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Photon Dispersion in Gradient Phase Fields Enables Rapid and High-Fidelity Scattering Imaging

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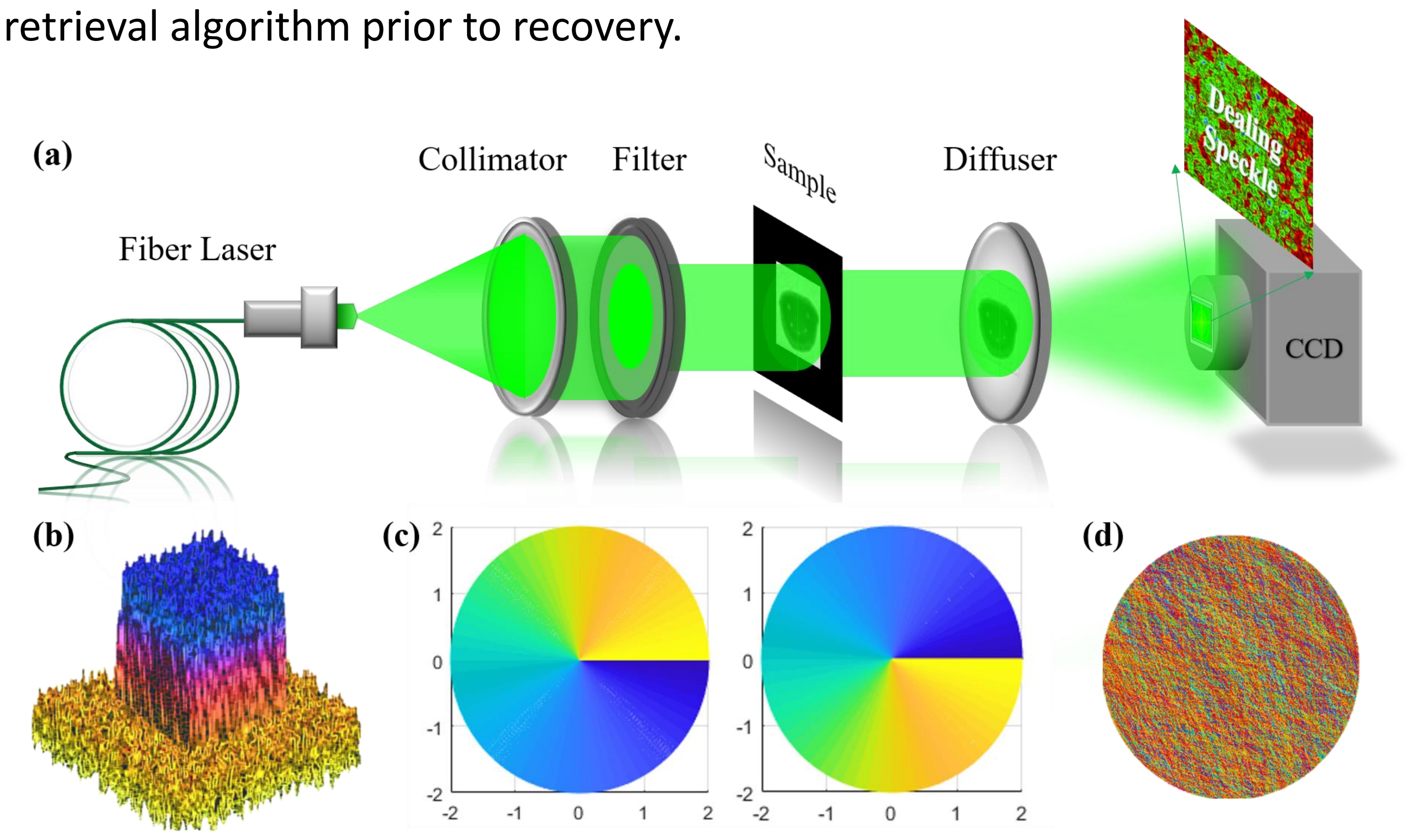
INTRODUCTION & AIM

