EE 123 Discussion Section 5
Sampling

March 2, 2018

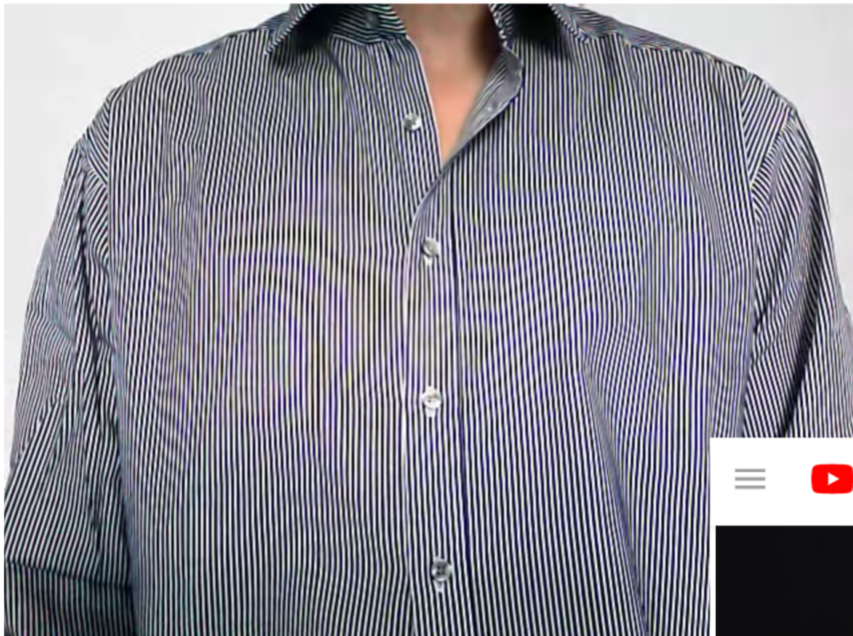
Li-Hao Yeh

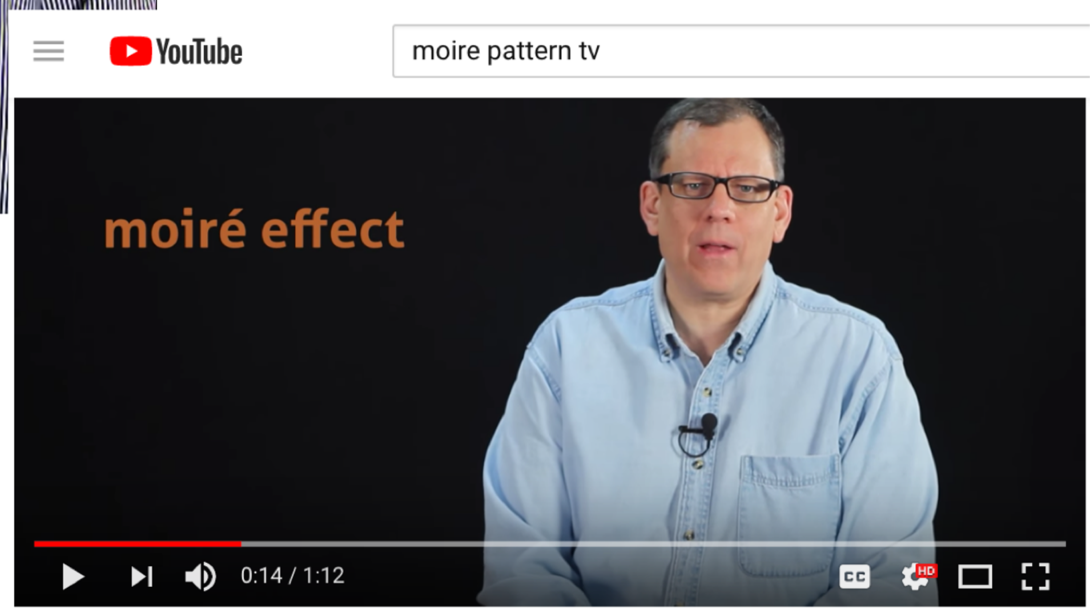
Based on slides by Frank Ong

Announcements

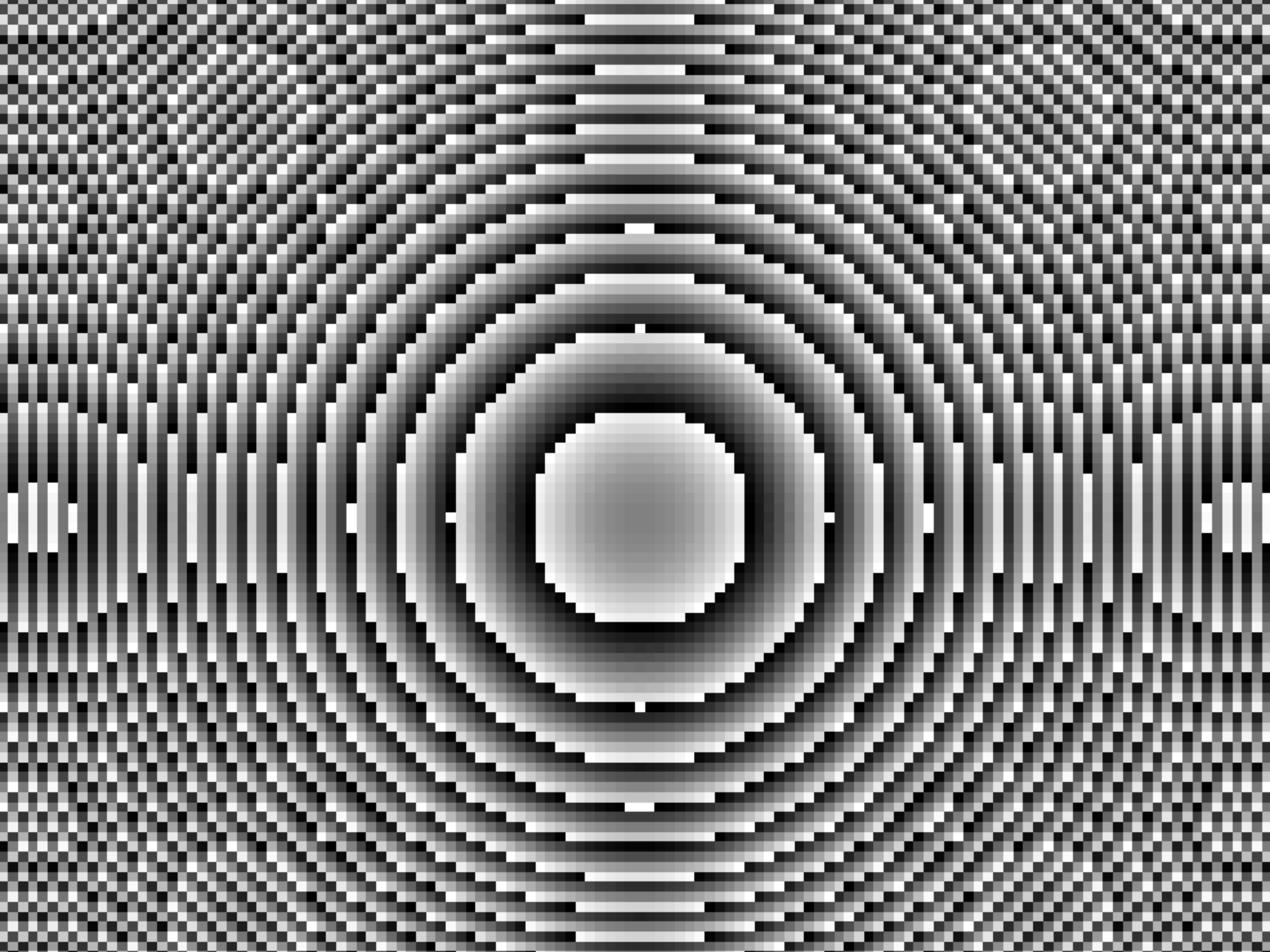
- Lab 2 – due today
- HW 5 – due next Wednesday March 7.
- Questions?

