RHEED & Its Role in MBE Systems

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Outline

- Molecular Beam Epitaxy Systems
- Importance of RHEED in MBE Systems
- Physics involved
- Conclusions

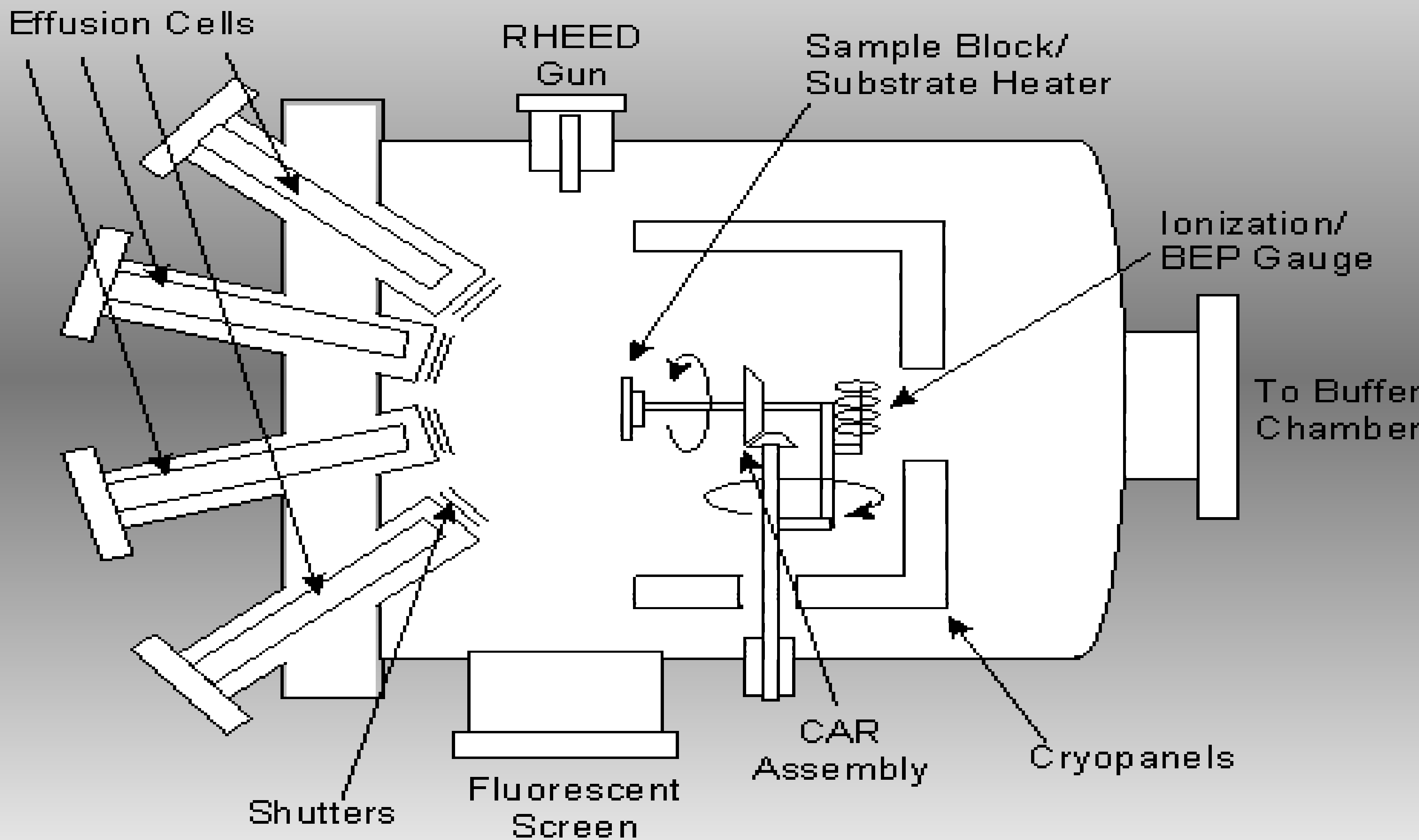
Molecular Beam Epitaxy

- Technique to grow high-quality layers with very abrupt interfaces
- Done in UHV environment
- Beams of atoms or molecules directed on to the heated wafer
- Now high throughput production systems possible for MBE

