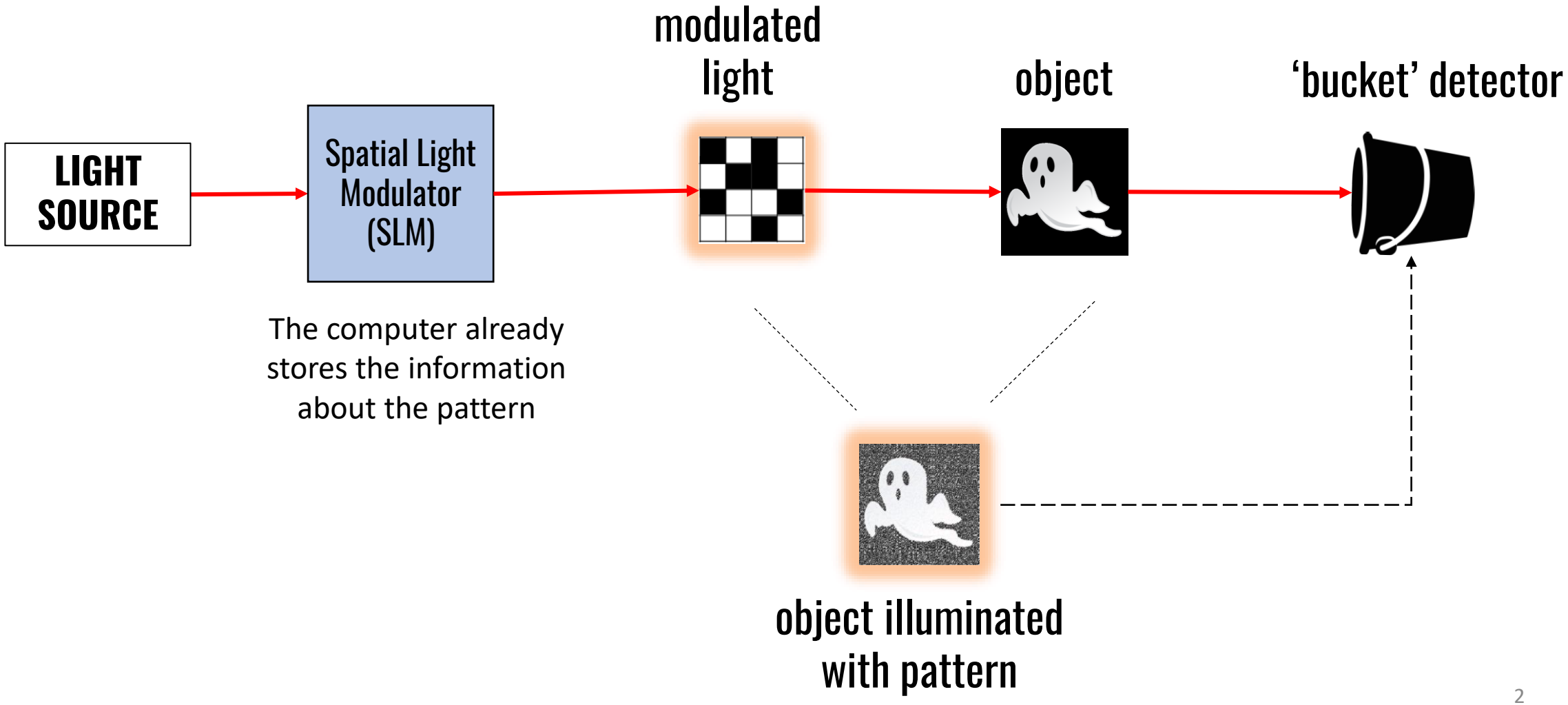
Ghost Imaging

Physics 305 Computational Imaging

Acknowledgement: Slides are from presentation by Dr. Ritz Ann Aguilar

GHOST IMAGING: COMPUTATIONAL

a.k.a Single-Pixel Imaging



Fourier Ghost Imaging (FGI)