Why do we care sampling





Preparing for a Video Shoot and Avoiding a Moire Pattern

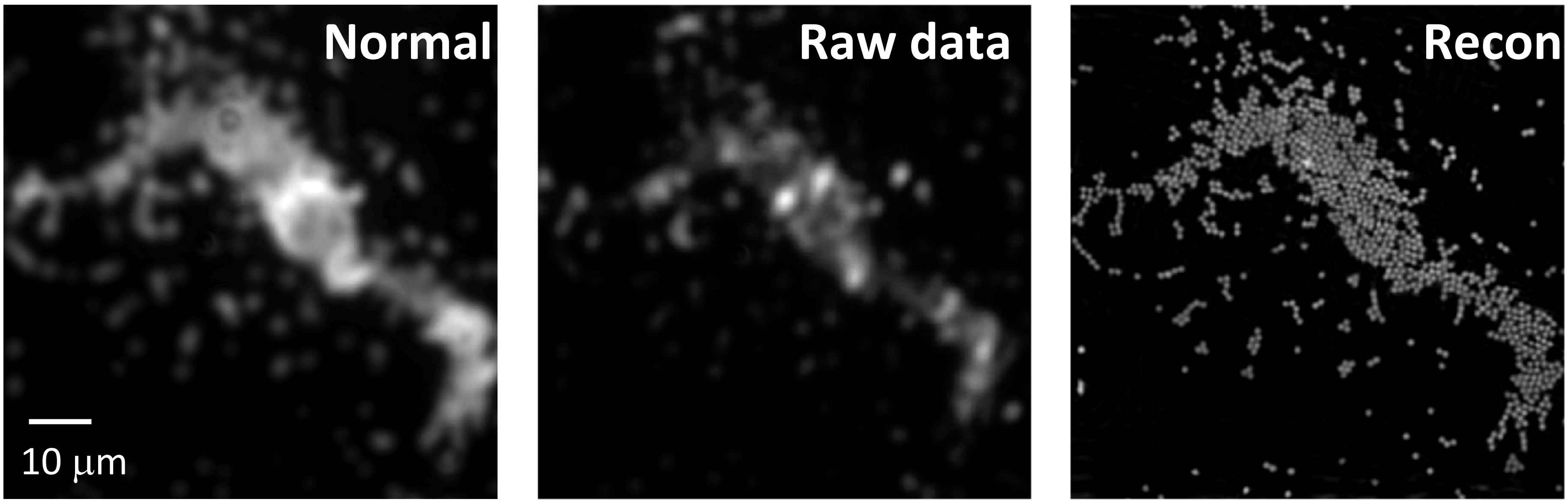


Why do we care sampling

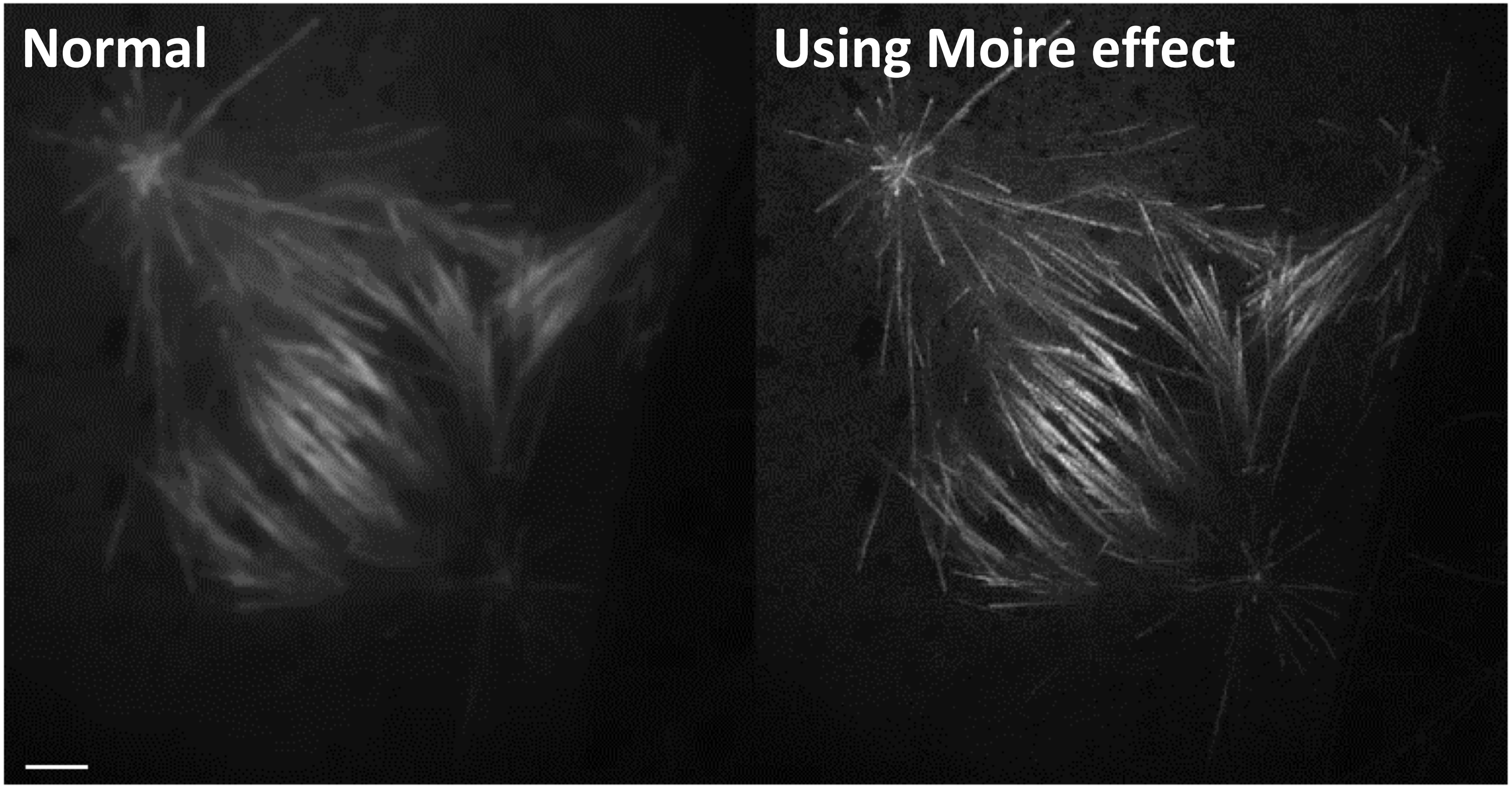
DEMO

Why do we care sampling

Why do we care sampling



Why do we care sampling



Kner, Peter, et al. "Super-resolution video microscopy of live cells by structured illumination." *Nature methods* 6.5 (2009): 339-342.

