清華大學
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A Brief Introduction to Correlated Imaging with Pseudothermal Light

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CONTENT

Section 1: My Seminar

Section 2: Introduction

Introduction

- Hanbury Brown and Twiss (HBT) Effect

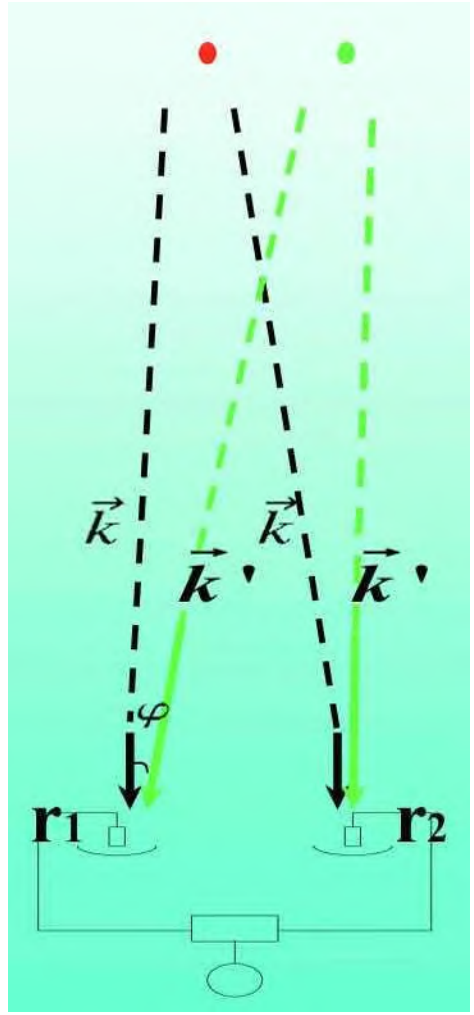
$$I_i = \kappa\left\langle\left[|E_k|^2 + |E_{k'}|^2 + E_k E_{k'} e^{i(k-k')\cdot r_i} + c.c.\right]\right\rangle$$

$$\langle I_1 I_2\rangle = \kappa^2\left\{\langle(|E_k|^2 + |E_{k'}|^2)^2 + 2\langle|E_k|^2\rangle\langle|E_{k'}|^2\rangle\cos[(k-k')\cdot(r-r')]\right\}$$

- Correlation Measurement

$$\langle E_k\rangle = \langle E_{k'}\rangle = 0$$

$$g^{(2)} = \frac{\langle I_k I_{k'}\rangle}{\langle I_k\rangle\langle I_{k'}\rangle} = \frac{\langle E_k^* E_{k'}^* E_k E_{k'}\rangle}{\langle E_k^* E_k\rangle\langle E_{k'}^* E_{k'}\rangle}$$



Du Chun-Guang, Lectures of Qt. Opt.

Introduction

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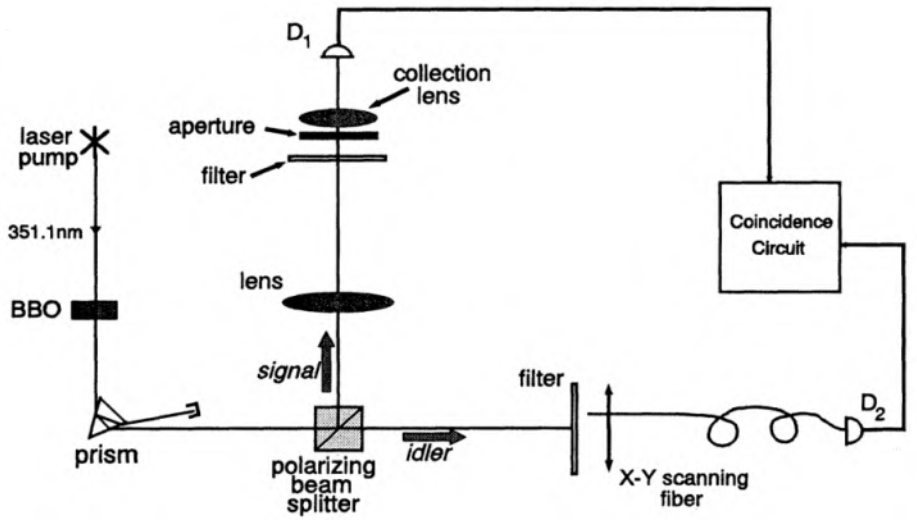
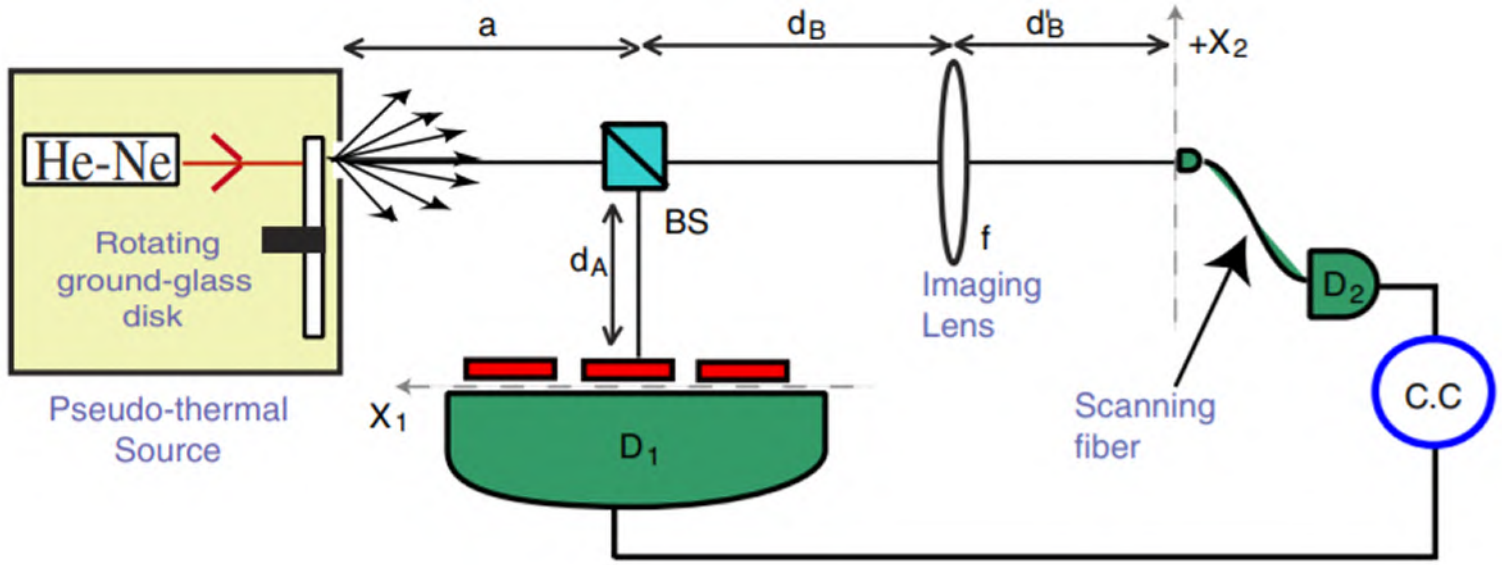
Correlated Imaging / Ghost Imaging / Single Pixel Imaging



