

Reflection High-Energy Electron Diffraction

Dr. John A. Carlisle
April 12, 2000

Outline

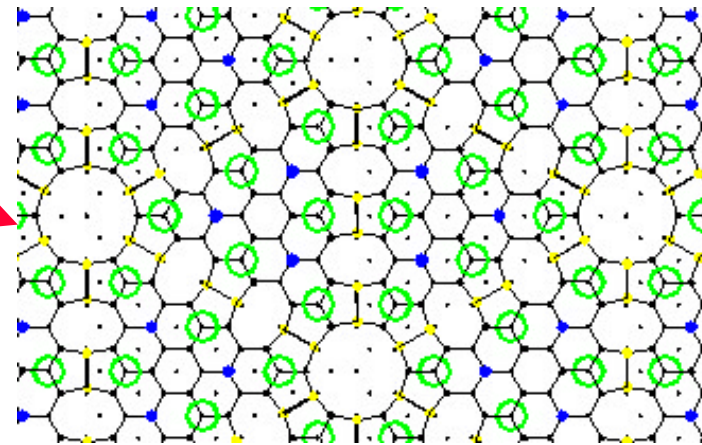


- Overview
- Review of Previous Concepts:
 - Laue Condition: $\Delta\mathbf{k}=\mathbf{G}$
 - Real Space & Reciprocal Space
 - Ewald Construction
- RHEED 101:
 - Basic Step-up & Diffraction Features
 - Interpretation of the RHEED Pattern
 - Rocking RHEED
 - Time-Resolved RHEED
- The MBE/RHEED Facility
- Your Lab This Week

Semiconductor Surfaces & Reconstruction



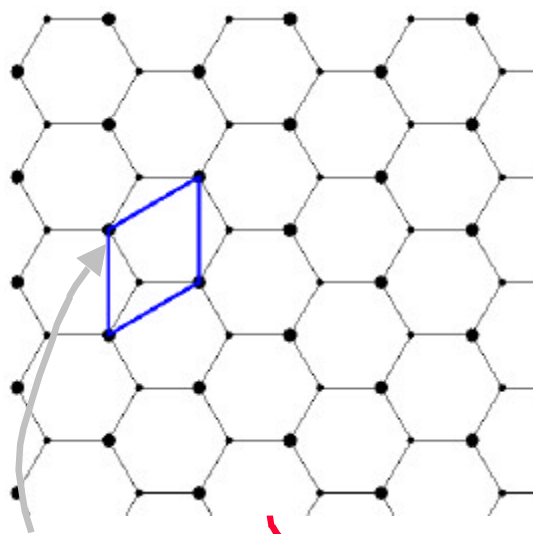
Si(111)-(7x7)



Anneal at 1250°C

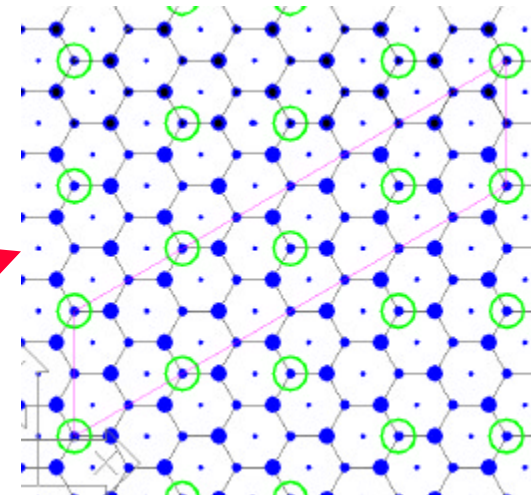


Bulk-Terminated (111) Surface



(1x1) Unit Cell
(Woods Notation)

Sputter-Anneal at 500°C



Ge(111)-c(2x8)

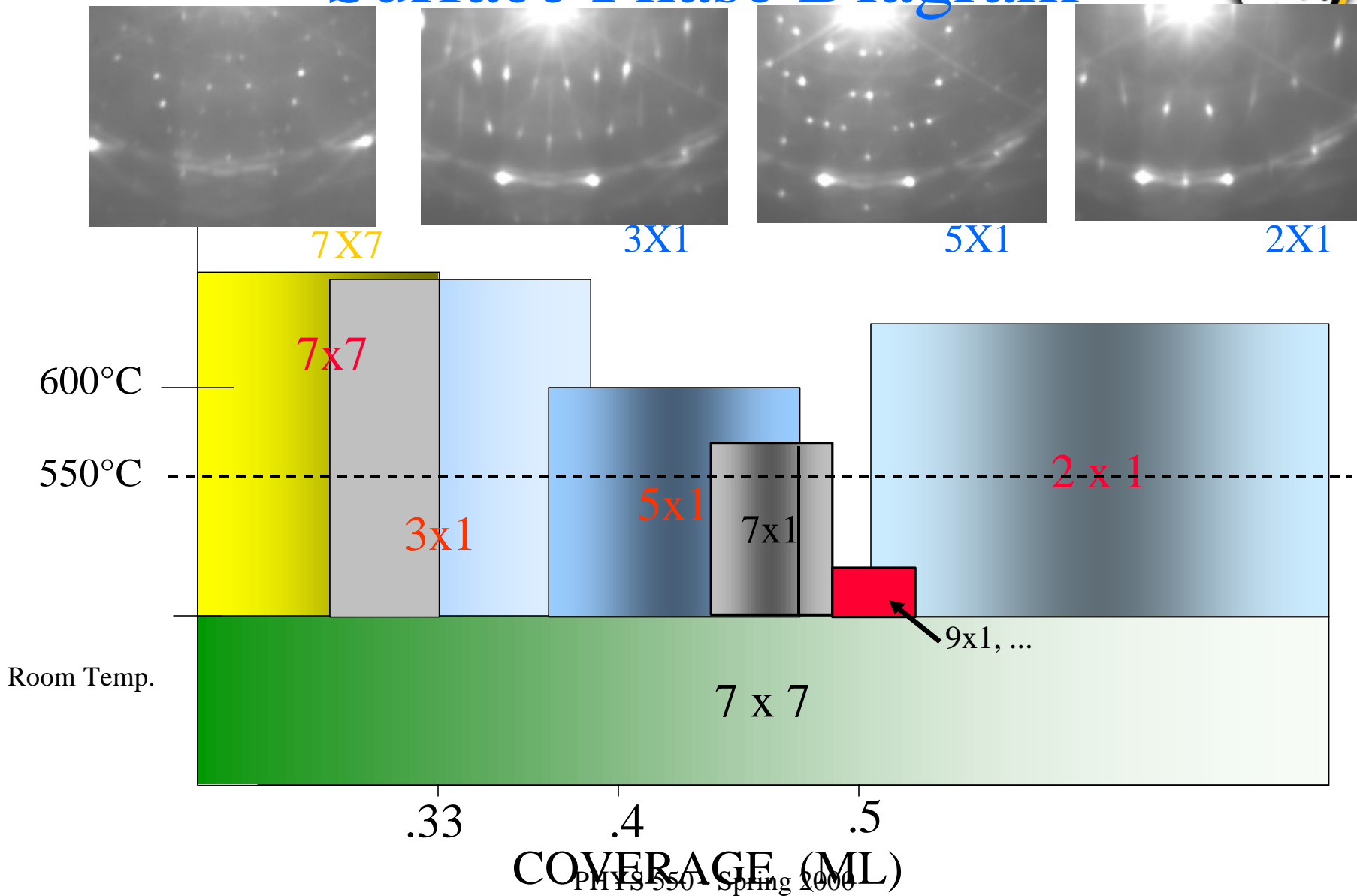
Other Examples:

Si(100)-(2x1)

Si(113)-(3x2)

Si(5 5 12)-(2x1)

Surface Phase Diagram



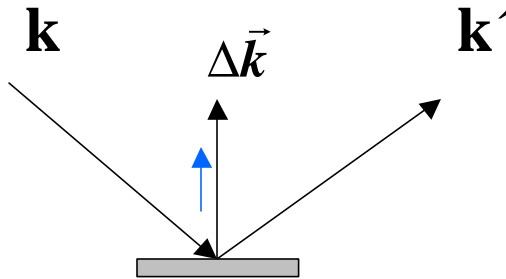
Laue Condition



$$\Delta \vec{k} = \vec{G}$$

$k=2\pi/\lambda$
(wave number)

$E=hc/\lambda$



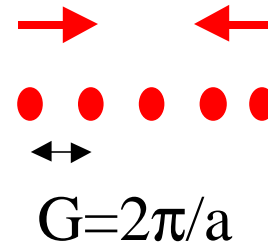
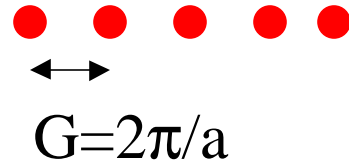
$\lambda \sim$ Lattice spacing (1 Å)

$E=104$ eV for x-rays, 0.1 eV for Neutrons

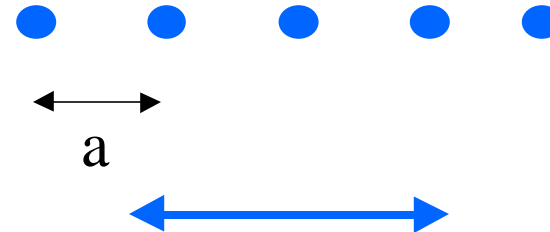
Real Space & Reciprocal Space



Reciprocal Space



Real Space



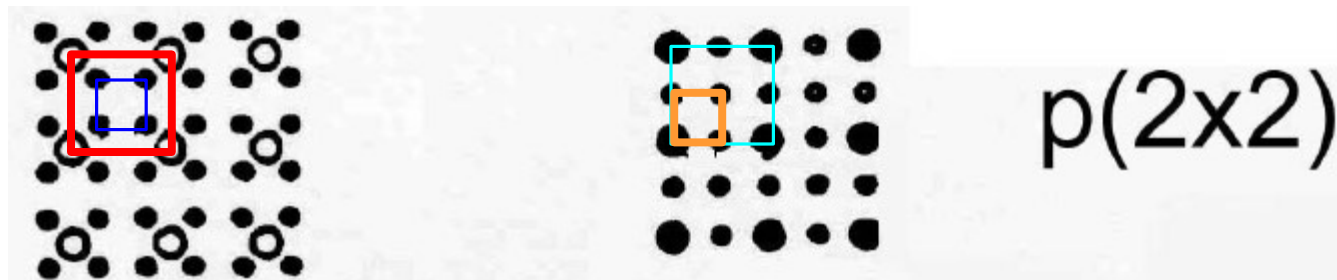
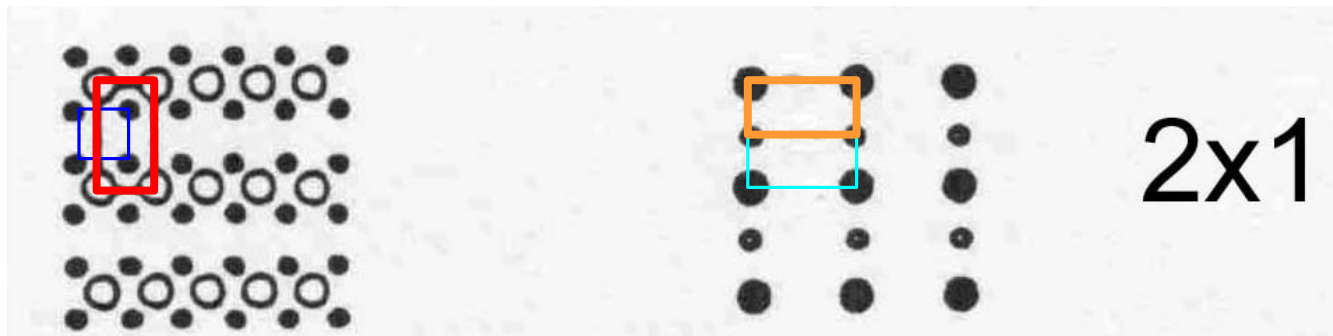
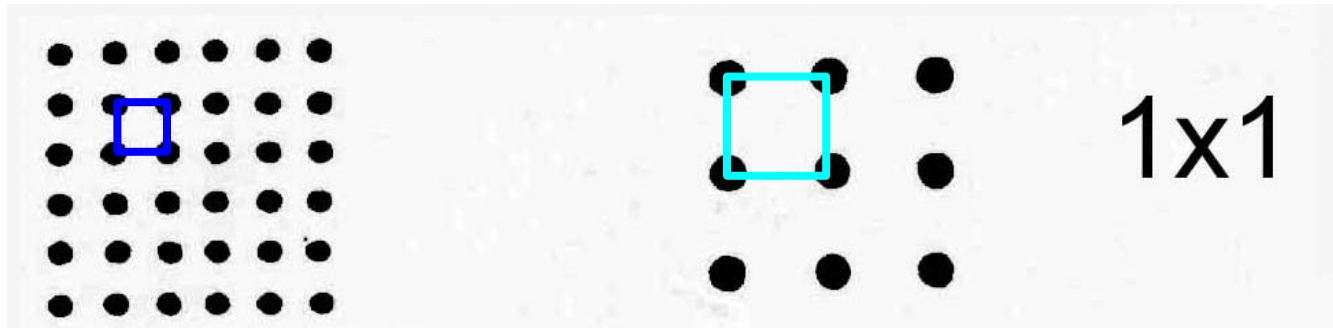
$$[\text{Reciprocal Space}] = \mathfrak{F}[\text{Real Space}]$$