Advantages

- Very precise control of layer thickness
- NO complicated reactions involved at the substrate surface
- Processes like RHEED can be used for surface characterization due to UHV environment
- Toxic chemicals contained in vacuum chamber

MBE System



Effusion Cells
RHEED
Gun
Sample Block/
Substrate Heater
Ionization/
BEP Gauge
To Buffer
Chamber
Shutters
Fluorescent
Screen
CAR
Assembly
Cryopanels

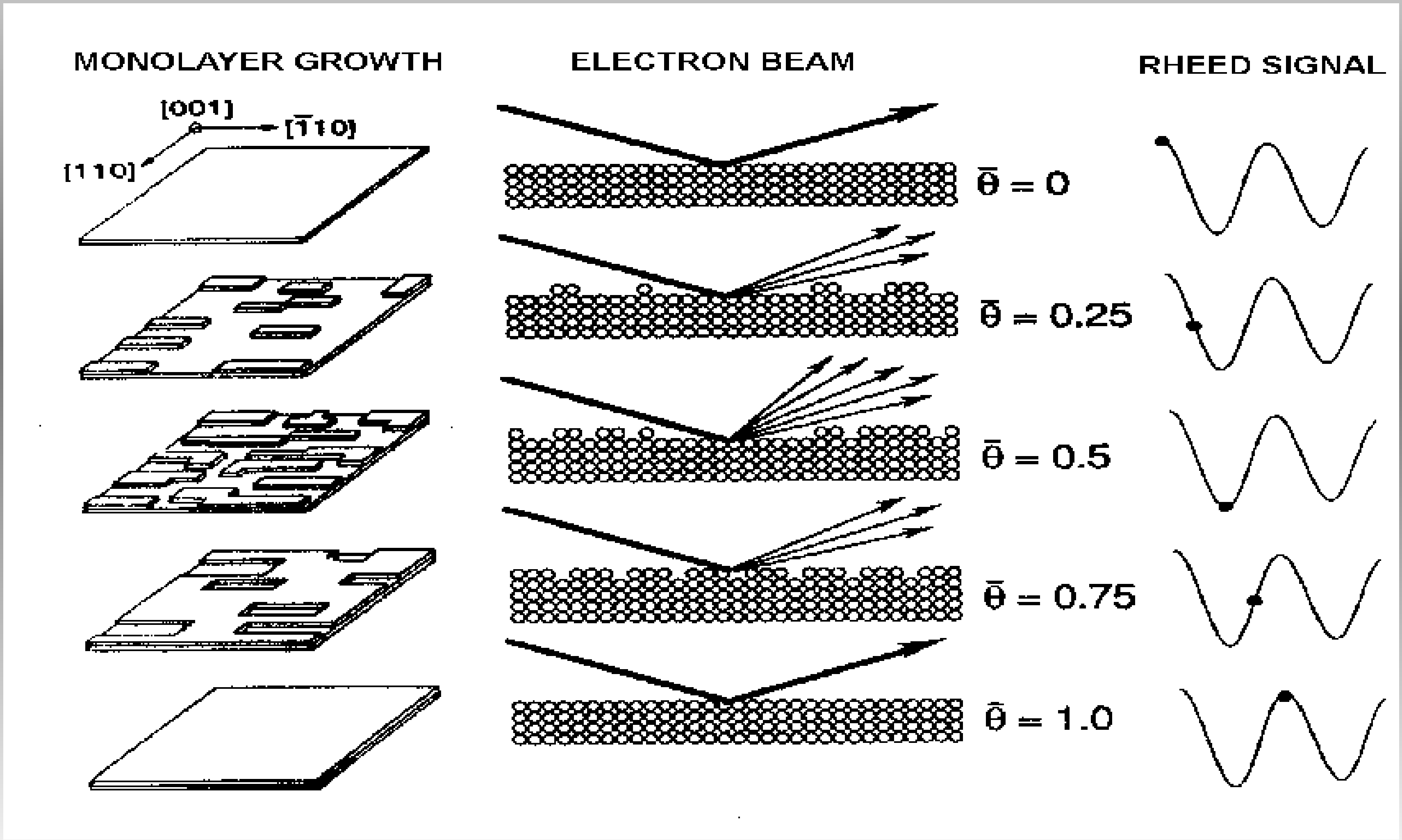
RHEED

- Beam of energetic electrons strikes the surface at grazing angles
- For surface characterization
- Gives the crystal growth rate
- Strong interaction with the crystal surface
- In-situ Compatibility
- High Surface Sensitivity