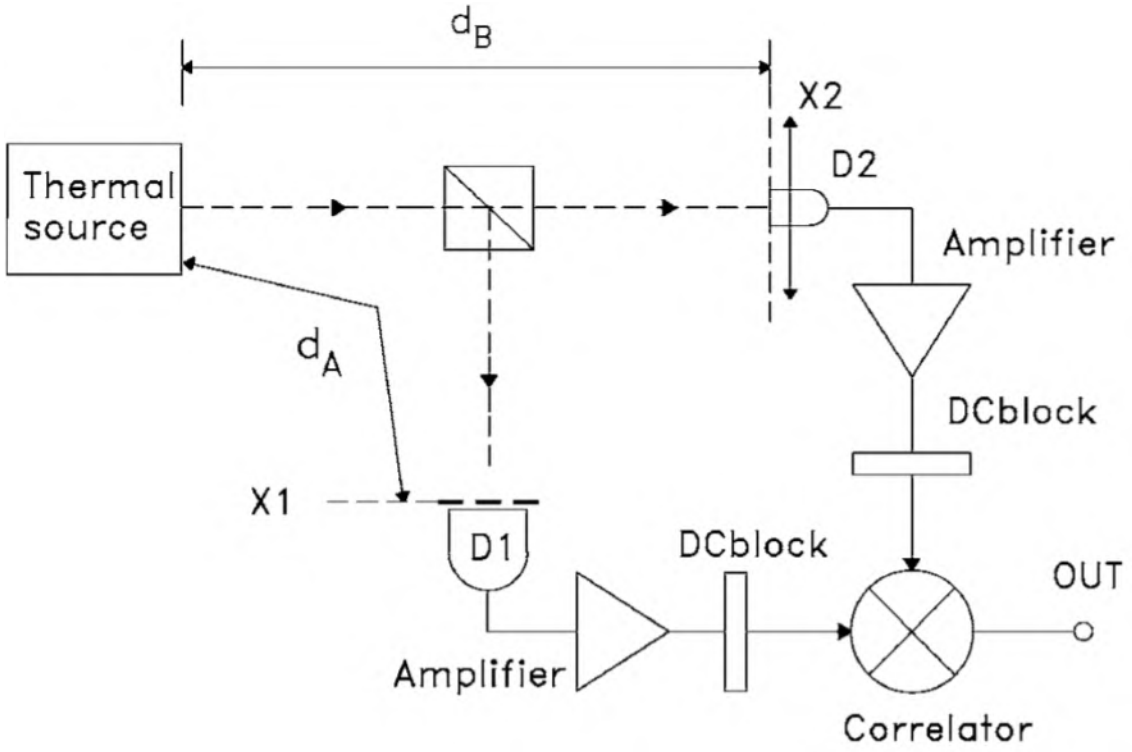
T. B. Pittman, Y. H. Shih, et al,
Phys. Rev. A. 52.R3429 (1995)



Y. H. Shih, et al, Phys. Rev. Lett. 94(6), 063601 (2005)

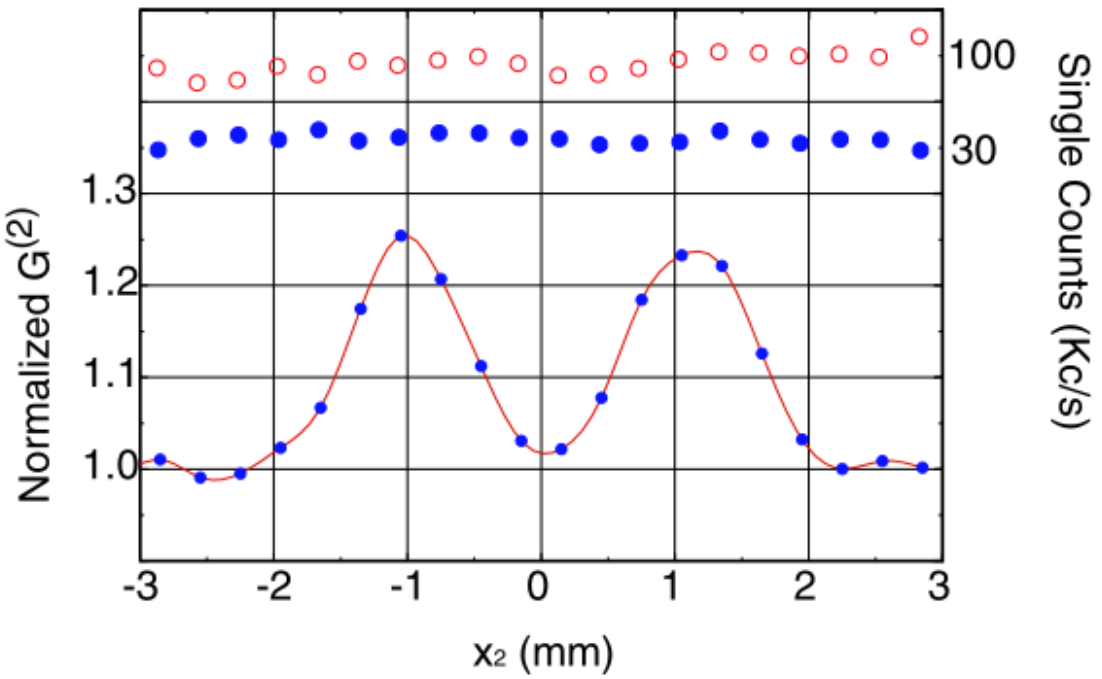
Introduction

Lensless Ghost Imaging (LGI)



L. Basano and P. Ottonello,
Appl. Phys. Lett. 89, 091109 (2006)

Ghost Imaging with pseudothermal light



Y. H. Shih, et al, Phys. Rev. Lett. 94(6), 063601 (2005)

Remarks

- Entangled pair signals is relatively fragile and has a weak signal, which has higher requirements for the experimental environment. -- a quantum interpretation, too expensive!!
- An alternative solution: Pseudothermal Light Source, which contributes to a classical effect. Shapiro and et al proved the equivalence between quantum and semi-classical treatment.