Real Space & Reciprocal Space

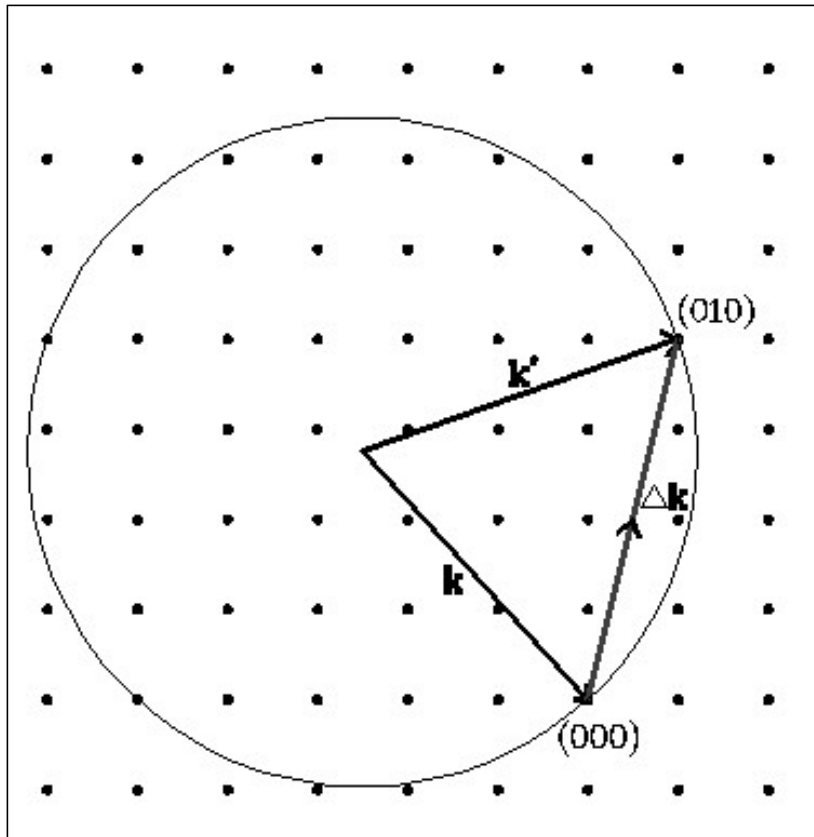


Real space

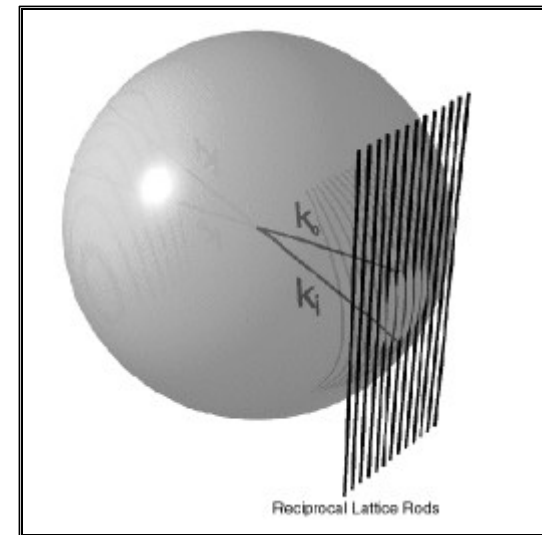
Reciprocal Space



Ewald Construction

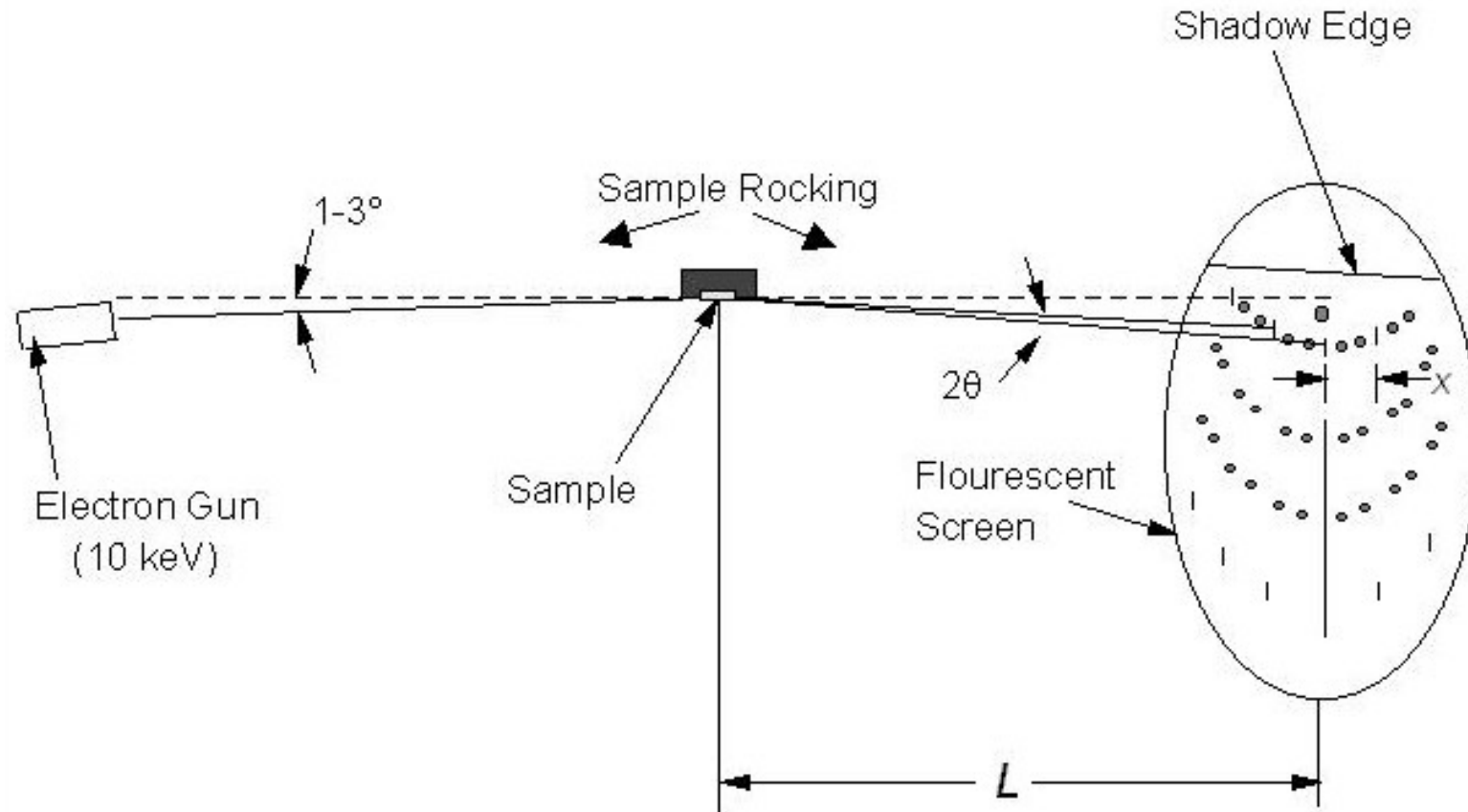


Ewald Construction for XRD



Ewald Construction
for RHEED