Review of sampling

Continuous time signal

$$x_c(t) \longleftrightarrow X_c(j\Omega) = \int x_c(t) e^{-j\Omega t} dt$$

Continuous time sampling

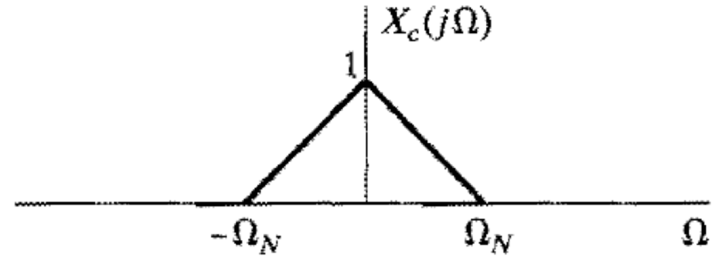
$$x_s(t) = x_c(t) \sum_{k=-\infty}^{\infty} \delta(t - kT)$$

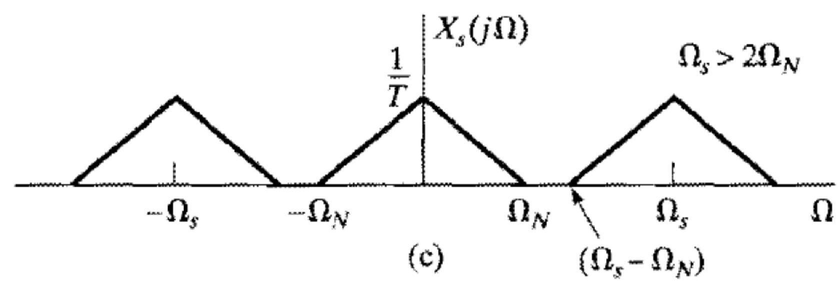
$$X_s(j\Omega) = \frac{1}{T} \sum_{k=-\infty}^{\infty} X_c(j(\Omega - k\Omega_s)), \quad \Omega_s = \frac{2\pi}{T}$$

