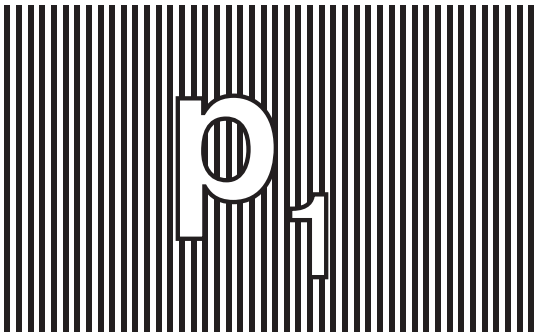
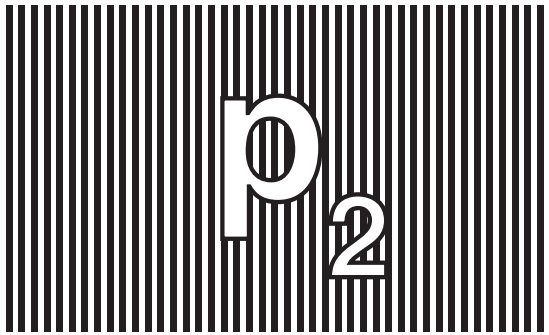
Moiré Principle Illustrated



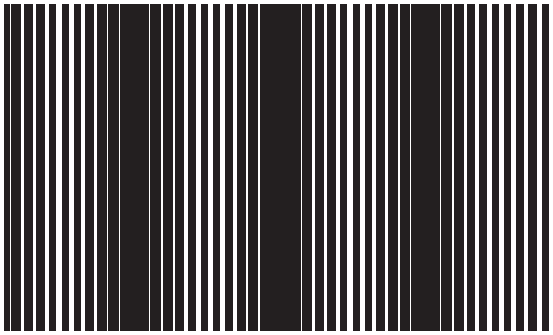
(not resolvable in optical microscope)

+



(not resolvable in optical microscope)

Moiré Pattern:



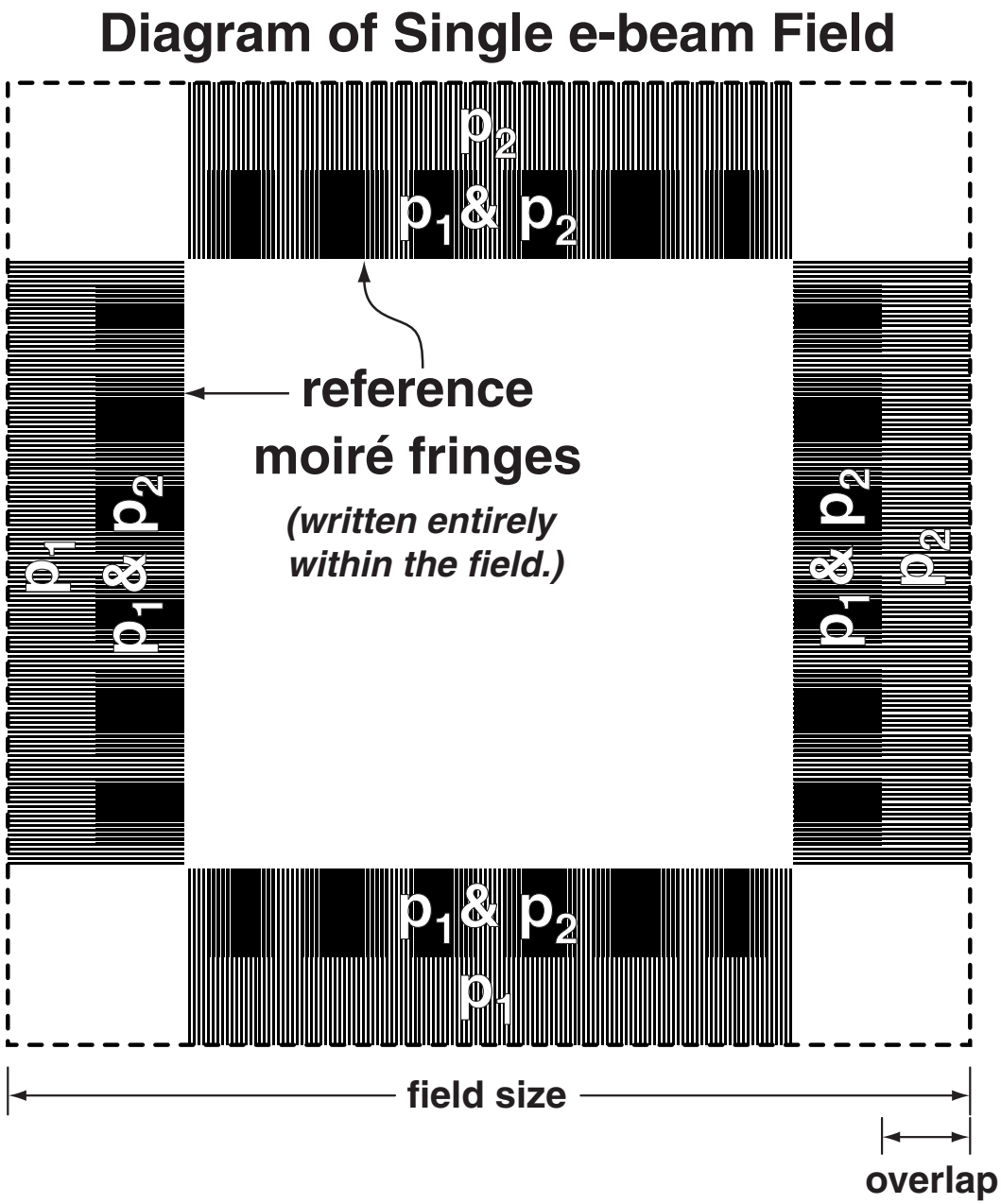
(easily resolved in optical microscope)