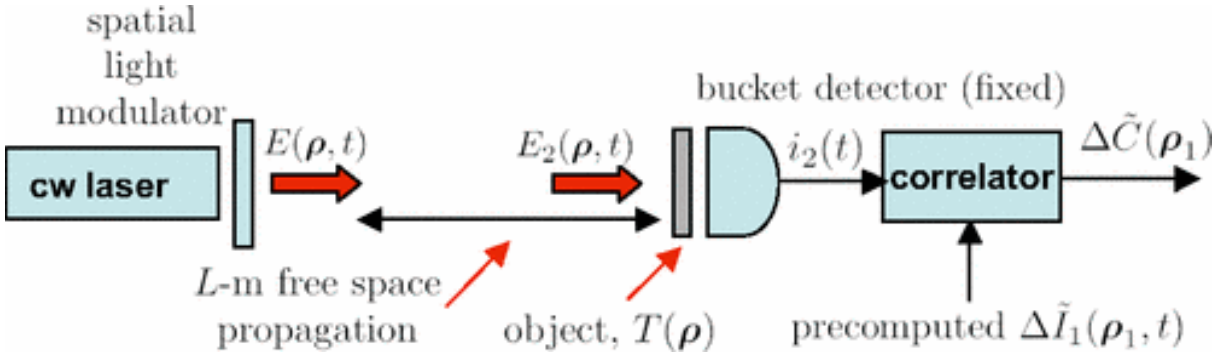
Jeffrey H. Shapiro, Phys. Rev. A 78, 061802 (2008)

B. I. Erkmen and J. H. Shapiro, Phys. Rev. A 77, 043809 (2008)

- There have been many studies on the further development of both methods in recent years.
- Compared with multi-pixels array, single pixel imaging is is cheaper in the visible light band, and the lensless imaging principle can be applied to non-visible light bands such as THz.

CGI and CS

- Computational Ghost Imaging (CGI)



Jeffrey H. Shapiro, Phys. Rev. A 78, 061802 (2008)

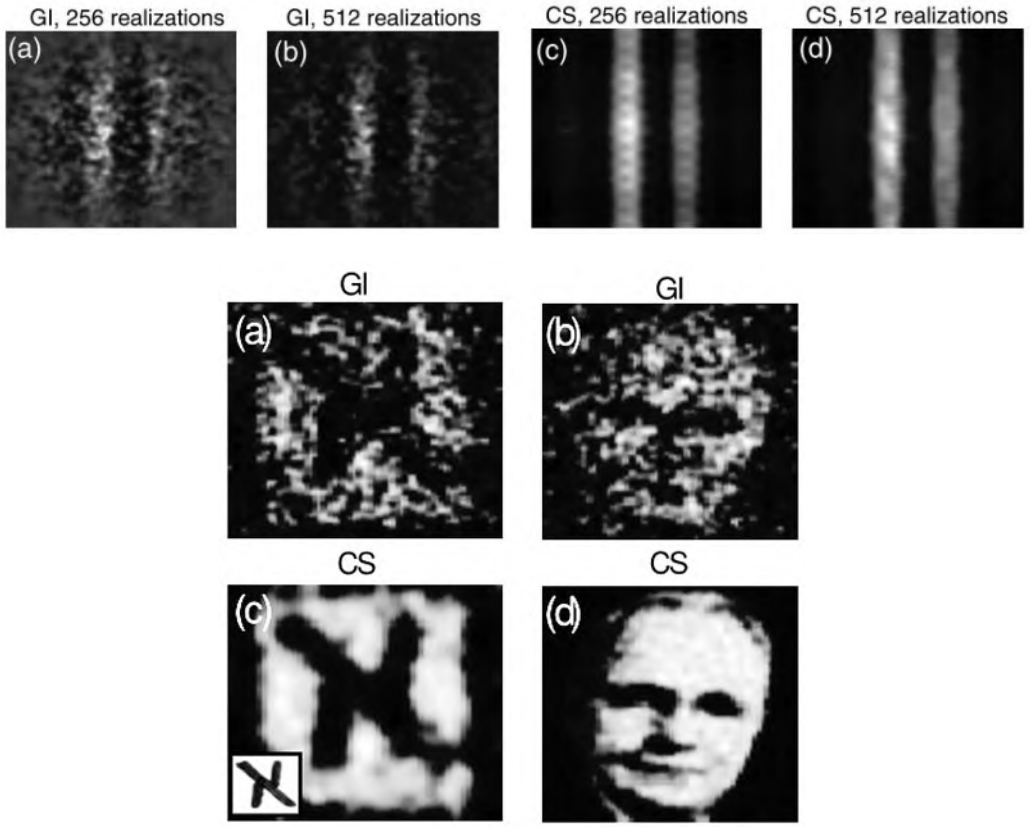
$$B_r = \int dxdy I_r(x,y)T(x,y)$$

$$T_{\mathrm{GI}}(x,y) = \frac{1}{M}\sum_{r=1}^{M}(B_r - \langle B\rangle)I_r(x,y)$$