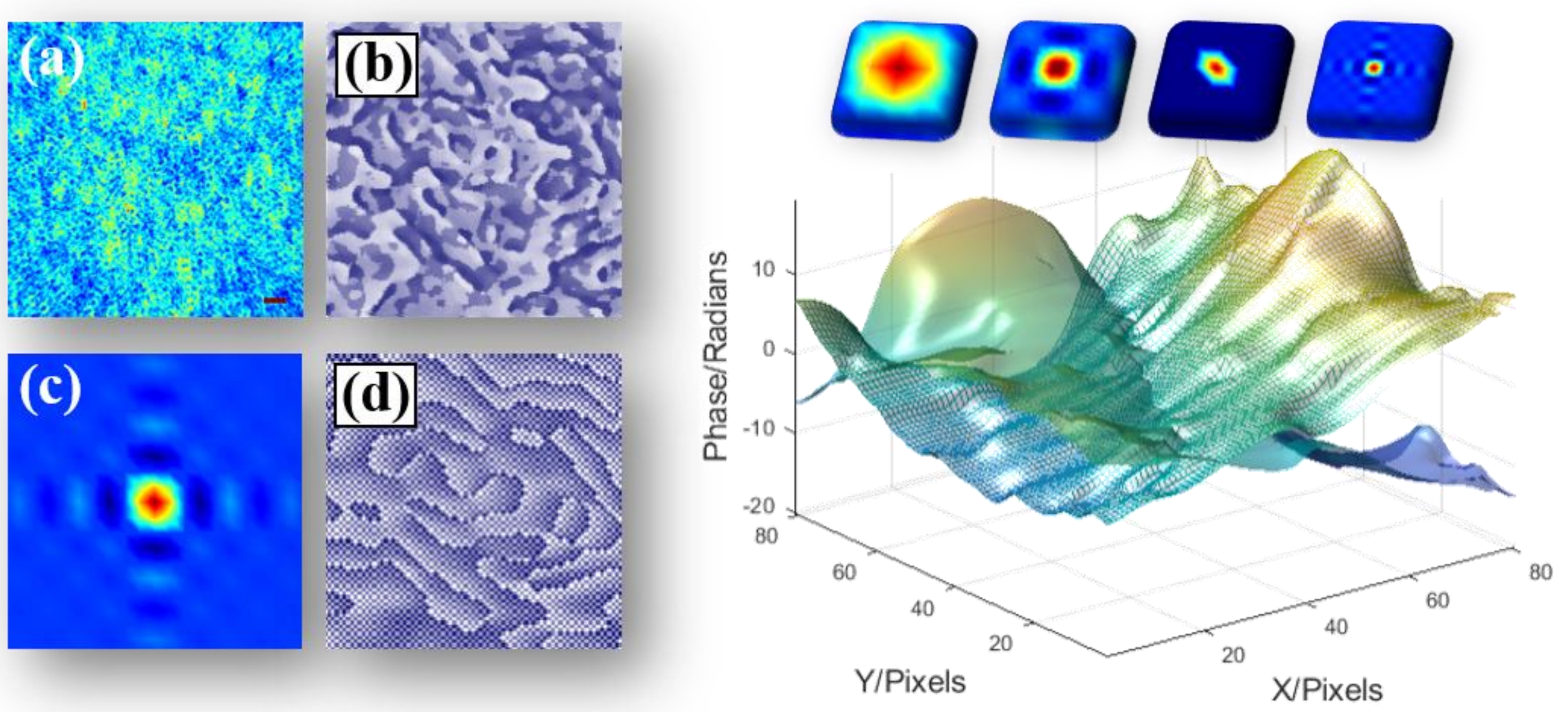
Photon scattering-induced wavefront aberrations impose significant limitations on optical imaging within scattering media, particularly in environments characterized by diffusion. Scattering imaging techniques leveraging memory effects offer a promising avenue for imaging under the regime of multiple scattering. Nonetheless, the presence of interference phase traps inherent to scattered light often results in failures and distortion. We propose an algorithm for computational imaging to address the challenges.