- Uses the knowledge of Fourier Transform
- Utilizes knowledge that most of the information of natural images is concentrated in **low** spatial frequency bands

[1] Marcellin M W, JPEG2000: Image Compression Fundamentals, Standards and Practice vol 1 (Springer), 2002
[2] Bian et al., 2016, Efficient single pixel imaging in Fourier space, Journal of Optics, 2016

Fourier Ghost Imaging (FGI)

- Project sinusoidal patterns onto the object. Sinusoidal pattern intensity is given by

$$I_n(x, y; f_x, f_y) = a + b \cdot \cos\big(2\pi(f_x + f_y y) + n\phi\big) \qquad (1)$$

- For 3-bucket algorithm, we set the phase shift to $\Delta\Phi = \frac{2\pi}{3}$ and n = 0, 1, 2.
- Total intensity of reflected light from the object with reflectance R(x,y) is

$$E_n(f_x, f_y) = \iint R(x, y) I_n(x, y; f_x, f_y) dxdy \qquad (2)$$

- Total response of the detector is

$$S_n(f_x, f_y) = S_r + kE_n(f_x, f_y) \qquad (3)$$

where Sr is ambient light, k is a scale factor.

- Substituting (1) into (3) we get detector output

$$D_n(f_x, f_y) = D_b + ak \iint R(x, y) dxdy + bk \iint R(x, y) \cdot \cos\big(2\pi(f_x x + f_y y) + n\phi\big) dxdy$$

$$(5)$$

Fourier Ghost Imaging (FGI)

Arrange as follows:

$$\frac{1}{3}[2S_0 - S_1 - S_2] + \frac{\sqrt{3}}{3} j \cdot [S_2 - S_1]$$

$$= bk \iint R(x,y) \cdot \left\{ \cos\left(2\pi\left(f_x x + f_y y\right)\right) - j \cdot \sin\left(2\pi\left(f_x x + f_y y\right)\right) \right\} dxdy$$