$$T_{\mathrm{CS}} = T' \ \text{ which minimizes: } \|\Psi\{T'(x,y)\}\|_{L_1},$$

$$\text{subject to } \int dxdy I_r(x,y)T'(x,y) = B_r \ \forall_{r=1..M}$$

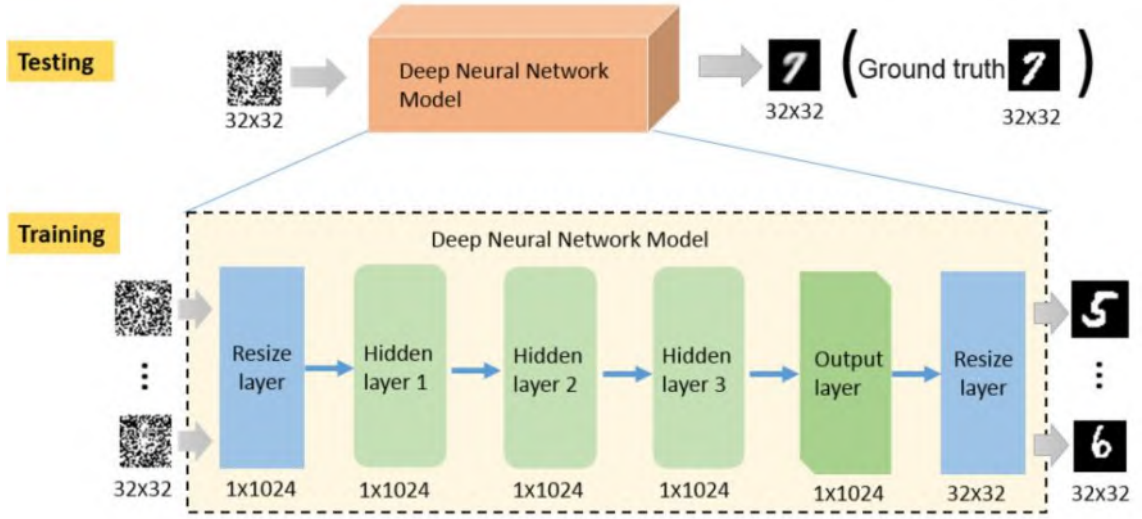
- Compressive Sense



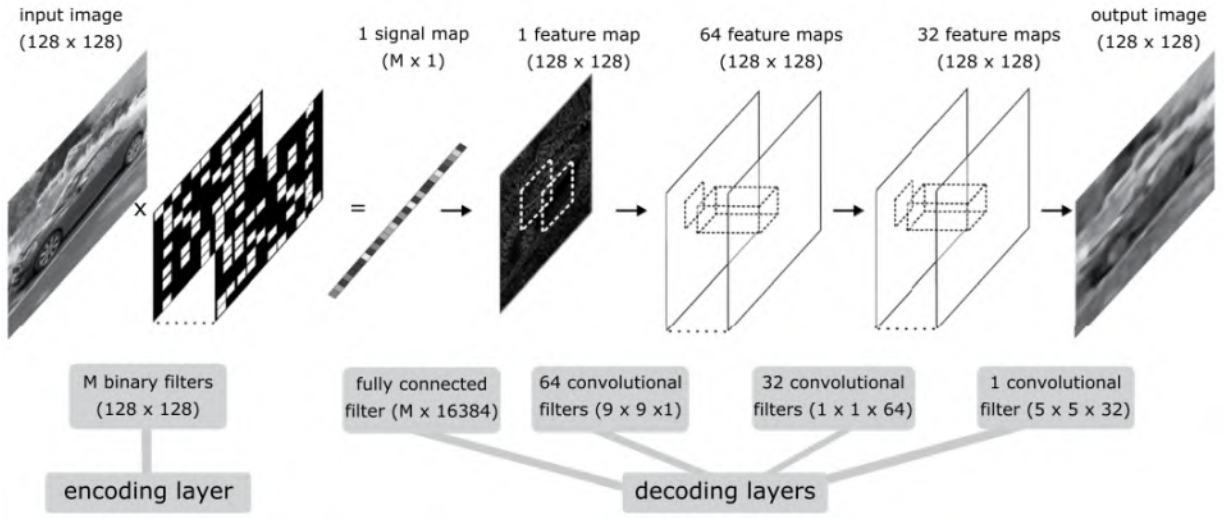
Y. Silberberg, et al, Appl. Phys. Lett. 95, 131110 (2009)

Section 3: Frontier & Our Work

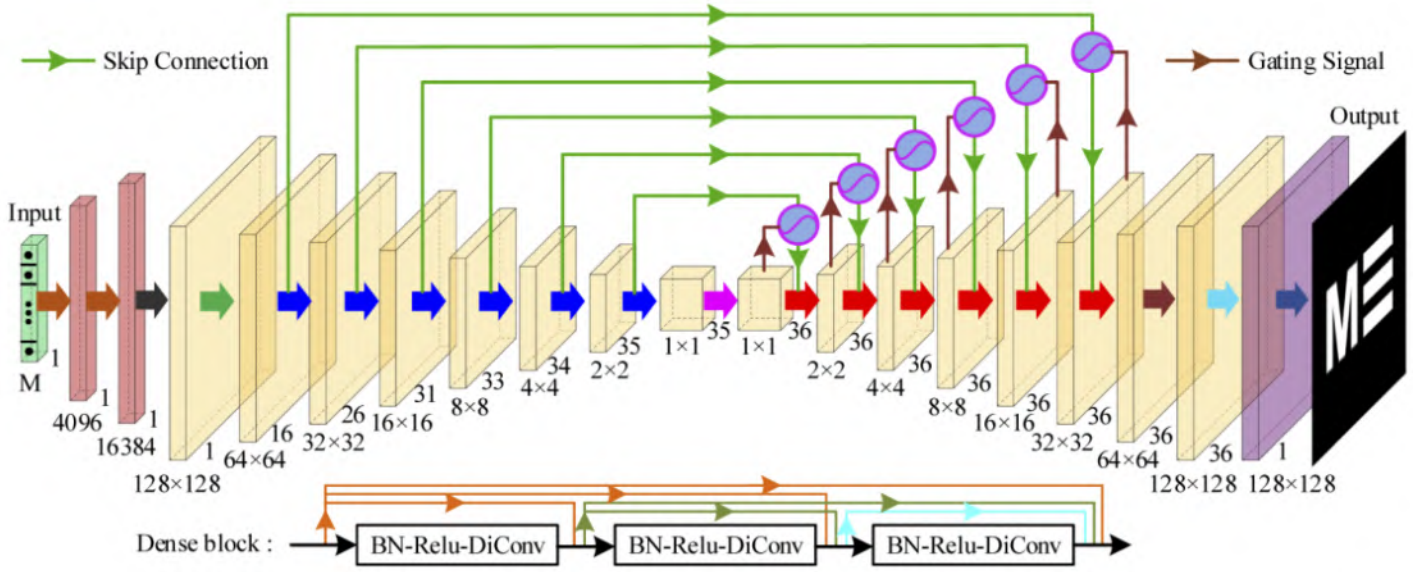
Deep Learning Implement on GI



Guohai Situ, et al, Sci. Rep. 7: 17865 (2017)

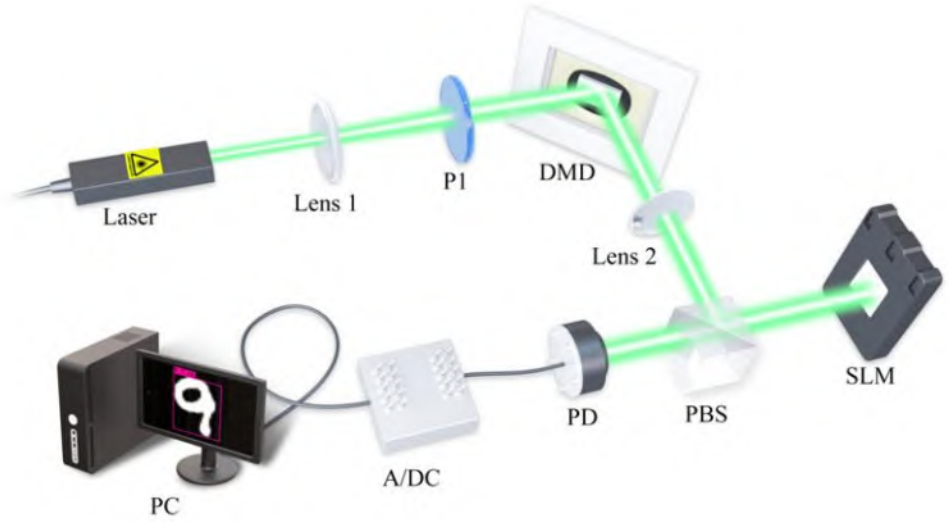


Matthew P. Edgar, et al, Sci. Rep. 8: 2369 (2018)