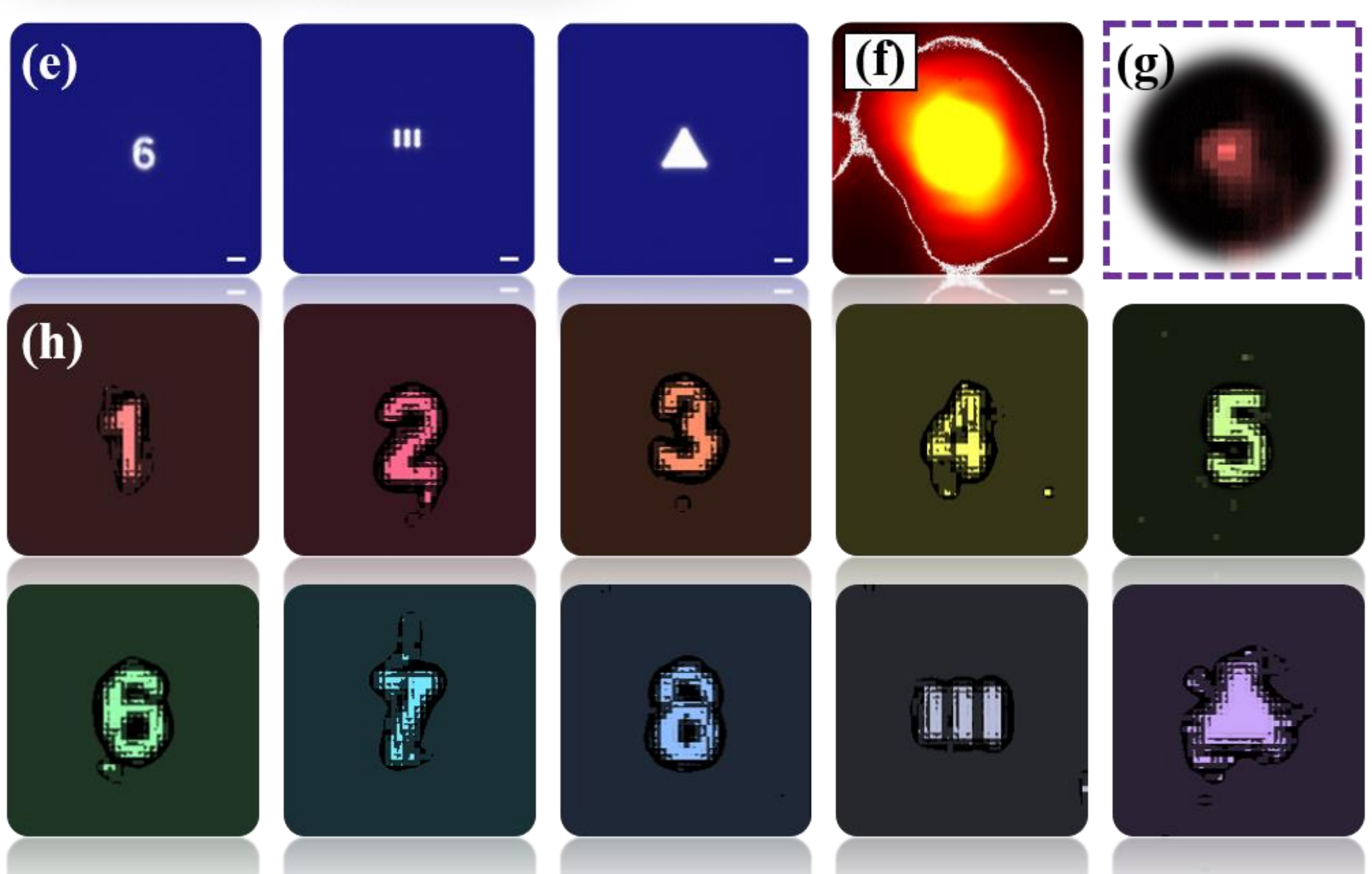
METHOD & RESULTS

By employing gradient-based calculations to delineate the phase distribution of photon ensembles amidst diffuse scattering, we preemptively assess the convergence or divergence of the state of the retrieval algorithm prior to recovery.



In the calculation region defined by x_s, y_s , we analyze the scattering light phase φ of the speckle pattern H, which is decomposed into the correct solution of the physical light U and the scattered background light R. We seek the gradient that indicates the direction 'a' of the steepest descent