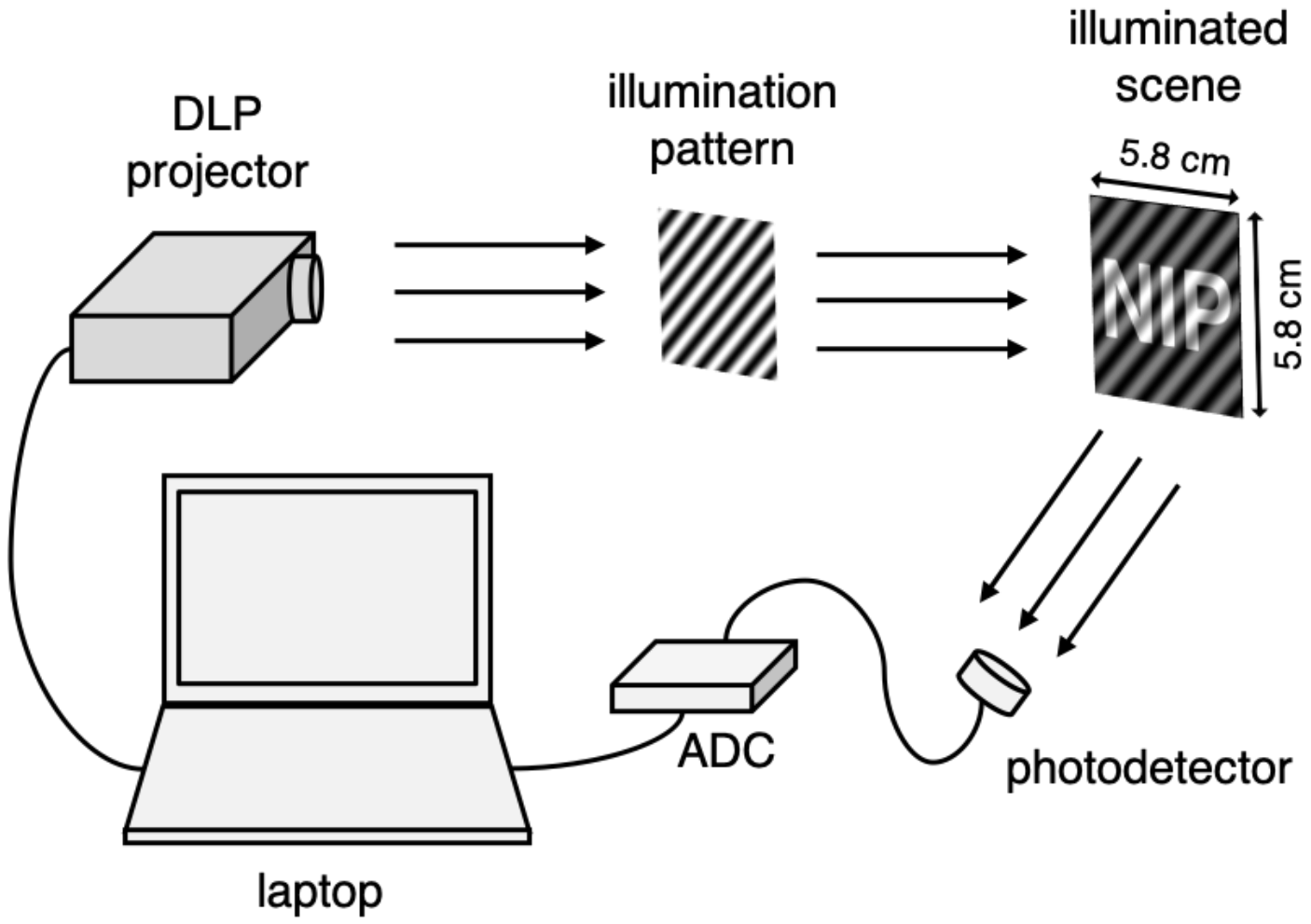
$$= bk \iint R(x,y) \cdot \exp[-j2\pi(f_x x + f_y y)] dxdy$$

$$\propto \mathcal{F}\{R(x,y)\}$$

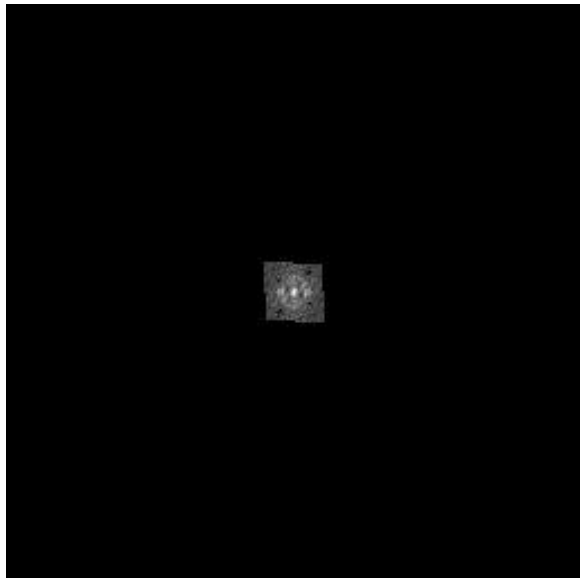
Total reflectivity of the object:

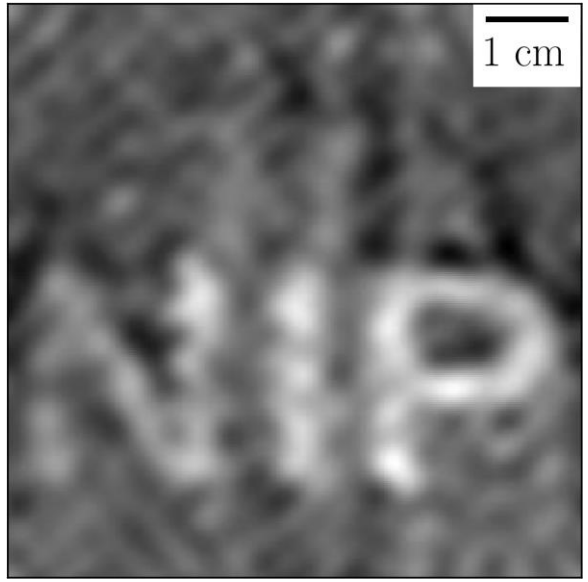
$$\boldsymbol{R(x,y) \propto \mathcal{F}^{-1}\left\{ \frac{1}{3}[2S_0 - S_1 - S_2] + \frac{\sqrt{3}}{3} j \cdot [S_2 - S_1] \right\}}$$