The RHEED Technique

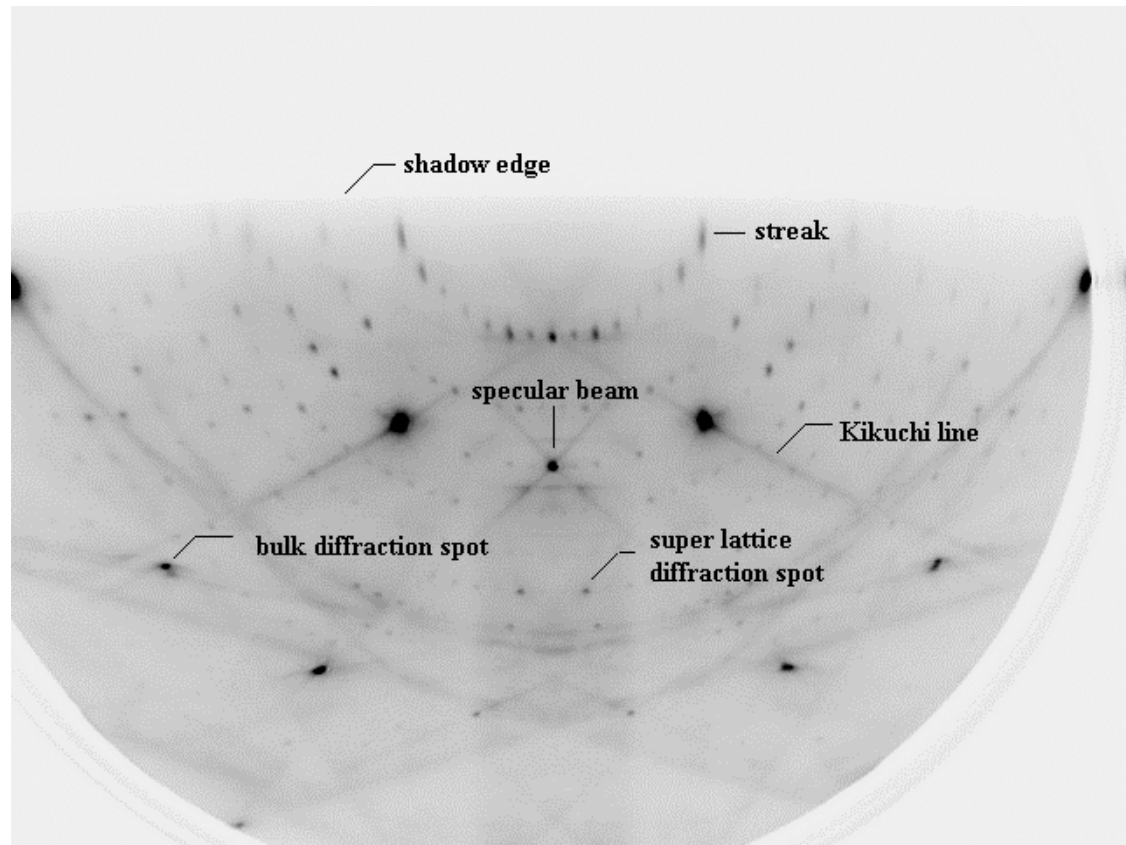


$$a = \frac{\lambda L 10^{10}}{x}$$

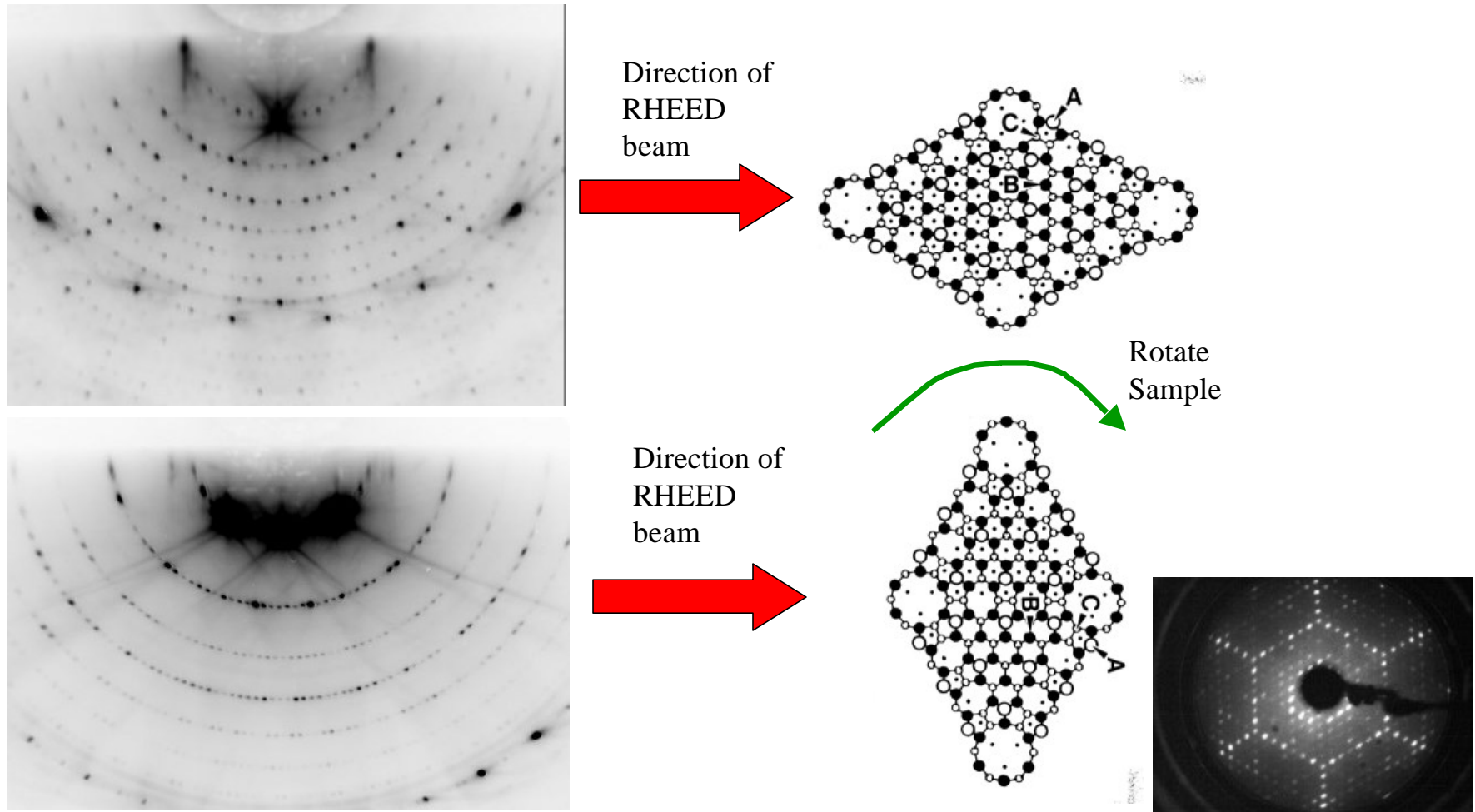
The RHEED Technique



- Bulk lattice spots
- Super lattice spots
- Specular beam
- Streaks
- Kikuchi lines, bands
- Shadow edge
- Others