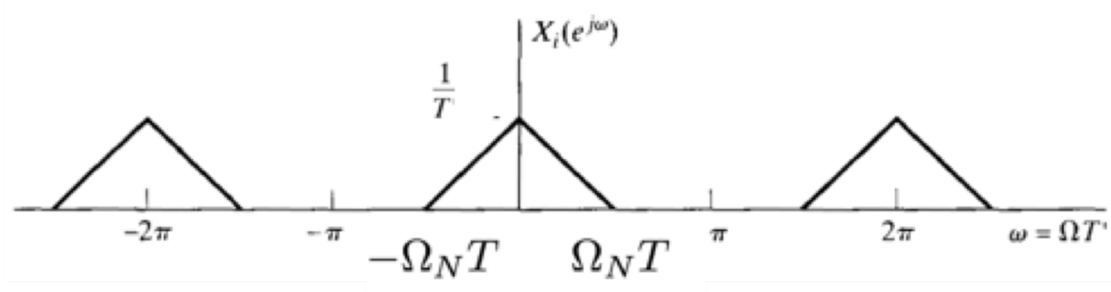
$$= \sum_{k=-\infty}^{\infty} x_c(nT) e^{-j\Omega T n}$$

Discrete time spectrum

$$X(e^{j\omega}) = X_s\left(j\left(\frac{\omega}{T}\right)\right)$$



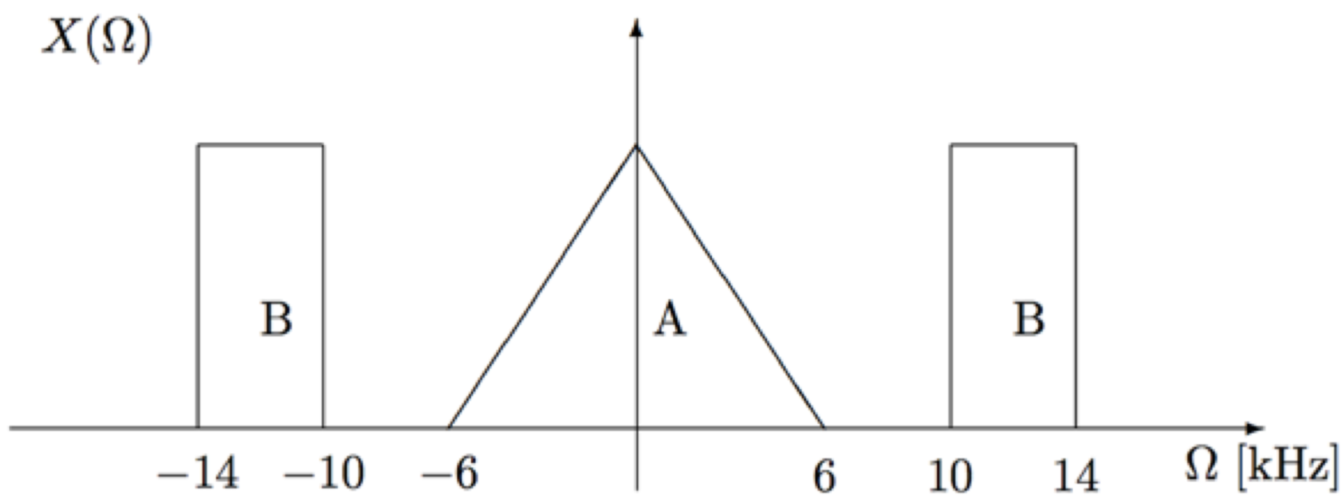




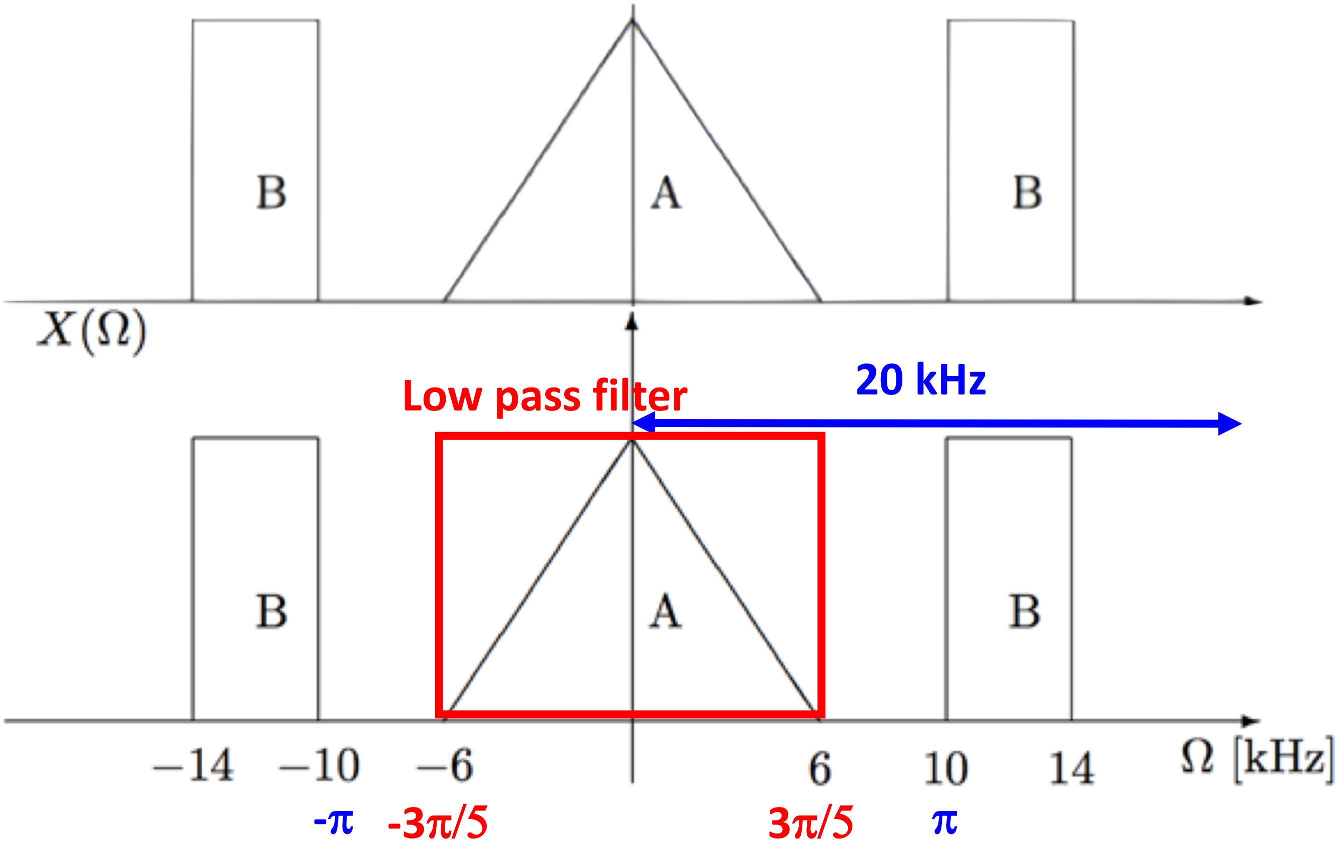
Sampling question 1

4. An analog signal, whose spectrum is shown below, is to be processed with a digital filter using ideal C/D and D/C converters (with no analog anti-aliasing filters).

a) (8 points) What is the minimum sufficient sampling rate to extract portion A of the signal? Sketch the magnitude of the digital filter that would be used at this sampling rate.