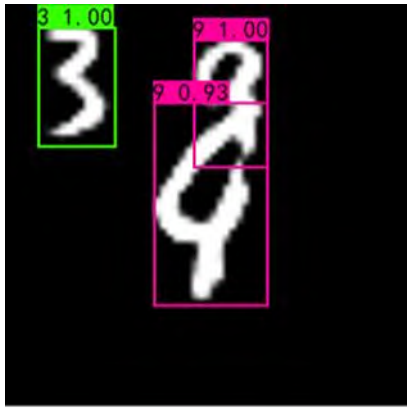


Heng Wu, et al, Opt. Express 28, 3846-3853 (2020)

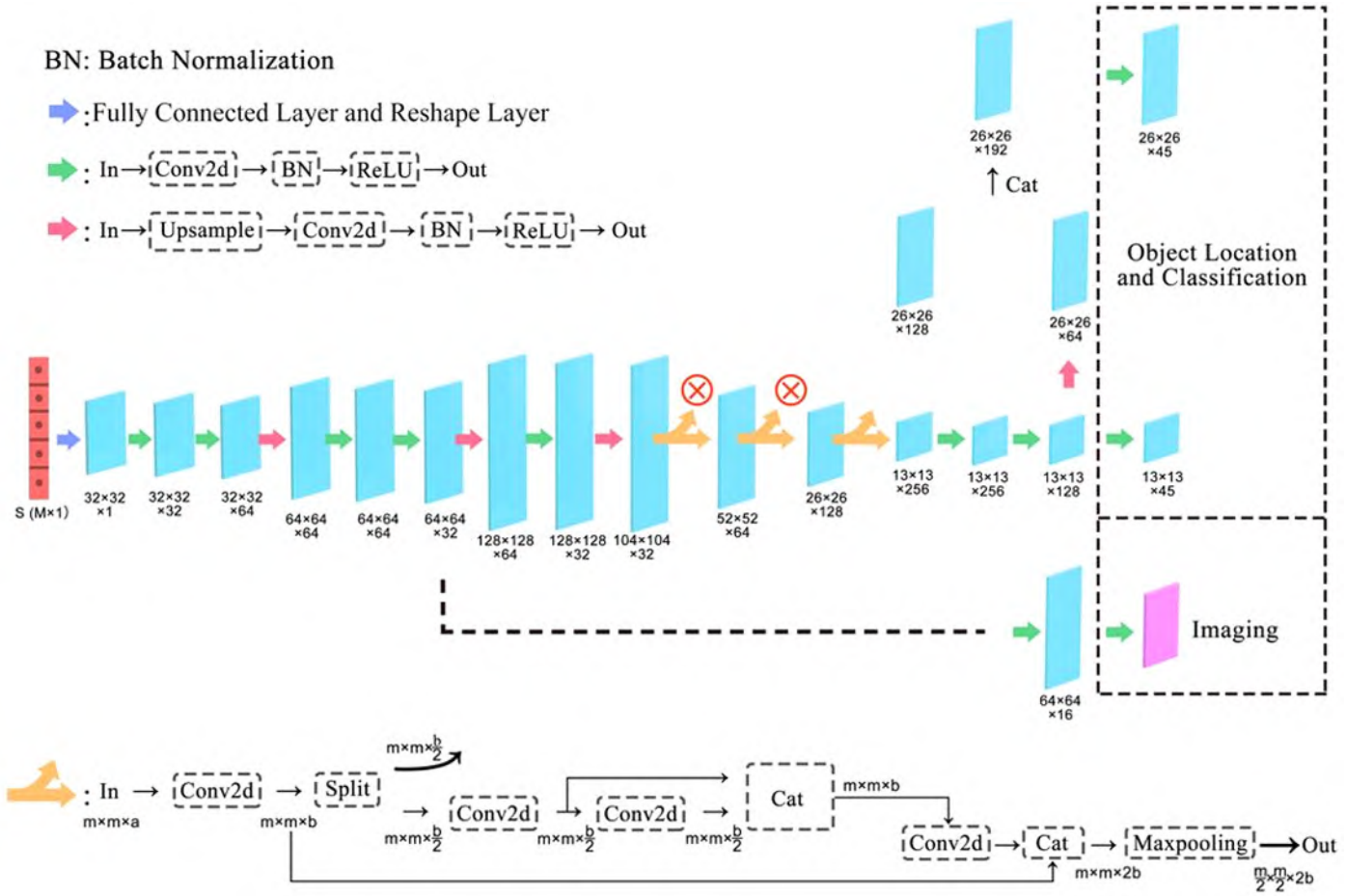
Our Work1: SP-ILC



Ground Truth

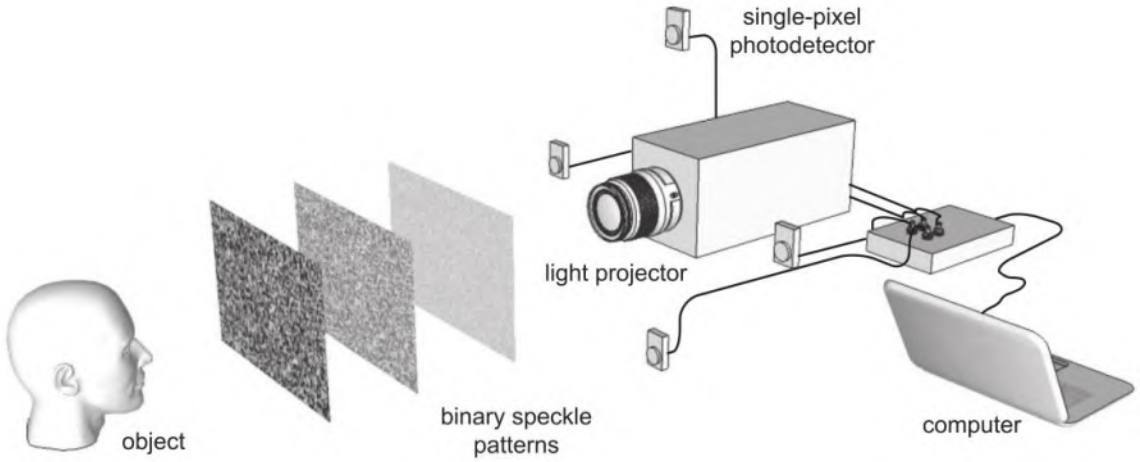


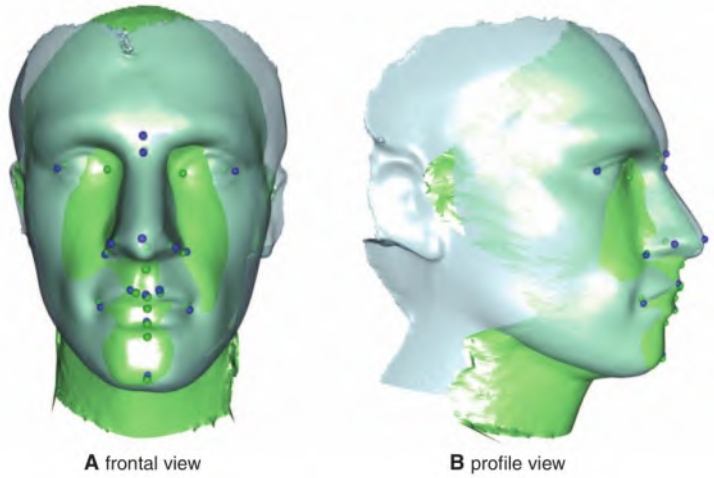
Our Prediction