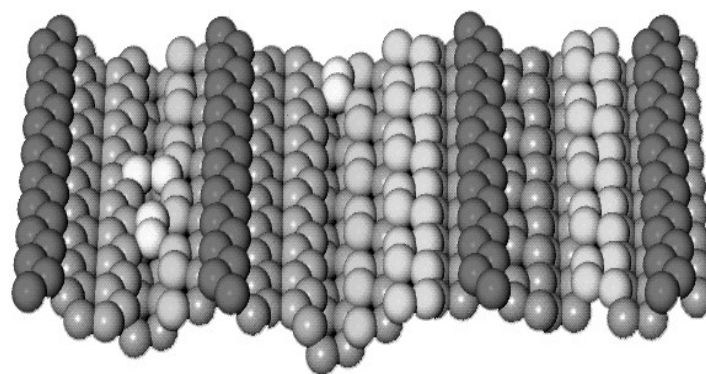
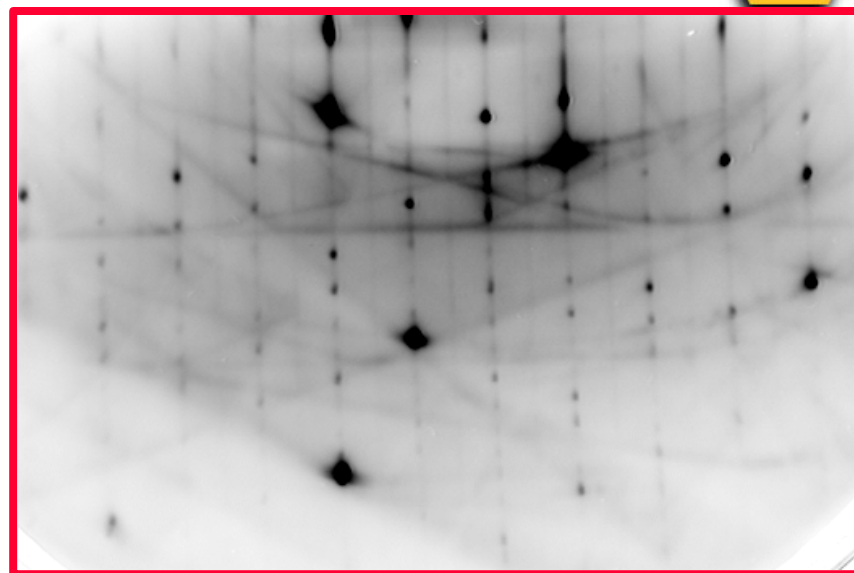
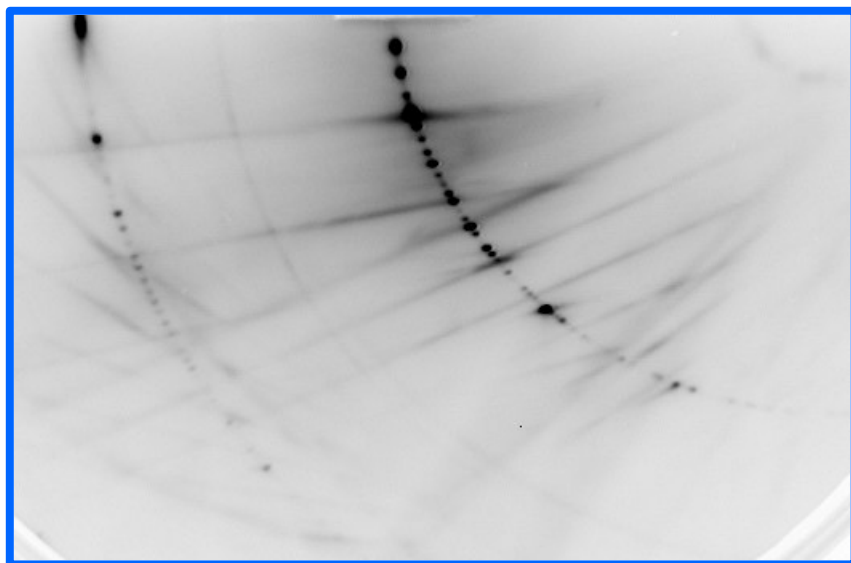


The RHEED Technique



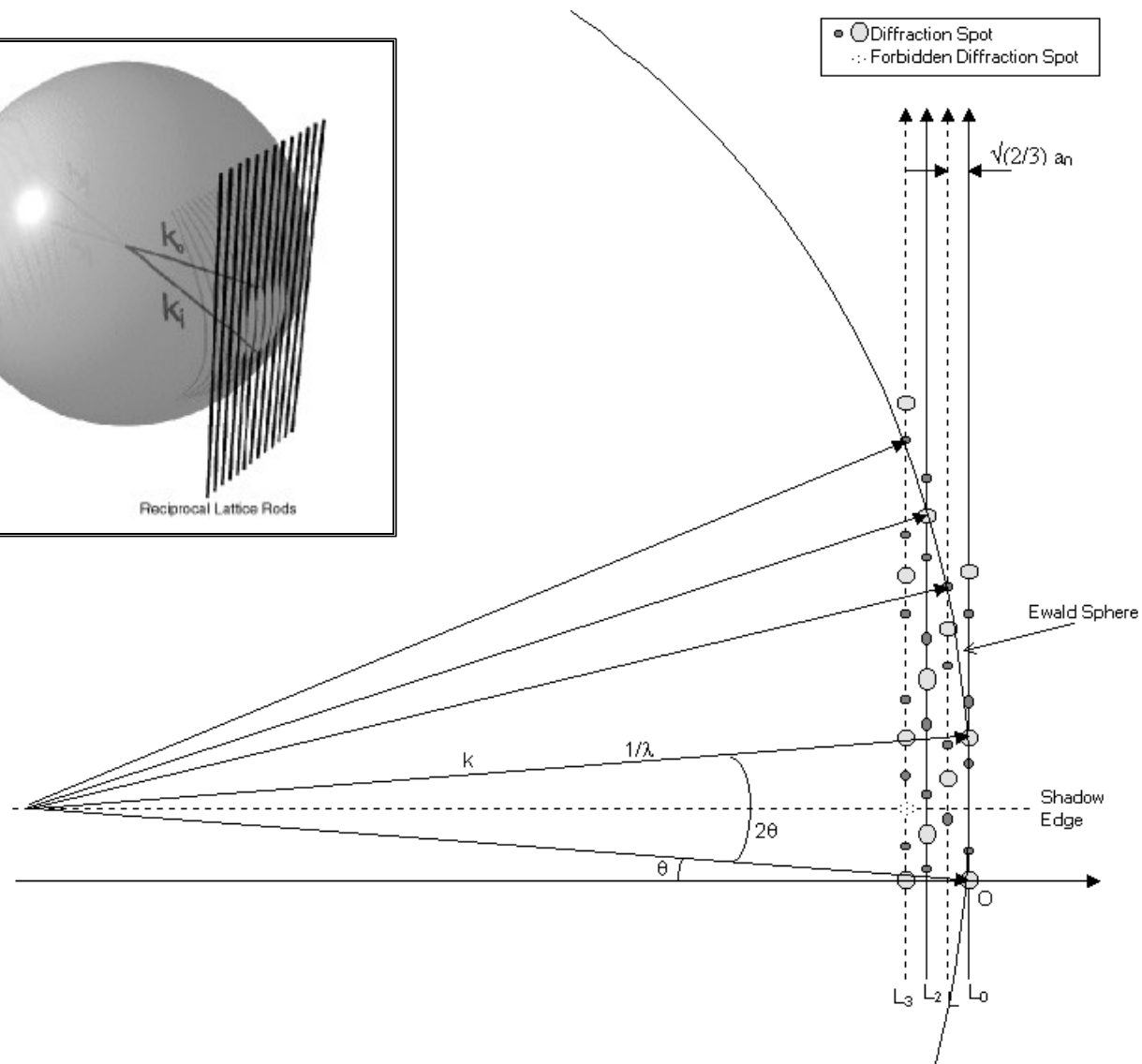
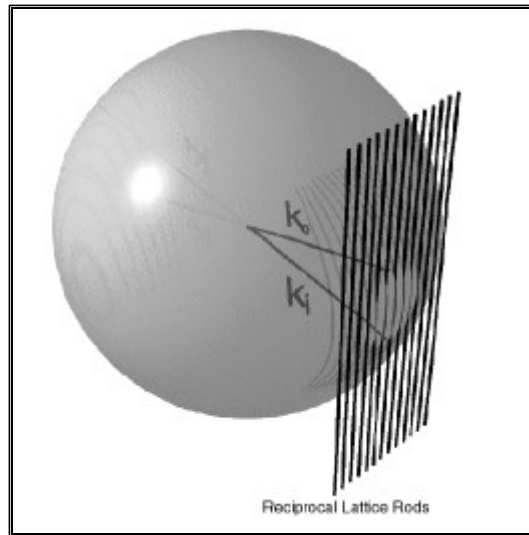
Diffraction Pattern observed depends strongly on incident beam direction!