P

$$P = \frac{p_1 p_2}{|p_2 - p_1|}$$

Position (phase) of moiré fringes is very sensitive to relative position of p_1 and p_2

Moiré Stitching Measurement

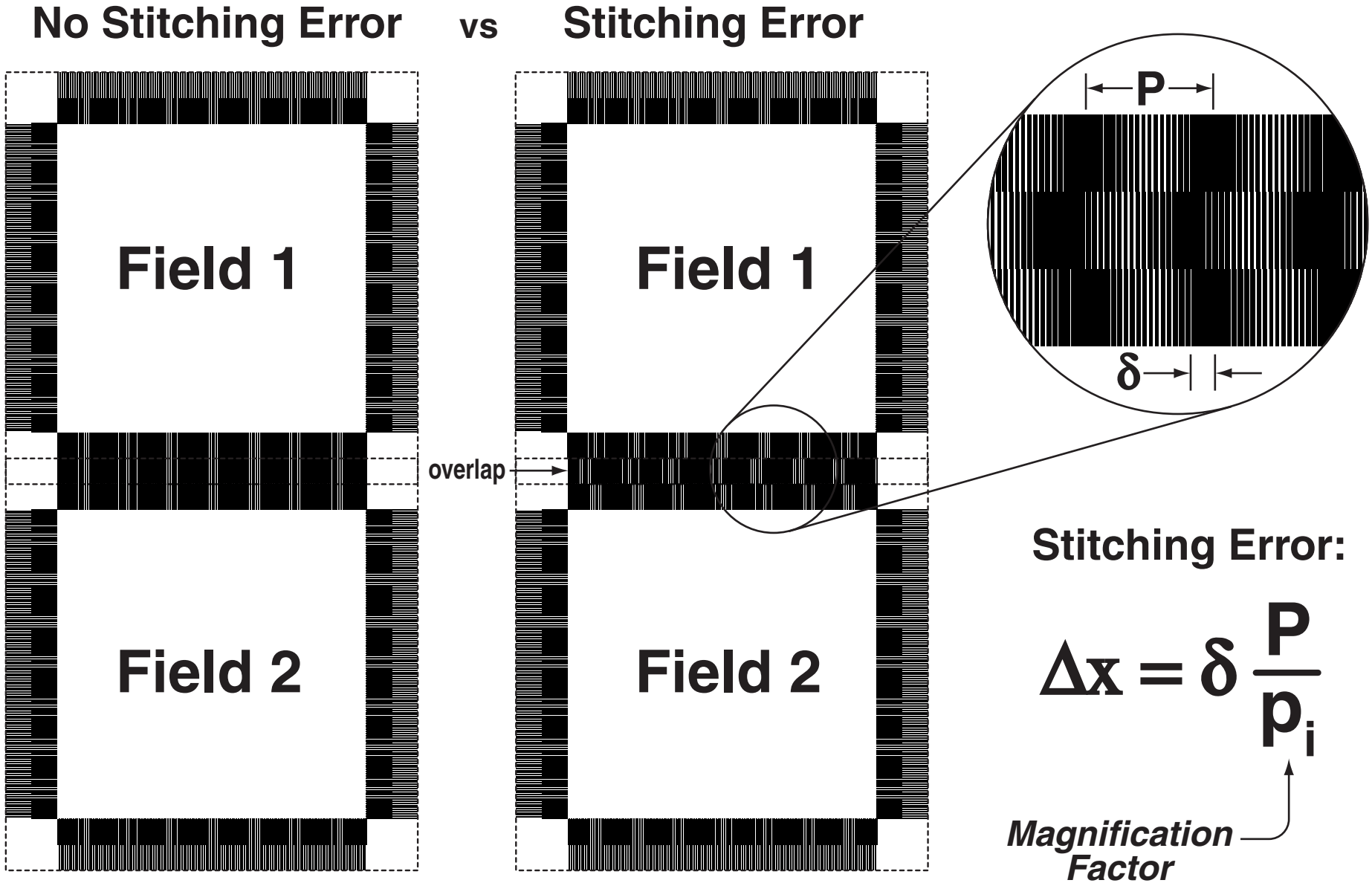


Edges of adjacent fields overlap, generating a moiré pattern.