Used in MBE for

- Measuring Growth rate
- Observing removal of Oxides
- Monitoring arrangement of surface atoms

Crystal growth rate by RHEED



PHYSICS Aspect (Kinematic Theory)

- The interaction of electron with crystal potential is governed by Schrodinger EQ.

$$\frac{-h^2}{8\pi^2 m_e}\nabla^2\Psi(\mathbf{r}) - |e|V(\mathbf{r})\Psi(\mathbf{r}) = \frac{h^2|\mathbf{k}_0|^2}{8\pi^2 m_e}\Psi(\mathbf{r}). \qquad (1)$$

- We expand the crystal potential in Fouriar components using reciprocal lattice vectors as (U®=2m_e|e|V®/$h^{2)}$

$$U(\mathbf{r}) = \sum_{\mathbf{g}} U_{\mathbf{g}} \exp(i\mathbf{g}\cdot\mathbf{r}), \qquad (2)$$

- Now the outgoing wave function is

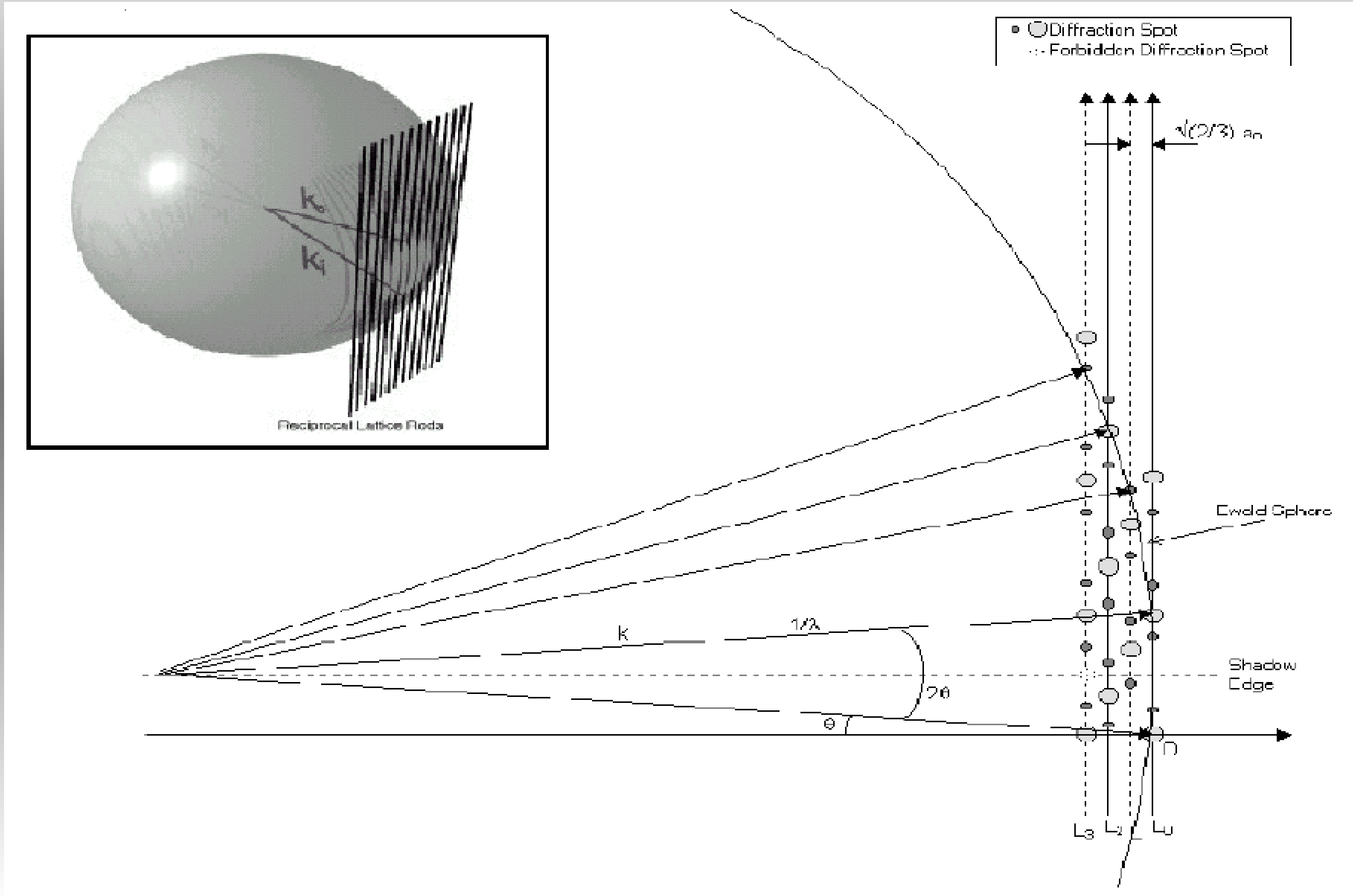
$$\Psi(\mathbf{r}) = \sum_i c_i \exp(i\mathbf{k}_i \cdot \mathbf{r}), \qquad (3)$$