RHEED Images of Clean Si(5 5 12)-(2×1)

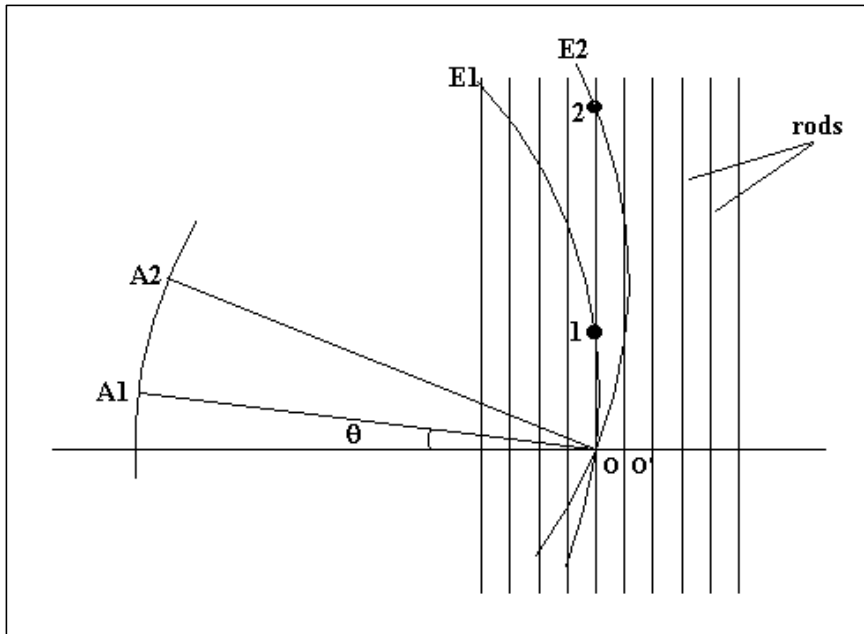


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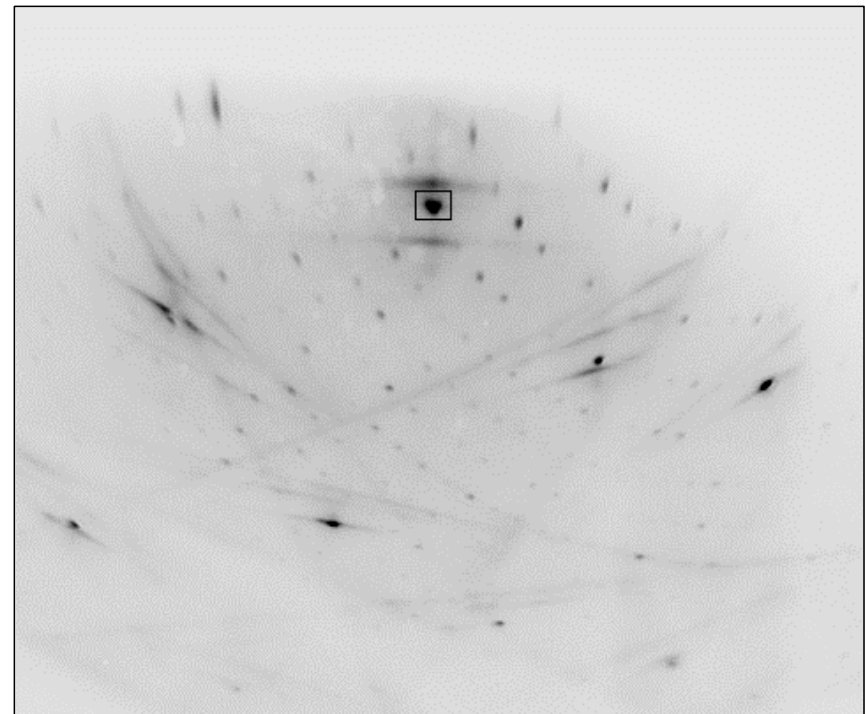
Ewald Construction for RHEED



Rocking RHEED



Diffraction spot for a particular rod moves from 1 to 2 when rock the sample

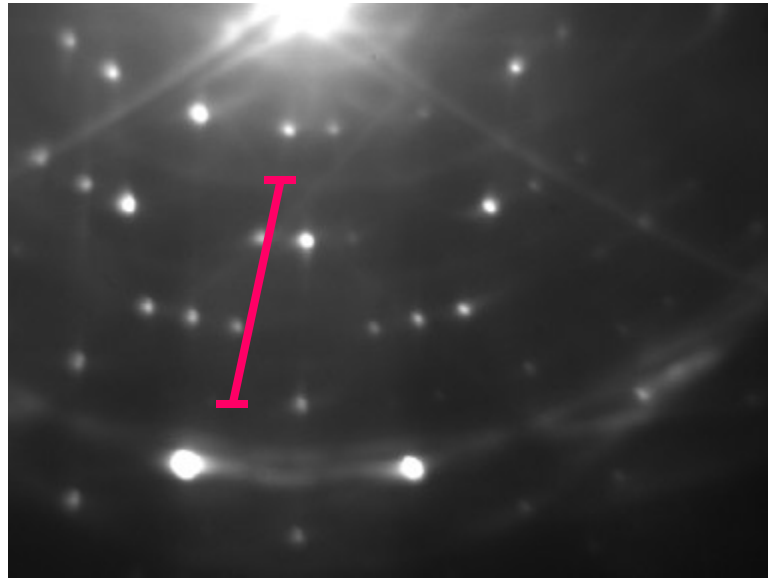


The boxed spot is the specular beam. The next slide shows its rocking curve.