Phase of moiré pattern indicates the amount of transverse stitching error

Reference moiré fringes provide a basis for comparison.

Illustration of Stitching Measurement

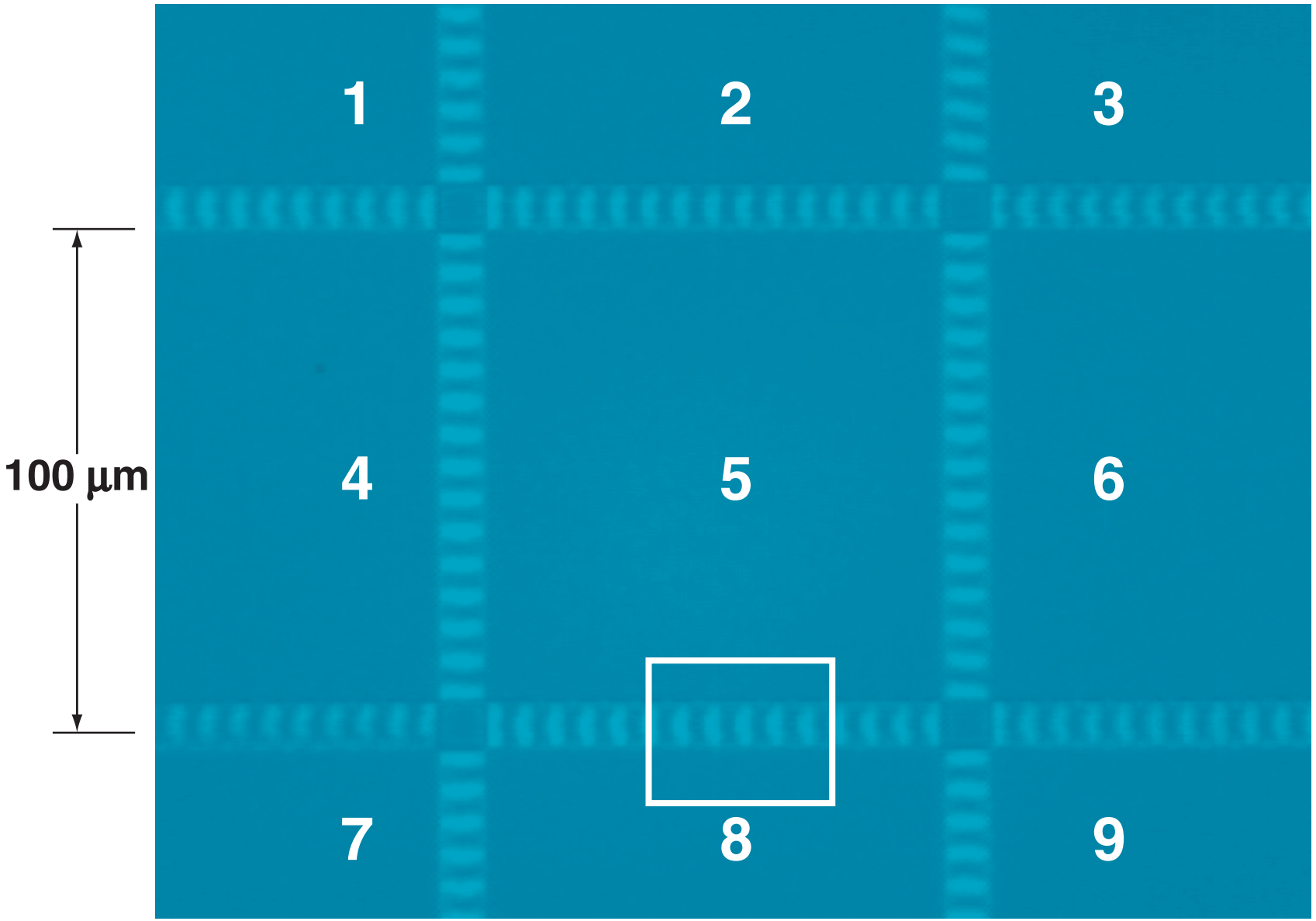


Stitching Error:

$$\Delta x = \delta \frac{P}{p_i}$$

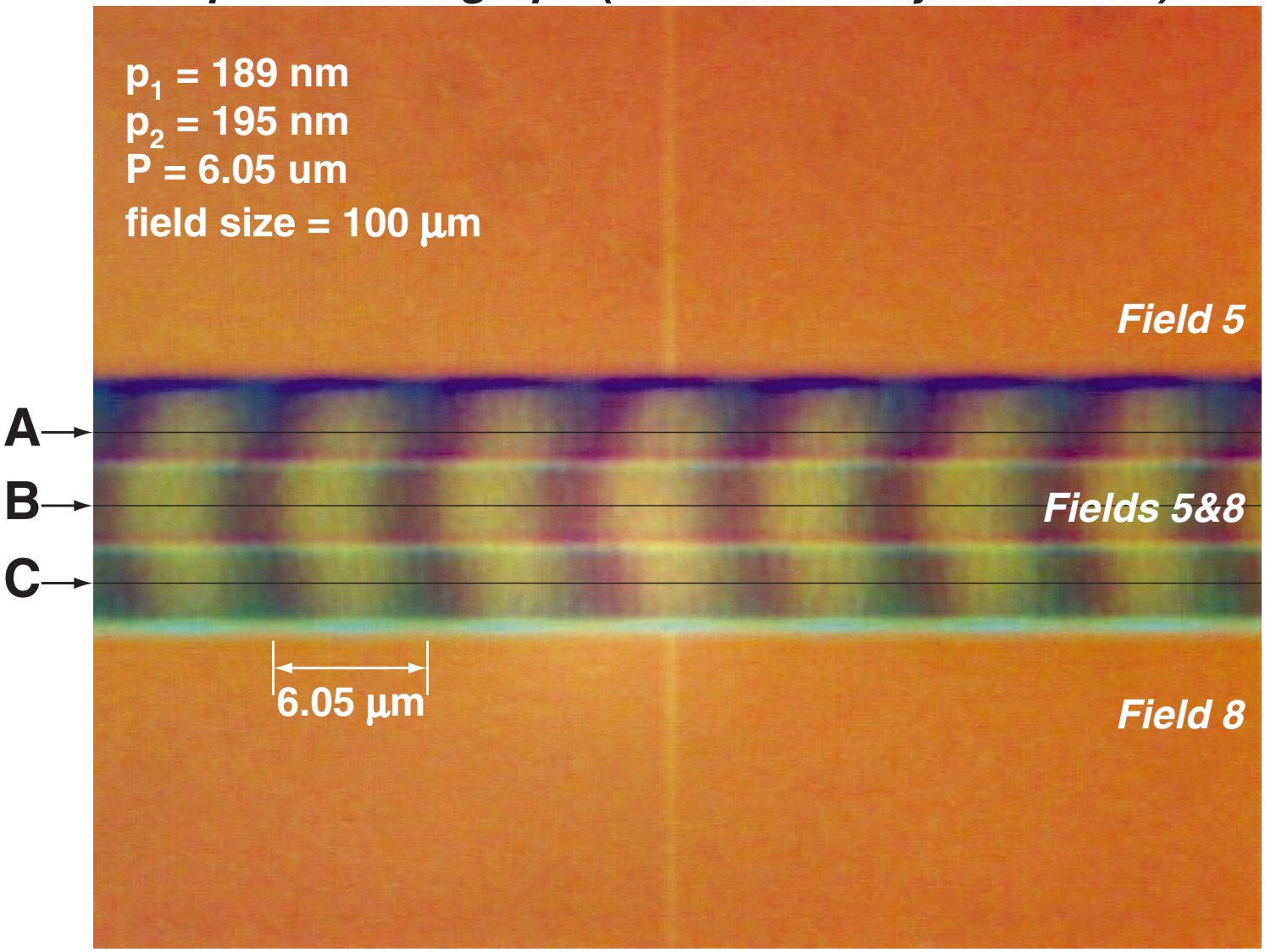
Magnification Factor

Optical Micrograph of Field Boundaries



Horizontal Boundary Between Fields

optical micrograph (20X 0.4 NA objective lens)