Sampling solution 1a

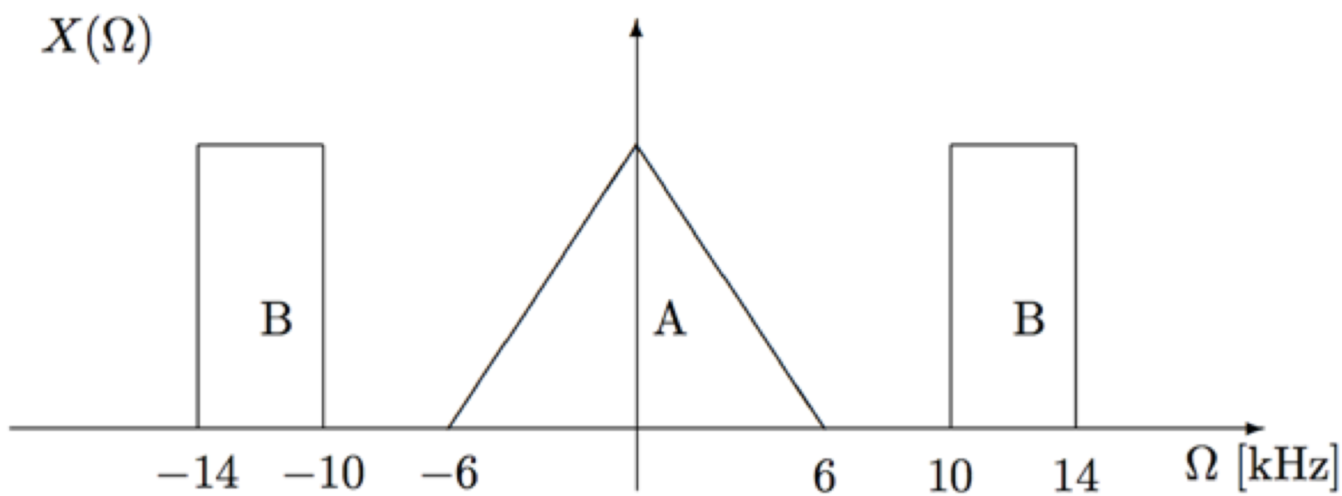


Sampling question 1

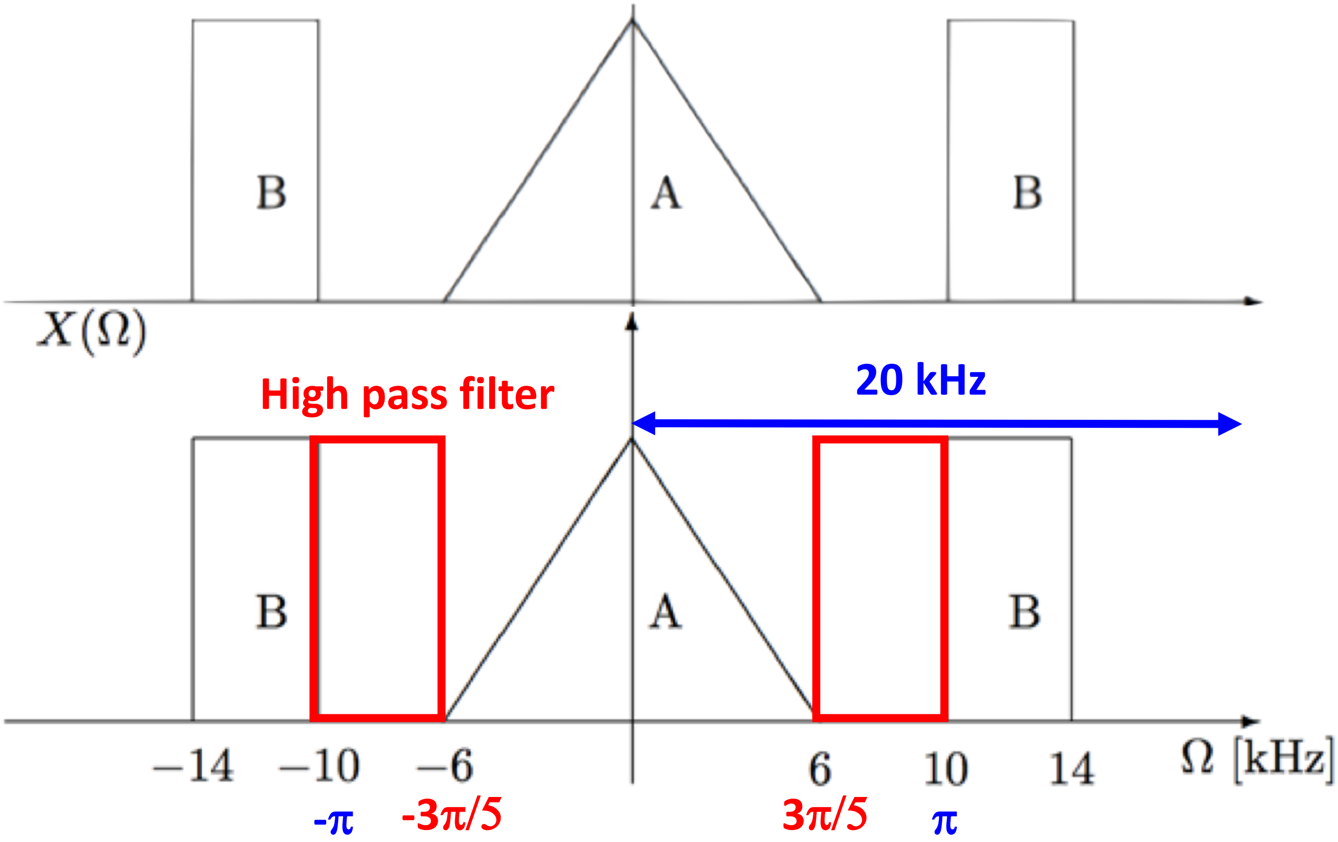
4. An analog signal, whose spectrum is shown below, is to be processed with a digital filter using ideal C/D and D/C converters (with no analog anti-aliasing filters).

a) (8 points) What is the minimum sufficient sampling rate to extract portion A of the signal? Sketch the magnitude of the digital filter that would be used at this sampling rate.

b) (7 points) Repeat for portion B of the signal.