PLAY THE MOVIE!!

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Time-Resolved RHEED

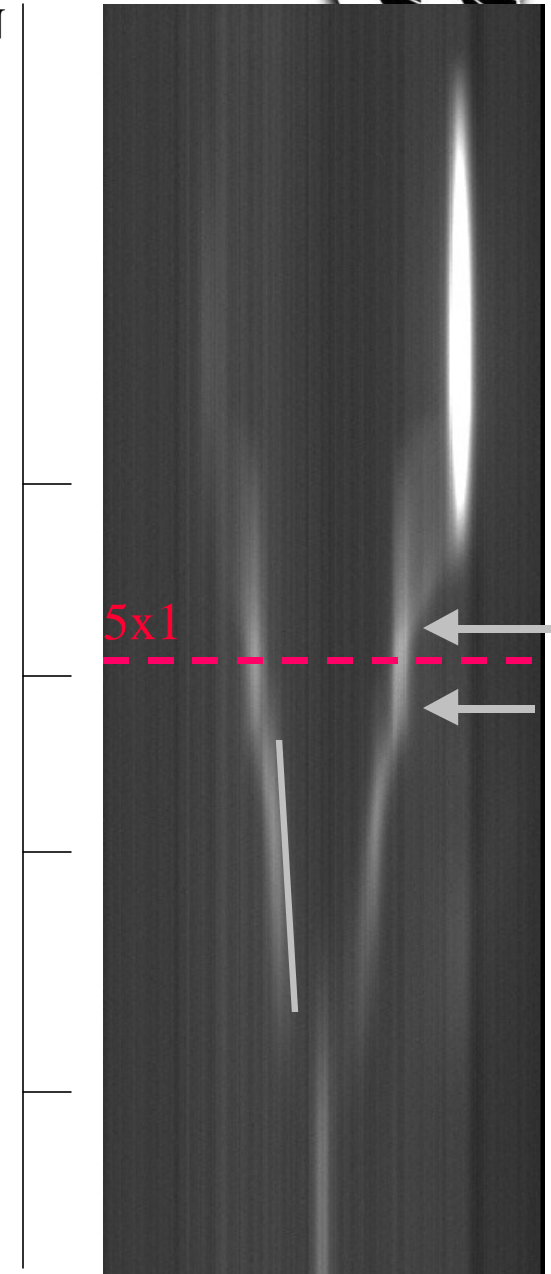


Ca / Si(111) 5x1

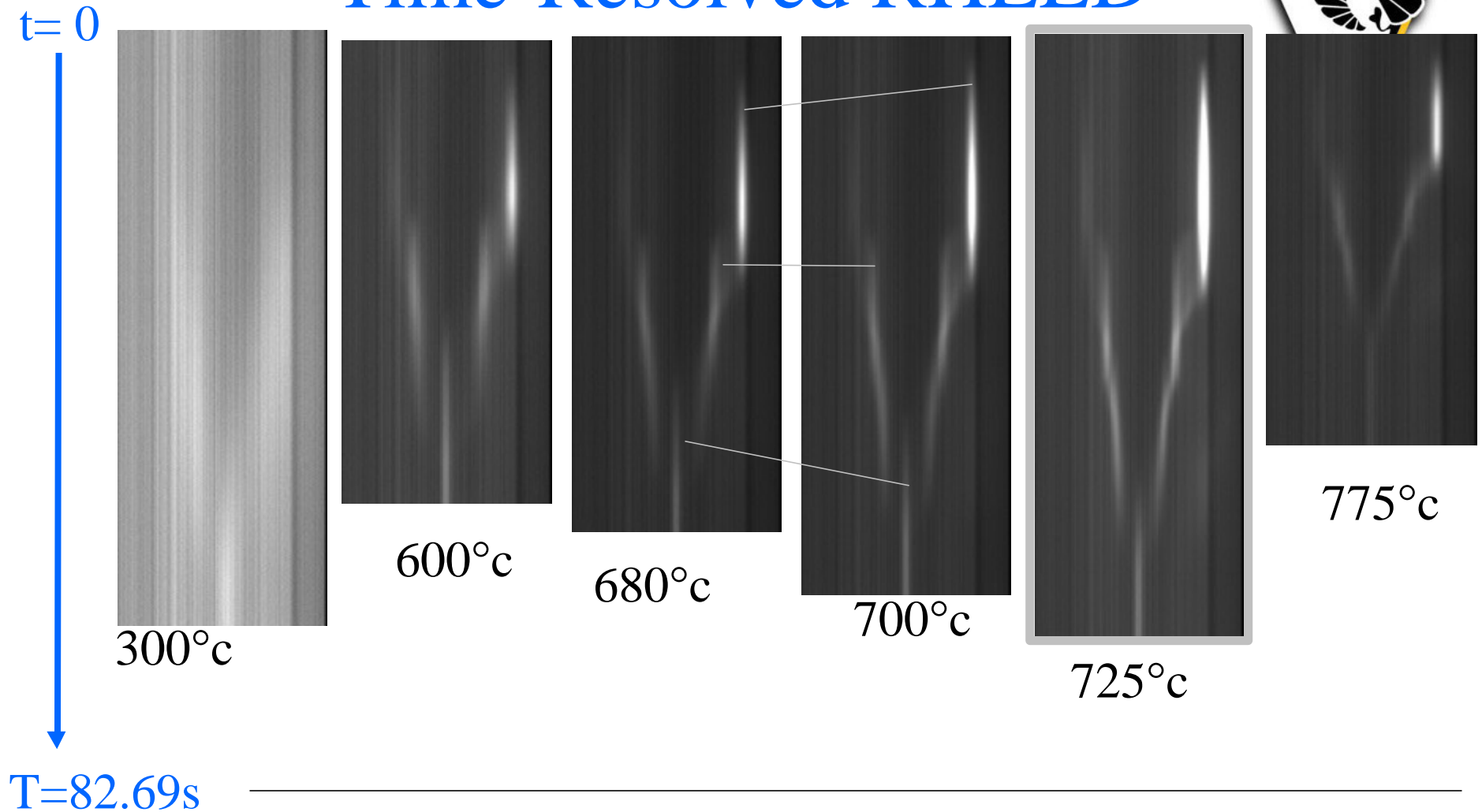
- * Pixel Intensity along the red line is monitored during deposition
- * Overlapping Transitions
- * Small Time/Coverage window for observing isolated 5x1 Structures

