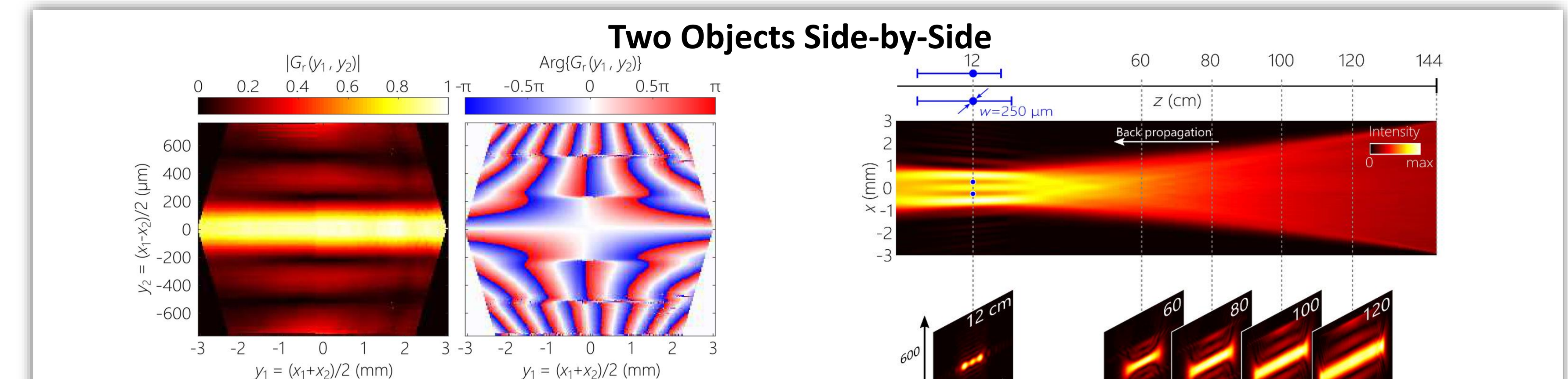
1D coherence functions are not sufficient for multiple object detection



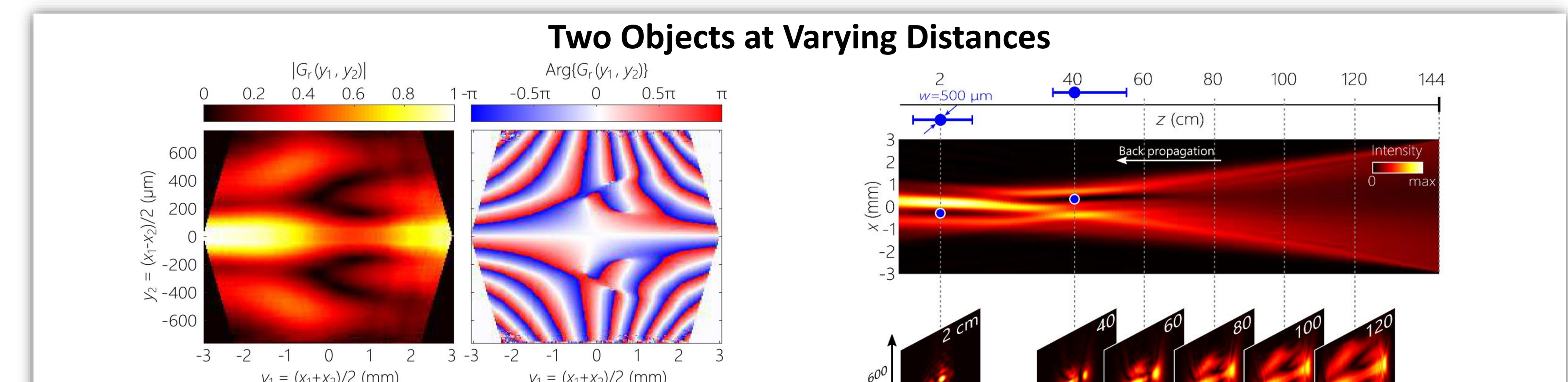
2D Coherence Results



	Actual	Estimated	Error
Object z position:	Actual = 20 cm	Estimated = 20 cm	Error = 0 %
Object width:	Actual = 500 um	Estimated = 419 um	Error = 16 %