visually: **can resolve fringes to ~P/10**

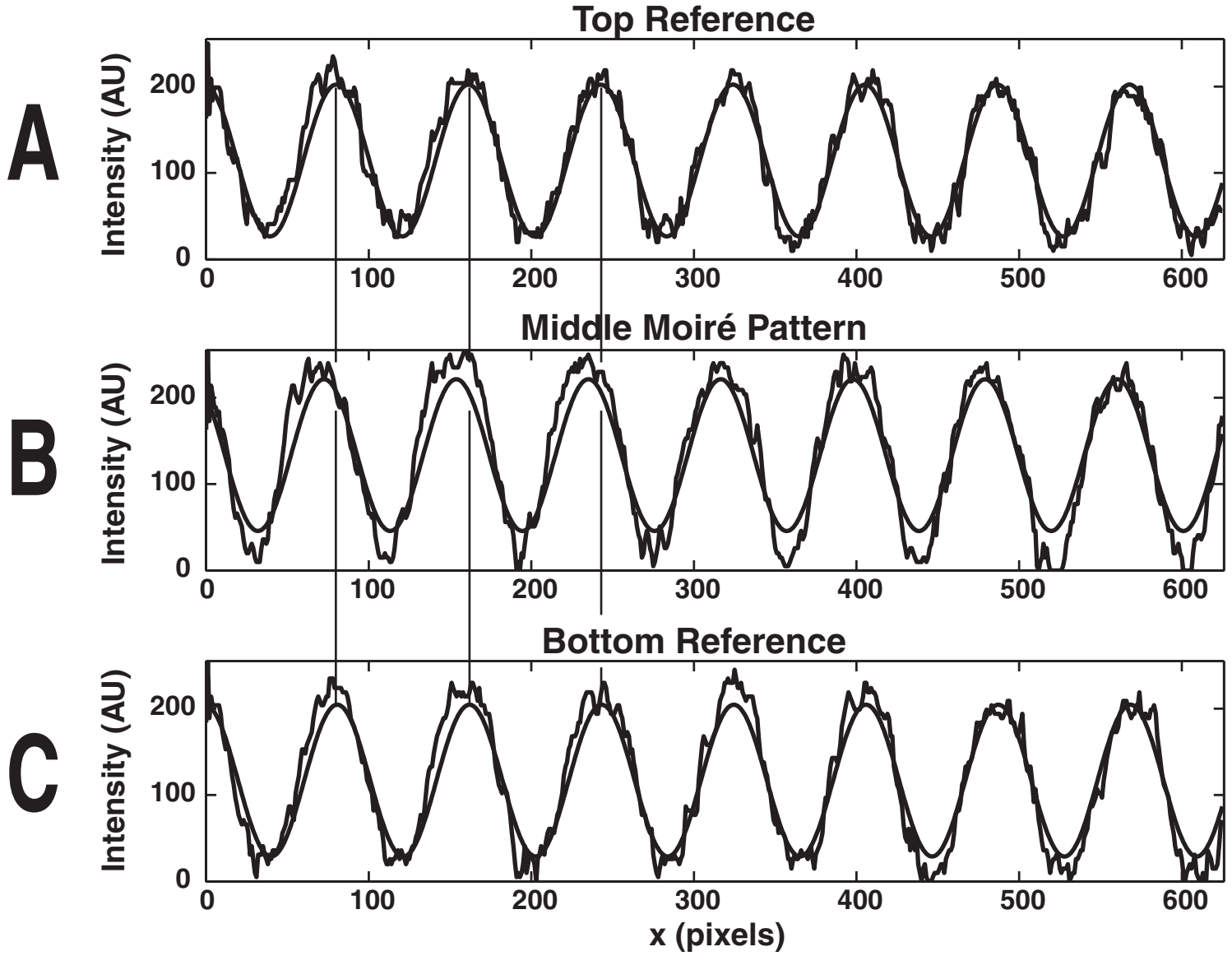
(~20 nm stitching resolution)

Measurement of Spatial Phase using offline FFT method:

1. $F[k] = FFT(f[n])$ *compute spectrum of signal*
2. $k_0 = \arg\max |F[k]|$ *find peak in spectrum*
3. $f = \text{angle}(F[k_0])$ *compute spatial-phase*

Can resolve fringes to ~P/100 (~2 nm stitching resolution)