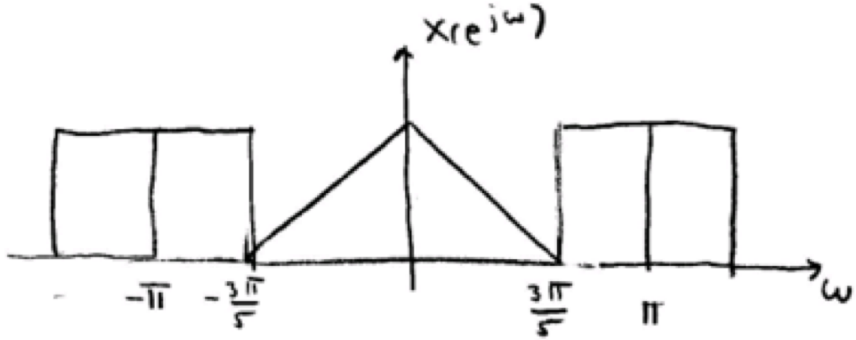


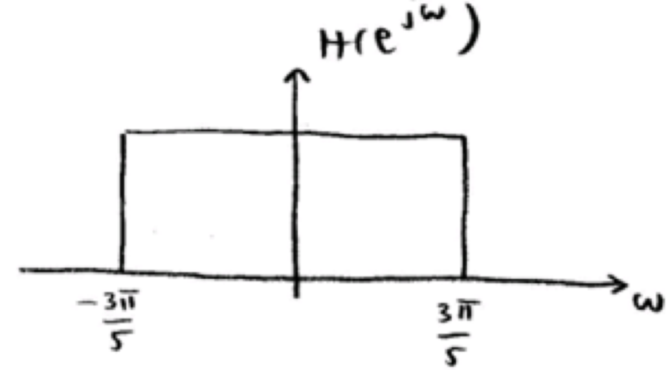
Sampling solution 1b



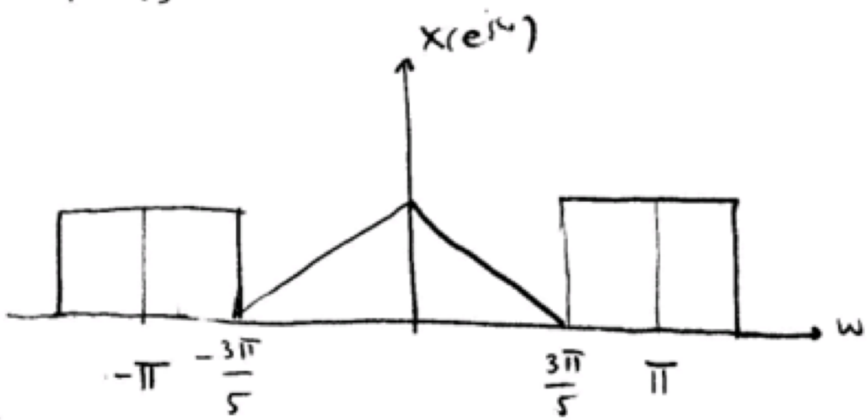
Sampling solution 1

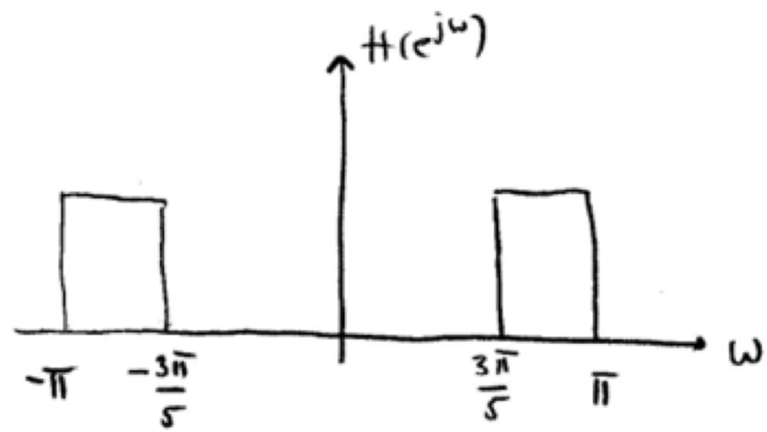
a) $f_s = 20\,kHz$



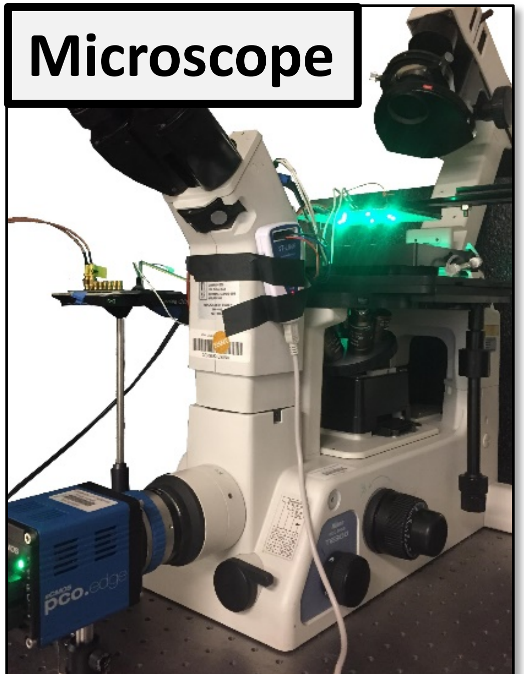


b) $f_s = 20\,kHz$





Sampling question 2 (Optics!!)



The imaging process of an microscopy can be described below.
Assuming camera pixel size is Δx