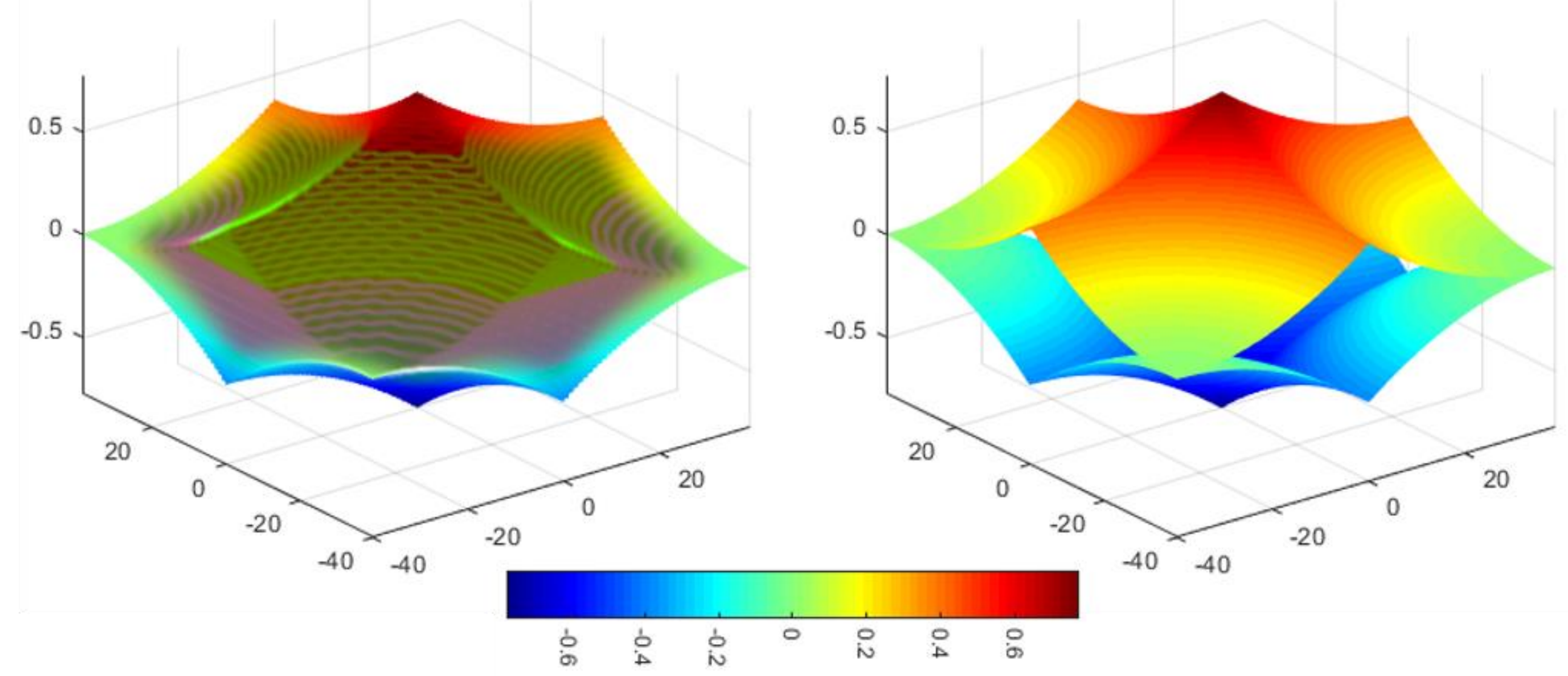
during the optical field distortion process. This direction serves as a big dipper for guiding the calculation, aimed at mitigating the significant disturbance caused by the trap solution U* in scattering imaging

$$H(x,y)=\left|U(x,y)+R(x,y)\right|^2=\left|U\right|^2+\left|R\right|^2+UR^*+U^*R$$

$$a=\left\{\frac{\partial^2\varphi}{\partial x^2}\frac{\partial^2\varphi}{\partial y^2}-\left(\frac{\partial^2\varphi}{\partial x^2}\right)^2-\left(\frac{\partial^2\varphi}{\partial y^2}\right)^2-i\left(\frac{\partial\varphi}{\partial x}\right)-i\left(\frac{\partial\varphi}{\partial y}\right)\right\}_{x_s,y_s}$$

This proactive strategy serves to circumvent disruptions caused by interference traps, expediting the identification of the accurate state from a myriad of stochastic photon projections, thereby facilitating rapid and high-fidelity scattering retrieval.

DISCUSSION



Target	PR	$Time_{PR}$(s)	This Work	$Time_{TW}$(s)
1	43%	162.48	88%	42.99
2	15%	133.33	51%	47.81
3	17%	126.20	37%	32.19
4	22%	128.71	63%	32.54
5	43%	134.37	64%	31.88
6	32%	180.94	68%	36.32
7	57%	173.97	93%	38.33
8	45%	133.07	61%	34.37
Stripe	42%	140.69	95%	35.46
Triangle	17%	144.25	66%	56.58

Through rigorous experimentation involving dozen-group targets and each group with 100 repeated trials, we quantitatively evaluate the proposed method. Our research demonstrates a substantial enhancement in success rates, approximately 3 times higher than those without interference mitigation, while achieving a reduction in computational time, down to 0.2 of the original.

CONCLUSION

We have proposed and experimentally demonstrated an algorithm to significantly enhance the convergence of speckle correlation scattering imaging, achieving high-fidelity retrievals and high success rates. This approach introduces a novel scattering imaging technique, 'achieving more with less,' offering technical support for dynamic video imaging in intricate scattering environments such as biological tissues and atmospheric conditions.

FUTURE WORK / REFERENCES

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[3] Z. Zhang, Z. Liu, and S. Liu, Phys. Rev. A 106, 043508 (2022).