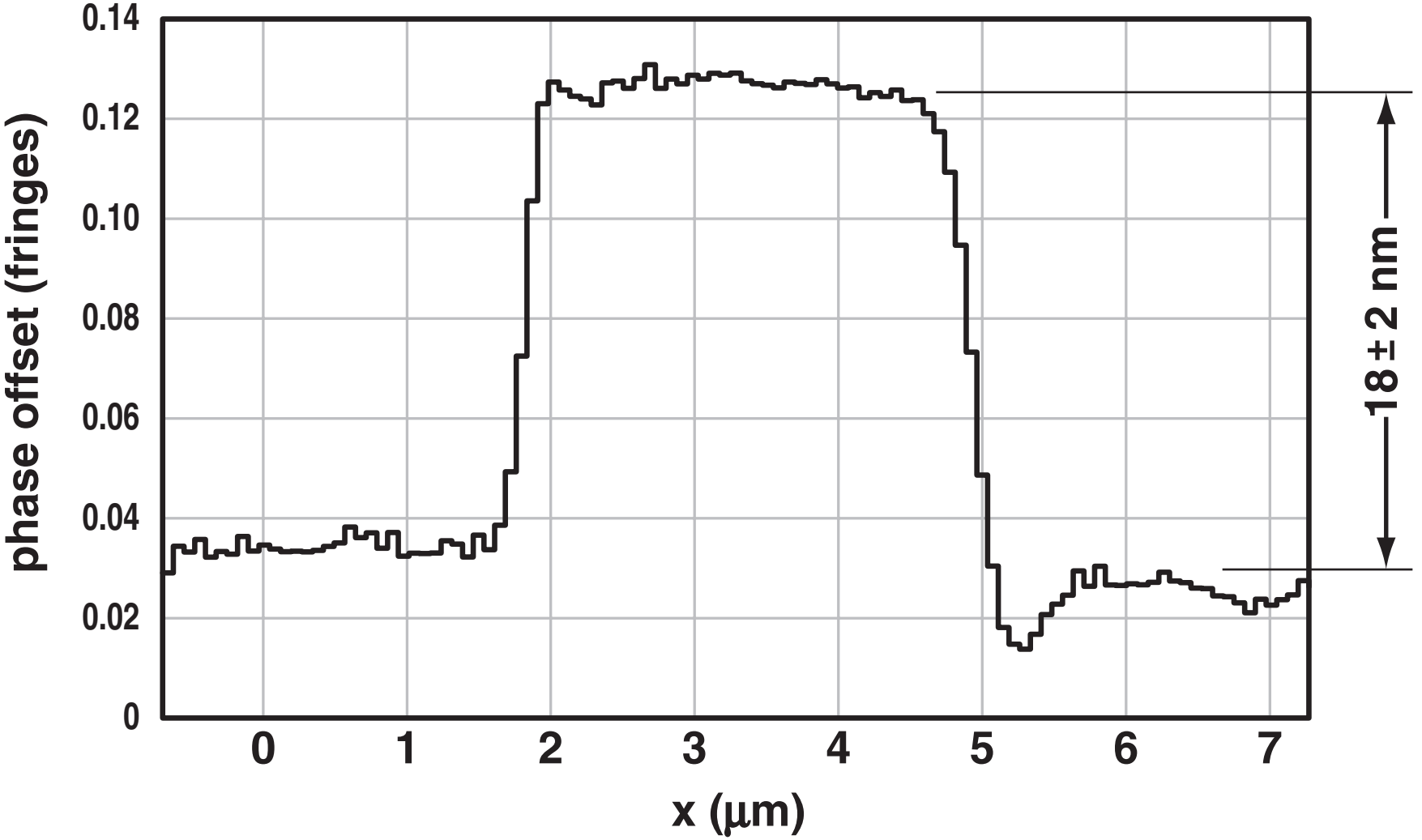
Line Profile of Moiré Images



stitching error = 18 ± 2 nm

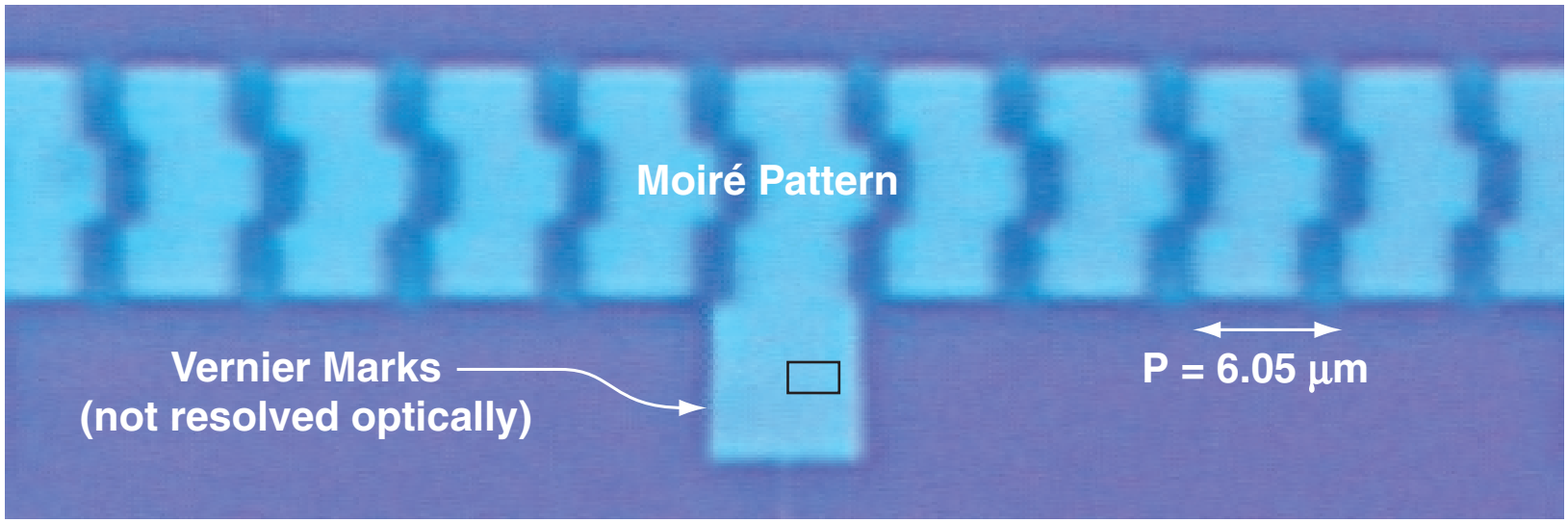
Moiré Fringe Discontinuity

Computed via FFT

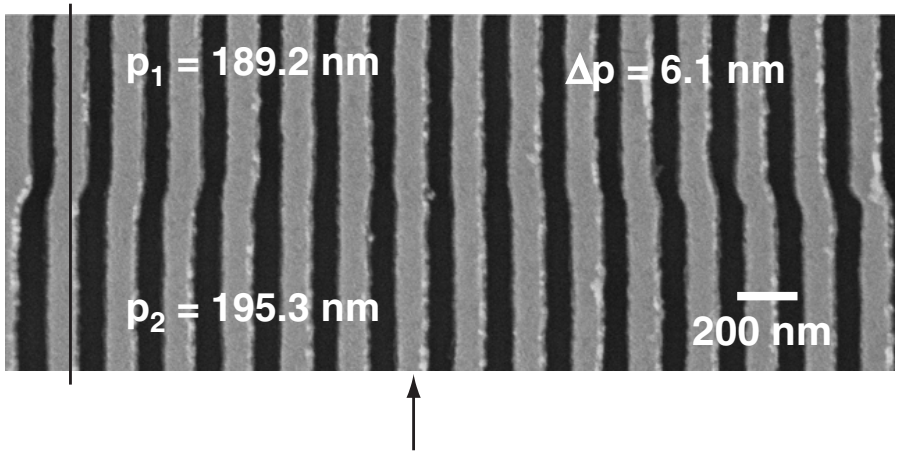


Moiré Technique vs Vernier Measurement

Optical Micrograph of Field Boundary (20X, 0.4 NA objective)