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DEPOSITION
TIME



Time-Resolved RHEED



Rate = .0083ML/s = .5ML/min

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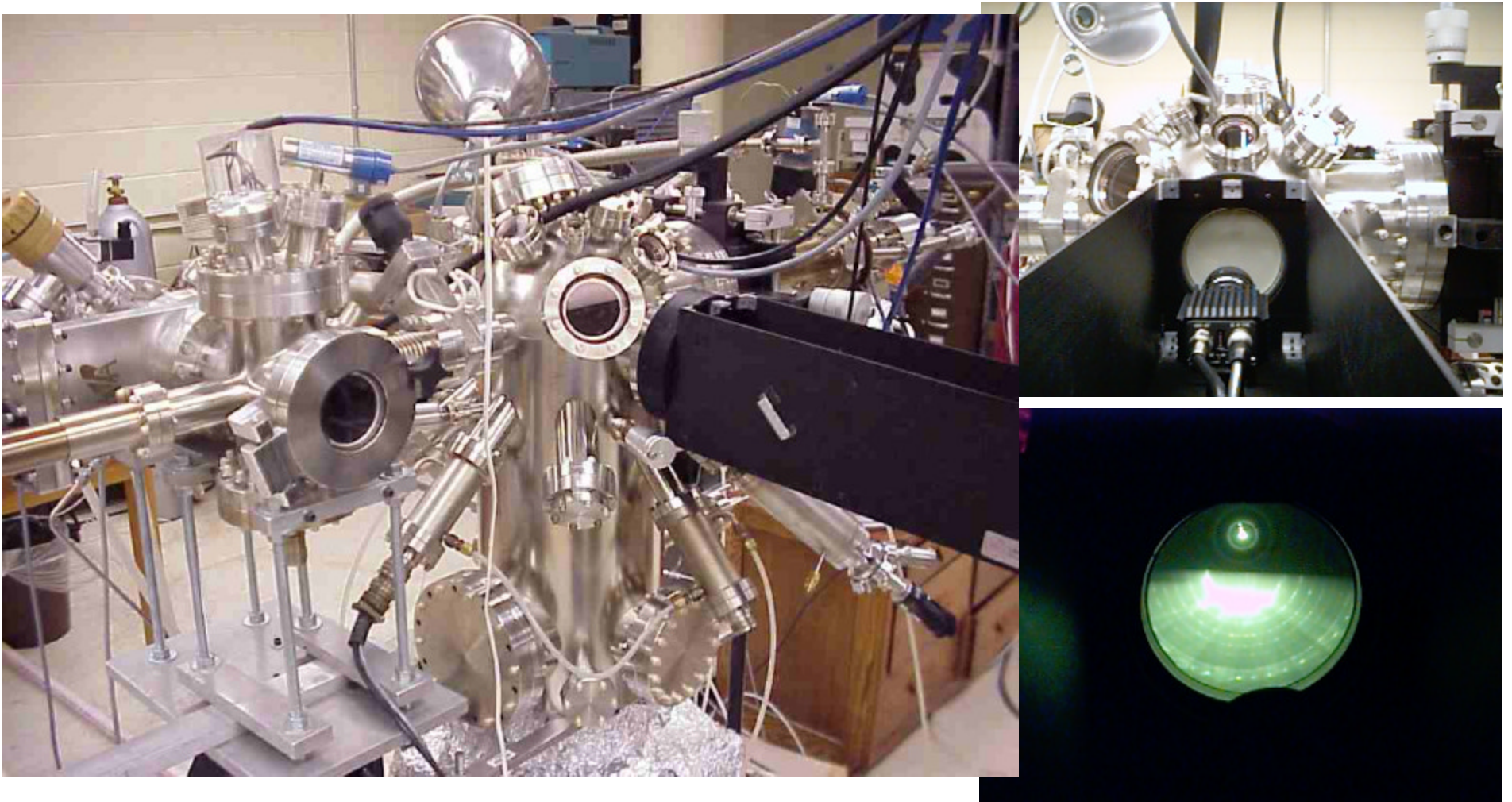
Images 5mar2 through 5mar8

Overview of the RHEED Technique



- Strengths of RHEED:
 - Robust: Allows one to observe changes in surface structure as function of time.
 - More sensitive to long-range order on the surface
 - Cost less than LEED
- Weaknesses:
 - Diffraction pattern harder to interpret than LEED
 - Quantitative analysis of surface structure difficult.

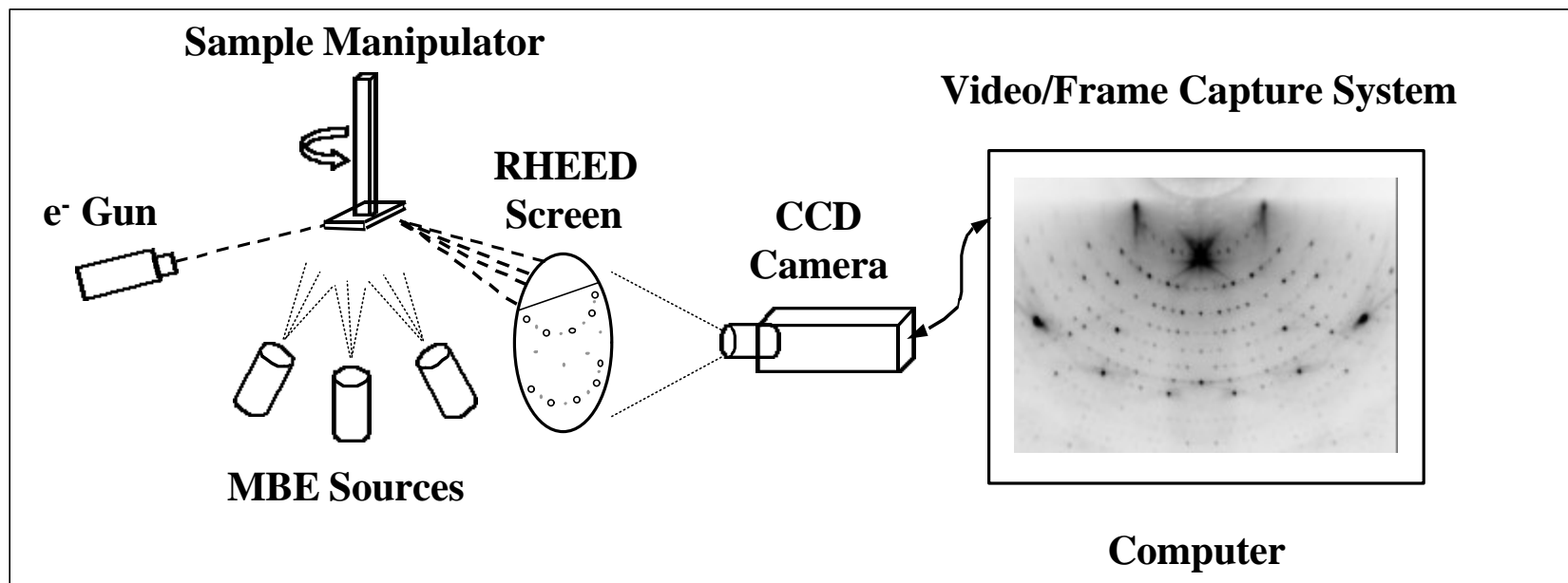
The MBE/RHEED Facility



Goto <http://saturn.vcu.edu/~jacarlis/equips.htm>

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The MBE/RHEED Facility



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Your Lab This Week



- Groups of three (One 450 student in each group).
- Clean Si(111) Surface
 - Capture Image at two angles
 - Measure spacing and deduce lattice constants
- Start Evaporator and Establish Approximate Rate.
- Deposit Ca/Ag/Au onto Si(111) Surface & Anneal --What reconstructions do you observe
- PLAY!!!