The kernel is bandlimited with bandwidth of B_x
The magnification of the microscope is M

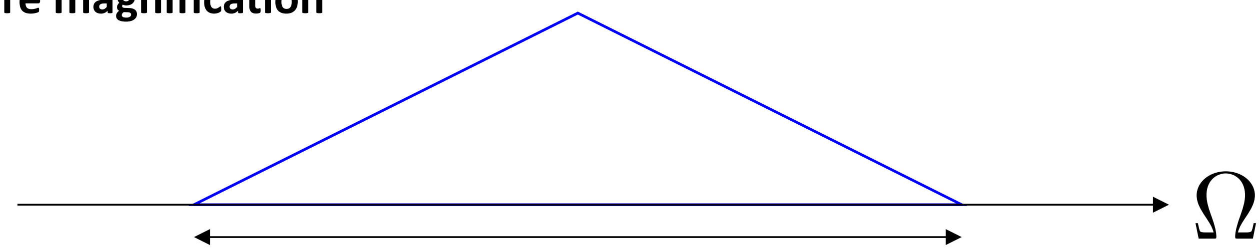
(a) Find the condition of M in terms of B_x and Δx such that there is no aliasing in the pictures taken by the camera.

$$\overset{\text{image}}{I(x)} = \overset{\text{object}}{o(x)} \otimes \overset{\text{kernel}}{h(x)} \xrightarrow{\text{Magnify}}$$

camera

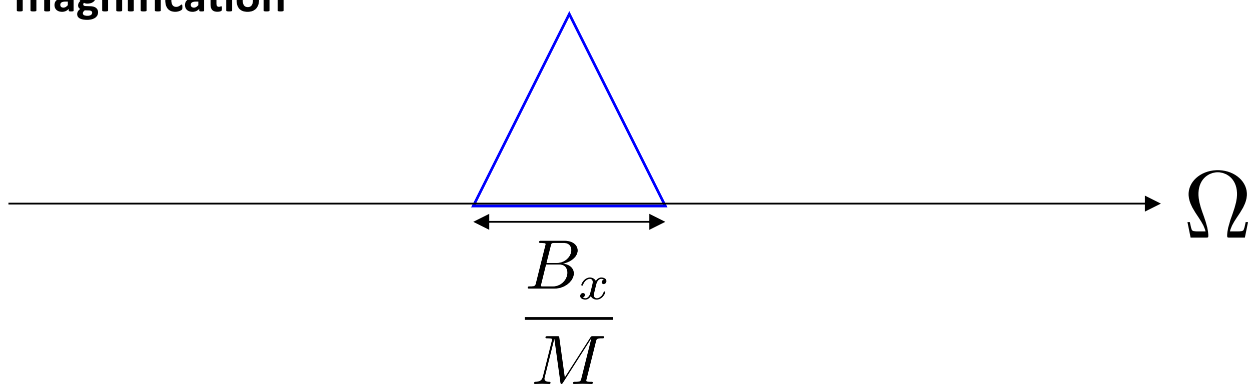
Sampling solution 2a (Optics!!)