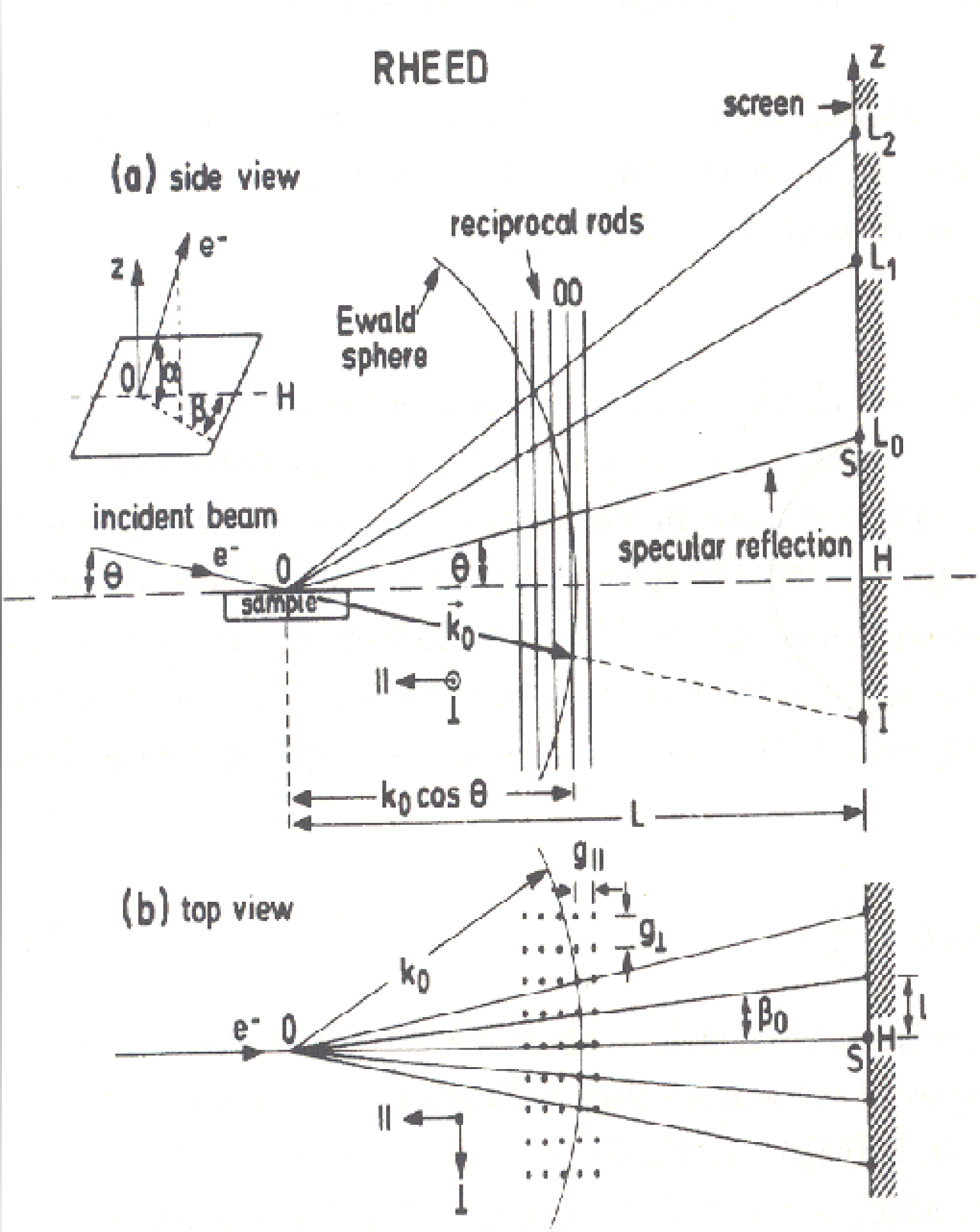
- According to perturbation theory

$$c_i = \frac{im_e}{\hbar^2 K_o} \int \sum_{\mathbf{g}} U_{\mathbf{g}} \exp(i(\mathbf{g} - \mathbf{k}_i + \mathbf{k}_0)\cdot\mathbf{r})\,d\mathbf{r}, \qquad (4)$$

- C_is are proportional to $U_{\mathbf{g}}\,\delta(\mathbf{k}_0 - \mathbf{k}_i + \mathbf{g})$ so the Laue diffraction condition is given by $\mathbf{k}_i$-$\mathbf{k}_0 = \mathbf{g}$.