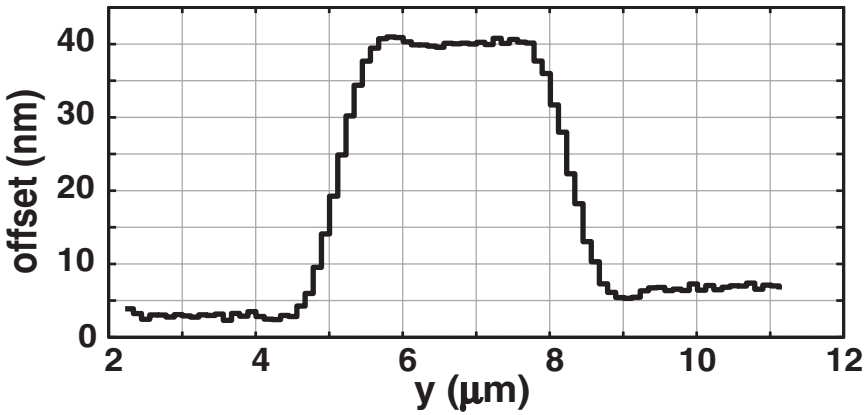


SEM of Vernier Marks (after liftoff of Chromium)



Δx = 37 ± 6 nm

Moiré Fringe Discontinuity (computed via FFT)