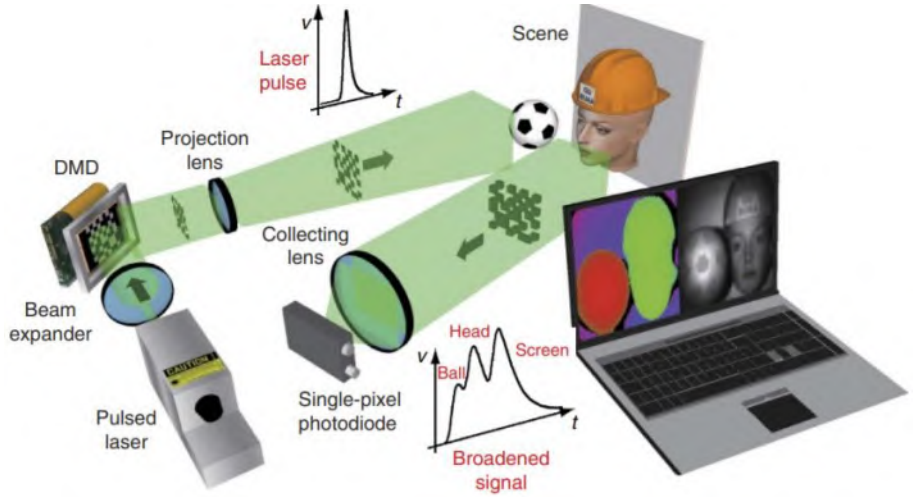
The current network has been optimizing, to fit lower sample rate and achieve real multitask of ILC.

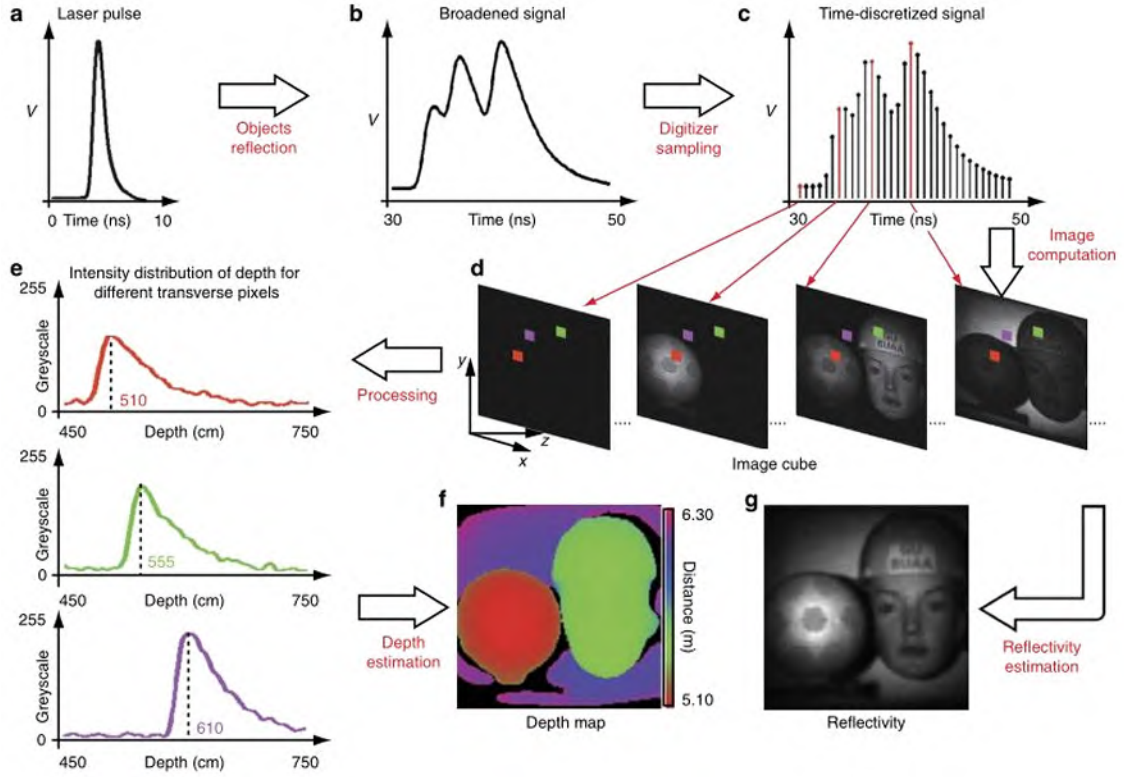
3D Imaging on GI





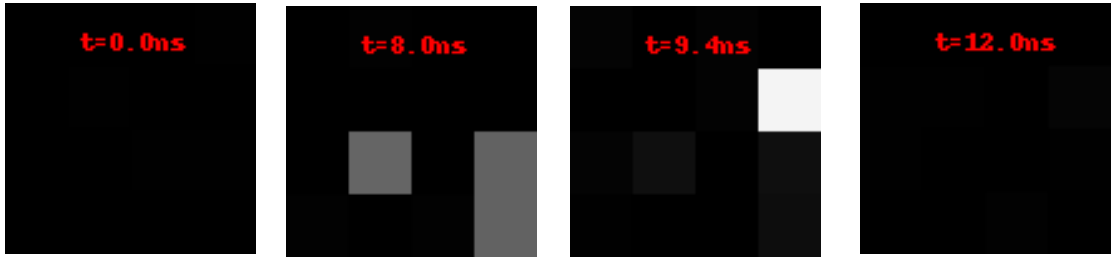
B. Sun, et al, Science. 1234454 (2013)