Setup

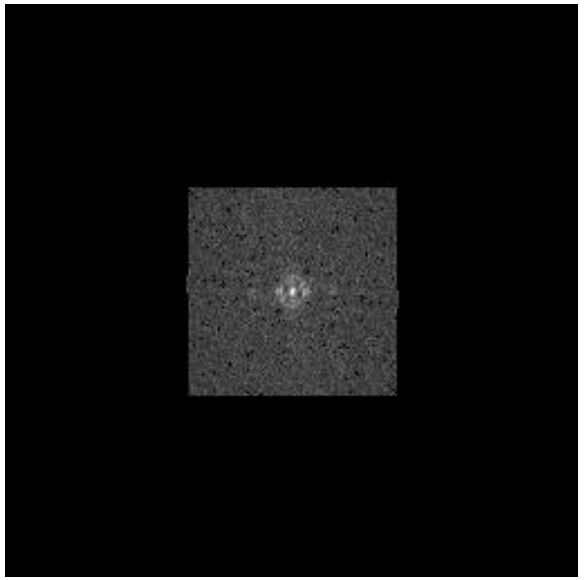

DLP
projector
illumination
pattern
illuminated
scene
5.8 cm
5.8 cm
NIP
ADC
photodetector
laptop

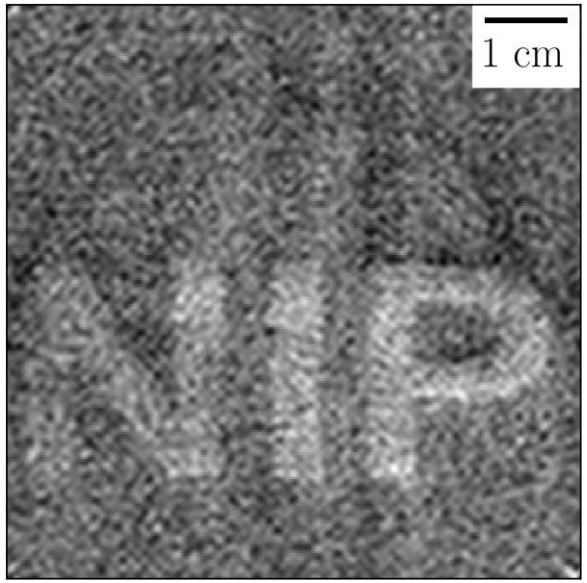
Experiment Results





1% Spectral Coverage

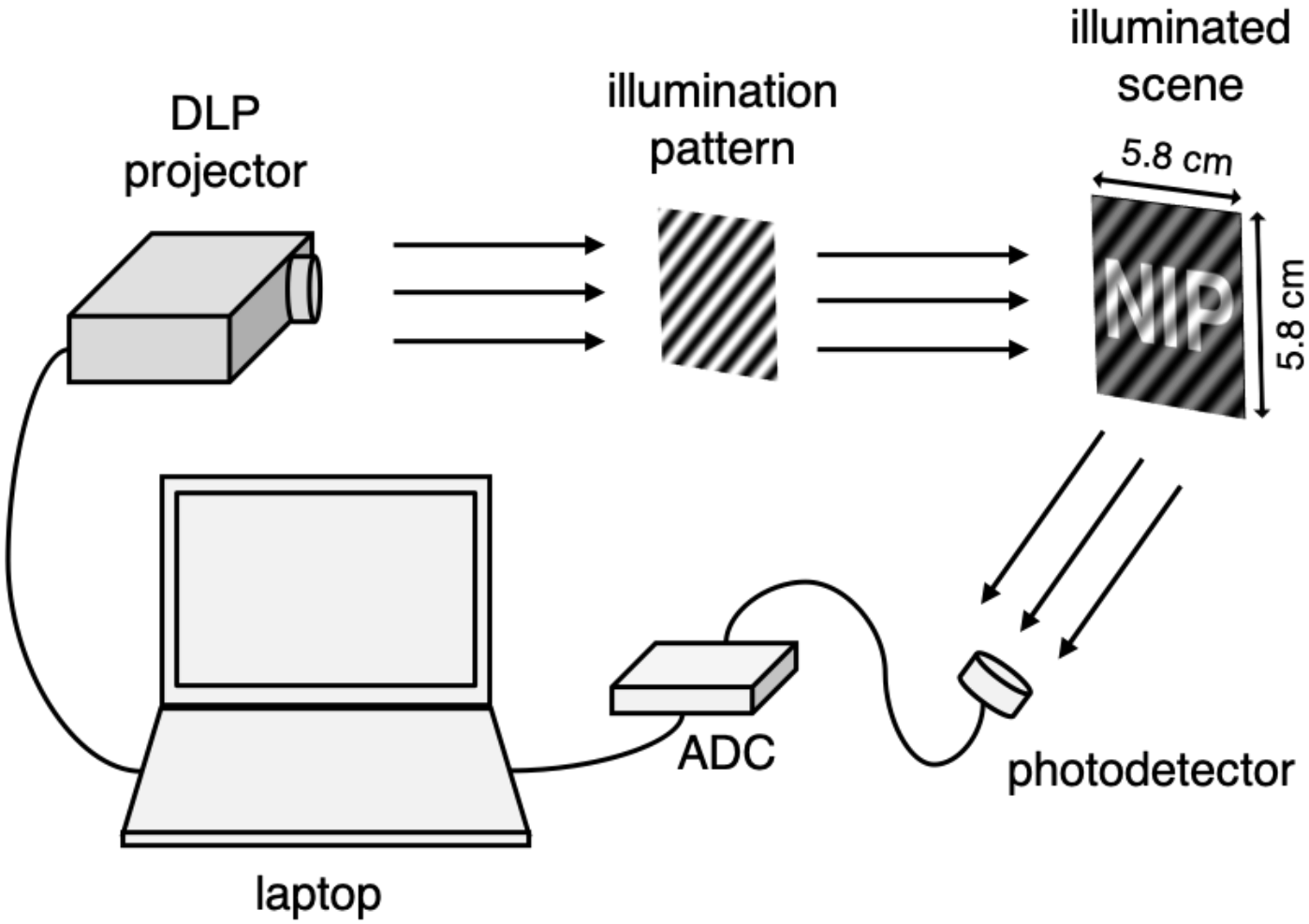




10% Spectral Coverage

Class Activity (Activity 5)

- We will rebuild the Computational Ghost Imaging Setup of Dr Ritz Ann Aguilar and we will capture images for FGI reconstruction
- Group the class into the following:
  - Photodetector group
  - Projector group
  - Computation group



Group Assignments

Photodetector Group	Projector Group	Computation Group
• Will calibrate and program a light-dependent resistor (LDR) to capture signals • Vince, Linus, Jem, Janelle, Christian V.	• Will generate the sinusoidal patterns for projection • Nina, Lem, Celso,Christian B., Reinier	• Will reconstruct the image from the signals captured by LDR • Don Ver, Ryan, Rene, JC , Hazel

Reference

- Aguilar, R. A., Hermosa, N., & Soriano, M. N. (2019). Low-cost Fourier ghost imaging using a light-dependent resistor. American Journal of Physics, 87(12), 976-981.