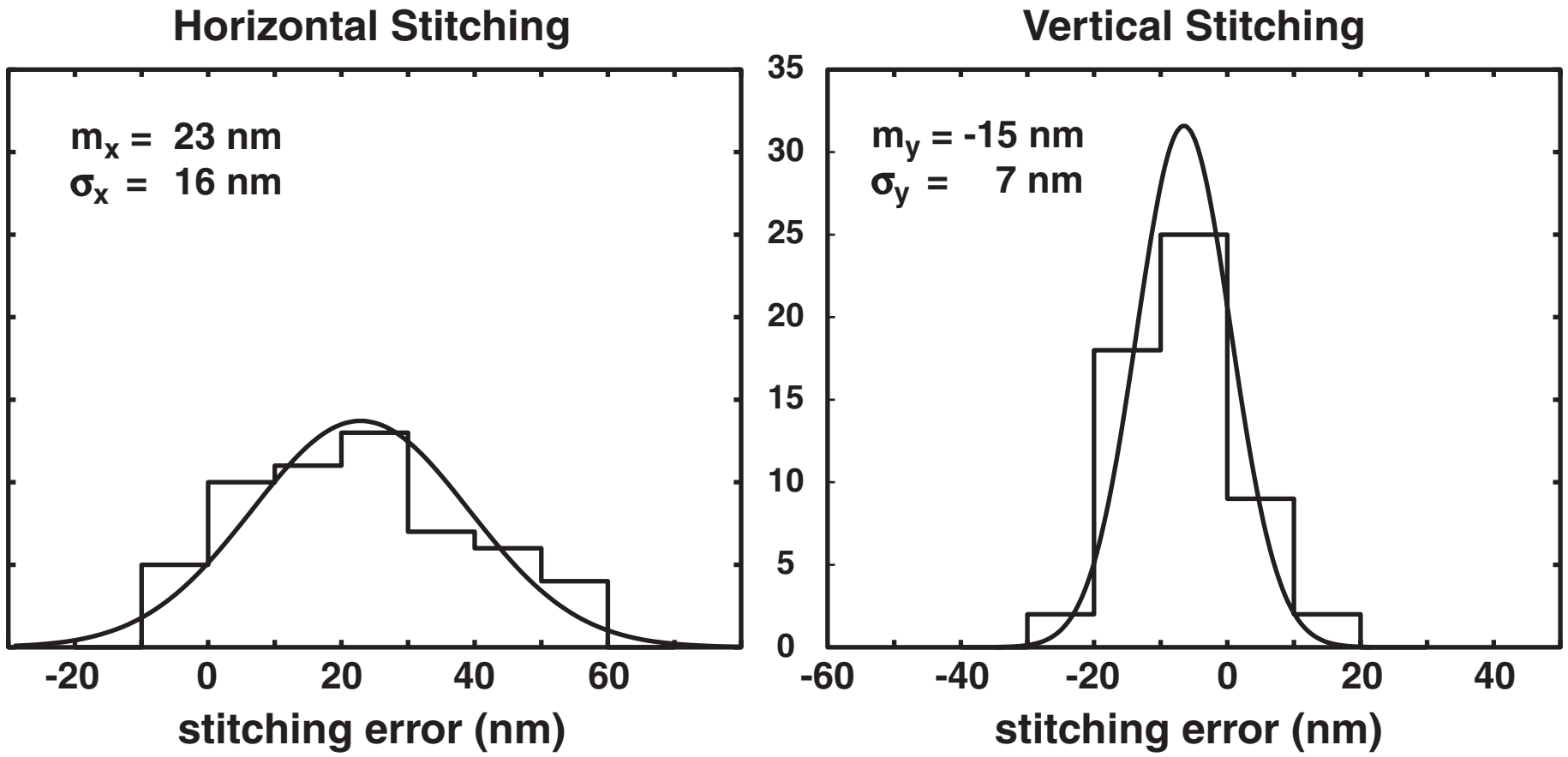


Δx = 35 ± 2 nm

Application: Measuring Stitching Statistics

wrote 8 x 8 array of 100 μm fields on VS2A e-beam system

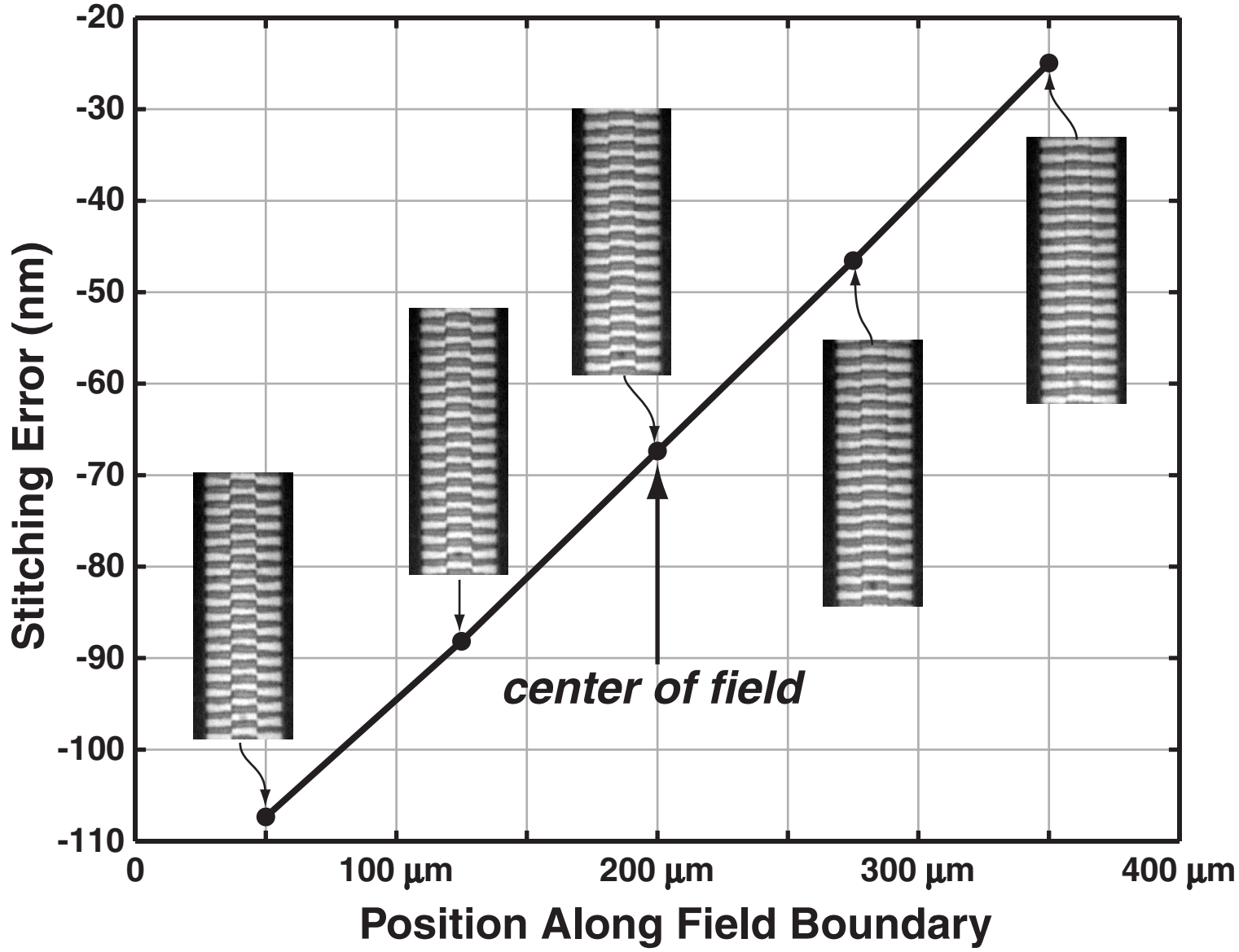
stitching error measured at each boundary using moiré technique



Application: Investigation of Field Distortion

Measure Stitching Error at Several Points along 400 μm Field Boundary

Infer Amount of Intra-field Distortion



Summary of Features

- ***SENSITIVE*: 2 nm resolution (better than Vernier method)**
- ***CONVENIENT*: Requires no liftoff or post-exposure pattern transfer**
- ***INEXPENSIVE*: uses only a conventional optical microscope**