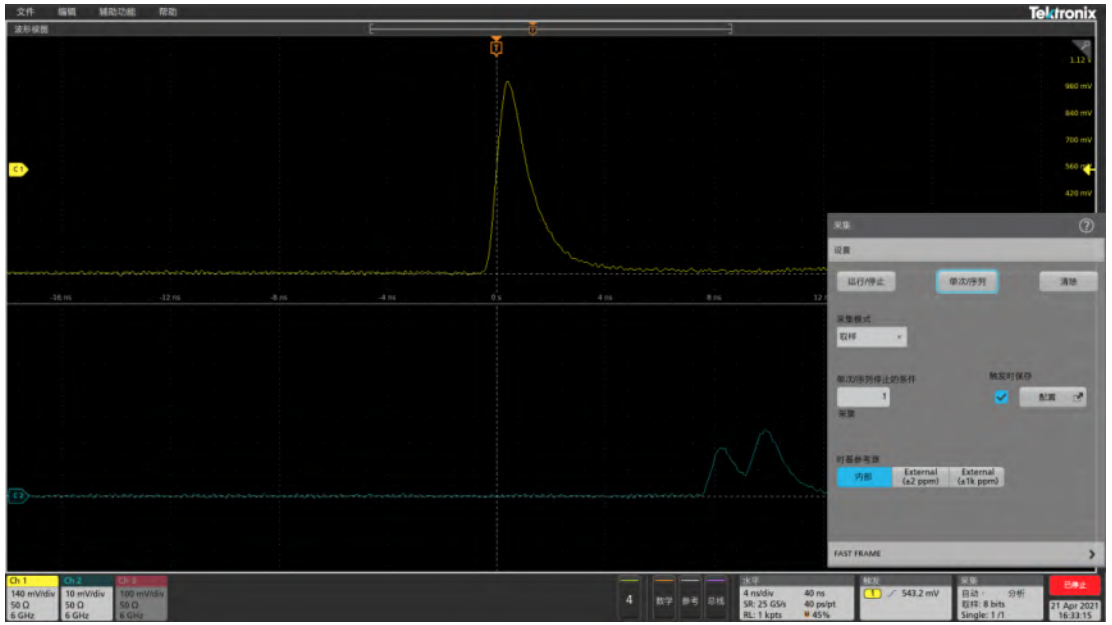




Ming-Jie Sun, et al, Nat Commun 7, 12010 (2016)

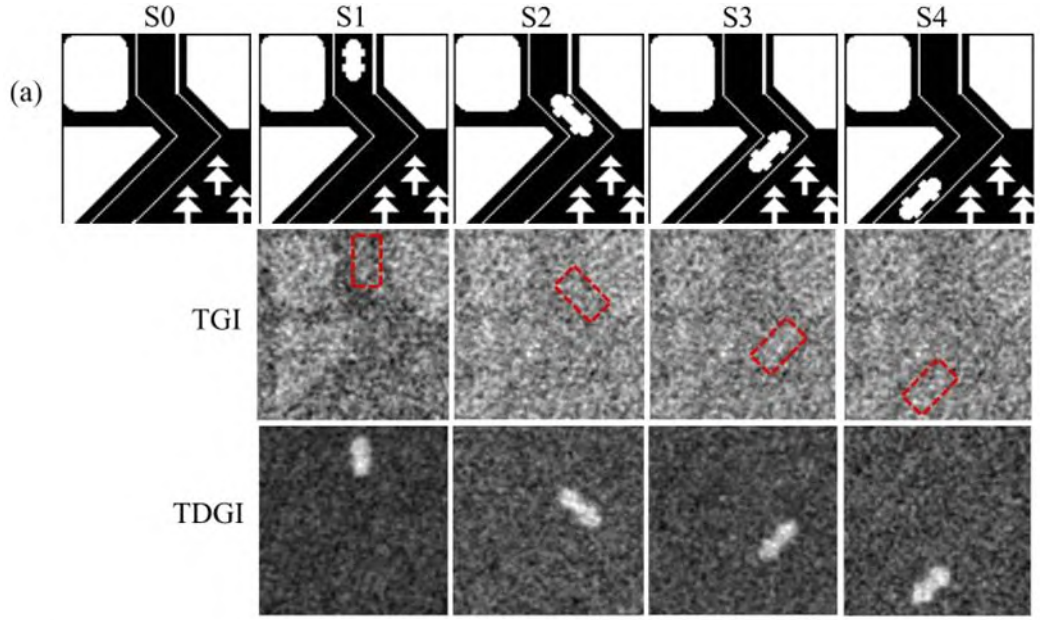
Our work2: ToF 3D Imaging on-chip Implement+

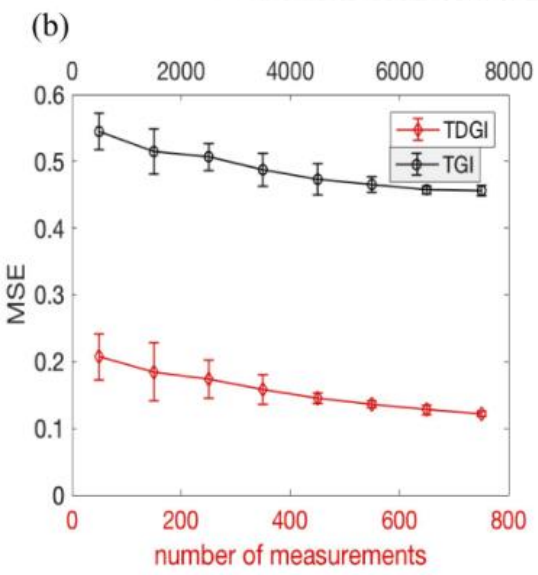


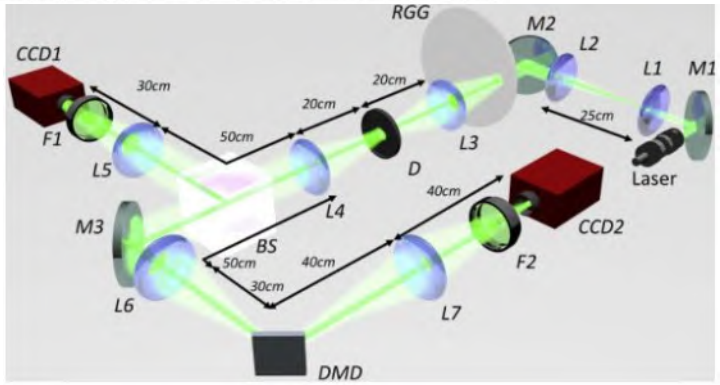


- Time of Flight based
- Principle recurrence
- Difficulties Remain:
  - Minimum Resolution Restriction
  - Continuous Object Detection
  - Reflectivity Distribution
  - Denoising in Physics
  - ……