Before magnification



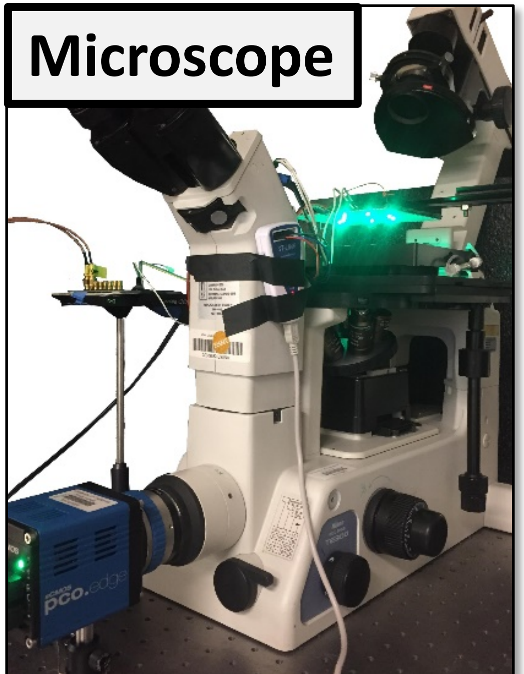
This is how we design optical system to have good enough sampling rate on the camera

After magnification



Nyquist sampling: $$\frac{1}{\Delta x} \geq \frac{B_x}{M} \Longrightarrow M \geq B_x \Delta x$$

Sampling question 2 (Optics!!)



The imaging process of an microscopy can be described below.
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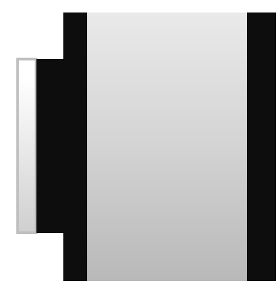
The magnification of the microscope is M

(a) Find the condition of M in terms of B_x and Δx such that there is no aliasing in the pictures taken by the camera.

(b) What if our kernel now is $[h(x)]^2$? What about $[h(x)]^3$?

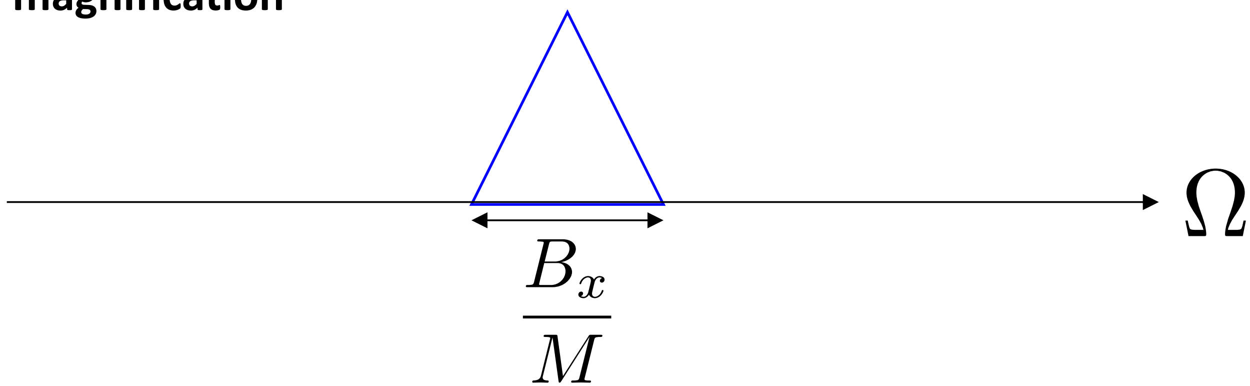
$$\overset{\text{image}}{I(x)} = \overset{\text{object}}{o(x)} \otimes \overset{\text{kernel}}{h(x)} \xrightarrow{\text{Magnify}}$$

camera

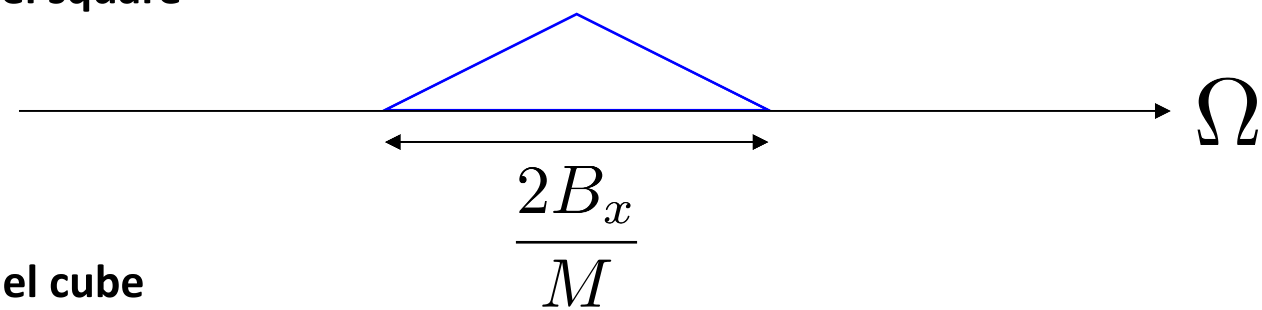


Sampling solution 2b (Optics!!)

After magnification



Kernel square



Kernel cube