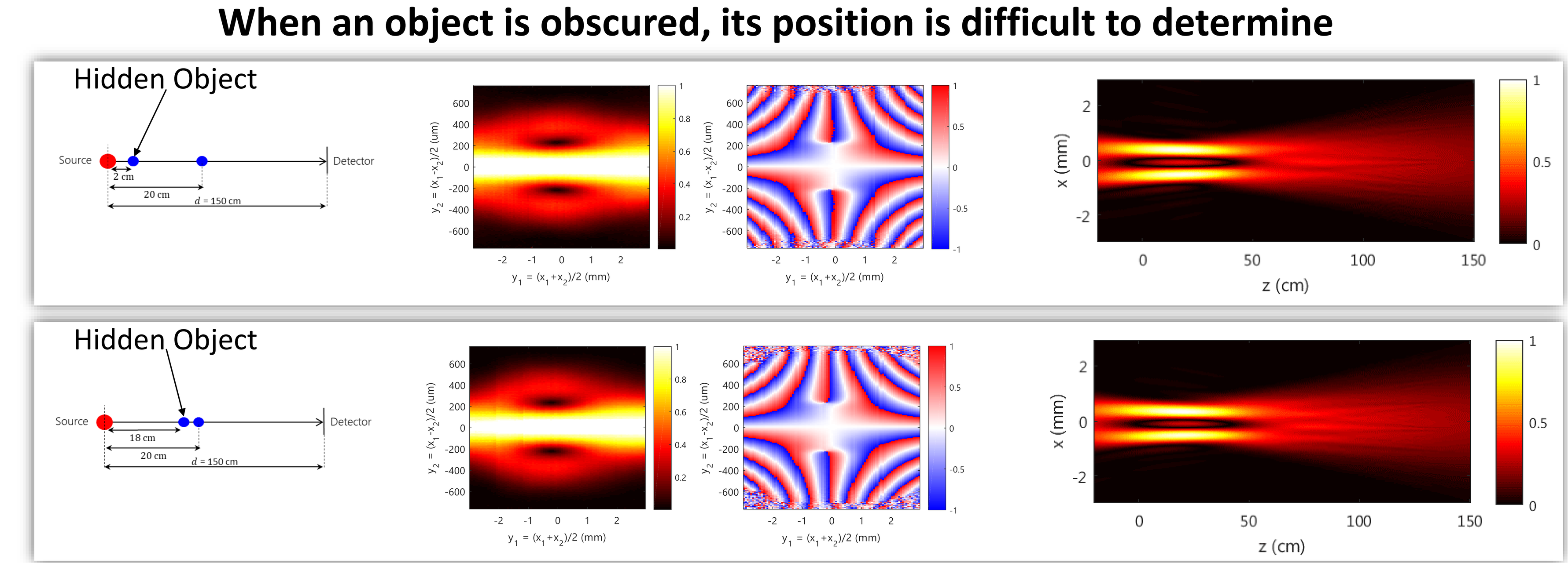
	Actual	Estimated	Error
Object 1&2 z position:	Actual = 7 cm	Estimated = 12 cm	Error = 3.6 %
Object 1&2 width:	Actual = 250 um	Estimated = 280 um	Error = 12 %
Object 1 x position:	Actual = 287 um	Estimated = 253 um	Error = 12 %
Object 2 x position:	Actual = -287 um	Estimated = -284 um	Error = 1.0 %



	Actual	Estimated	Error
Object 1 z position:	Actual = 22 cm	Estimated = 40 cm	Error = 15 %
Object 2 z position:	Actual = 7 cm	Estimated = 2 cm	Error = 3.6 %
Object 1&2 width:	Actual = 500 um	Estimated = 400 um	Error = 20 %
Object 1 x position:	Actual = 375 um	Estimated = 309 um	Error = 17 %
Object 2 x position:	Actual = -375 um	Estimated = -321um	Error = 14 %

Null Space

When an object is obscured, its position is difficult to determine



References

1. H. Esat Kondakci, Andre Beckus, Ahmed El Halawany, Nafiseh Mohammadian, George K. Atia, and Ayman F. Abouraddy, "**Coherence measurements of scattered incoherent light for lensless identification of an object's location and size**," Opt. Express 25, 13087-13100 (2017)
2. Ahmed El-Halawany, Andre Beckus, H. Esat Kondakci, Morgan Monroe, Nafiseh Mohammadian, George K. Atia, and Ayman F. Abouraddy, "**Incoherent lensless imaging via coherency back-propagation**," Opt. Lett. 42, 3089-3092 (2017)
3. Andre Beckus, Alexandru Tamasan, Aristide Dogariu, Ayman F. Abouraddy, and George K. Atia, "**Effective spatial coherence of planar generalized sources propagating in the Fresnel model**," ArXiv e-prints (2017)

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