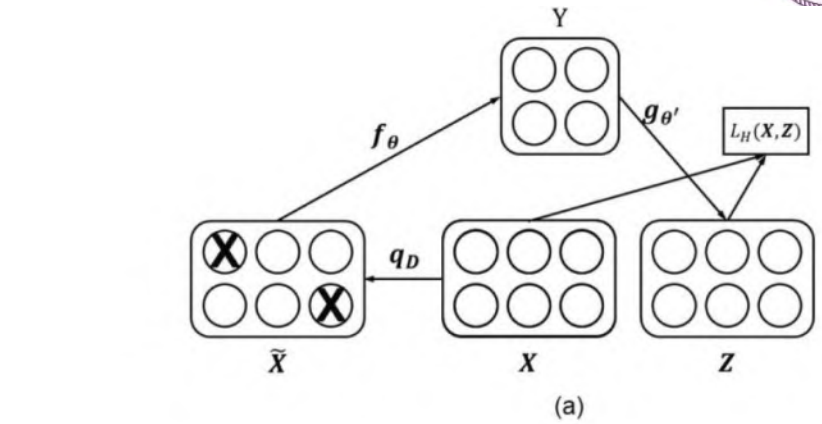
Movement Tracking on GI

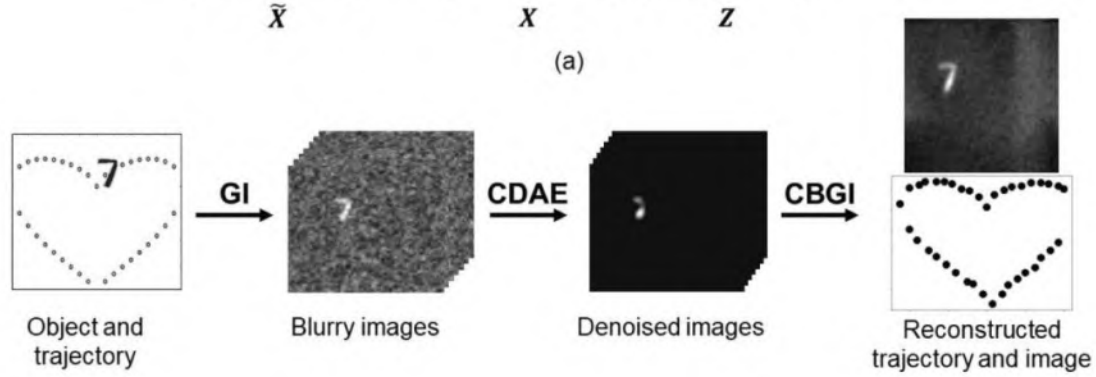


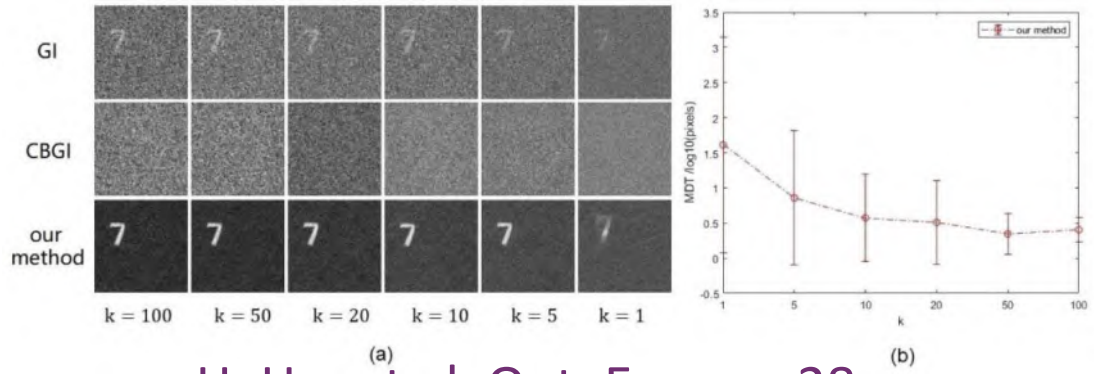




S. Sun, et al, Opt. Express 27, 27851-27861 (2019)



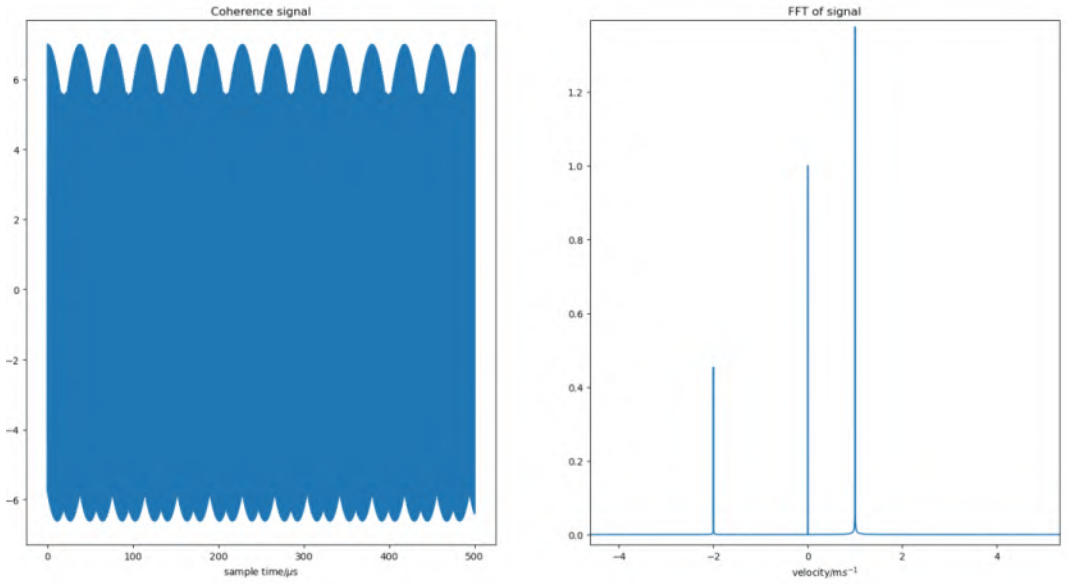


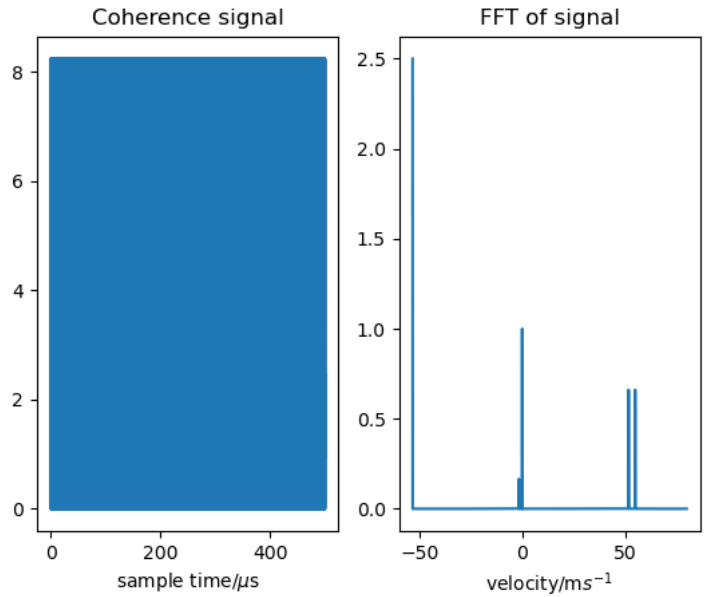


H. Hu, et al, Opt. Express 28, 37284-37293 (2020)

Our Work3: Longitudinal Movement Track

- Transverse movement can be observed by differential method. (Temporal & Spatial)
- Doppler Effect Based
- Difficulties Remain:
  - Multi-Object Movement
  - Diffuse Glitch Signal
  - Time Coherence Wall
  - Weak Signal Detection
  - Motion Produce
  - ……





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Q&A