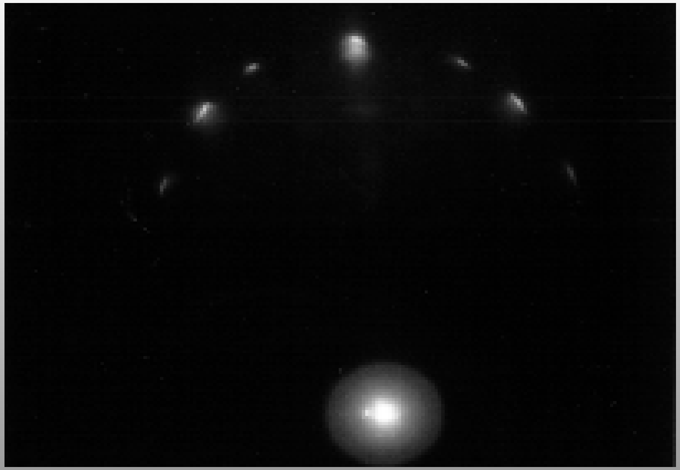
- For a finite sized crystal reciprocal lattice points elongates to form the rod like structures



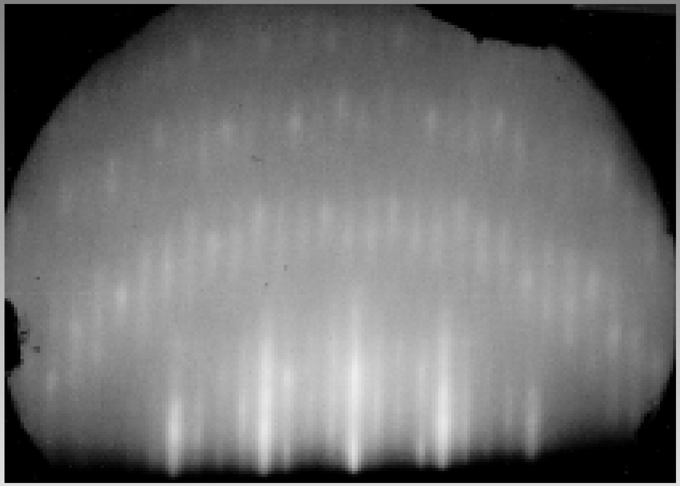


$$ng_{\parallel} = k_0 \left[\cos\theta - \frac{1}{\sqrt{(L_n/L)^2 + 1}} \right];$$

$$ng_{\perp} = \frac{k_0}{\sqrt{(L/nl)^2 + 1}},$$

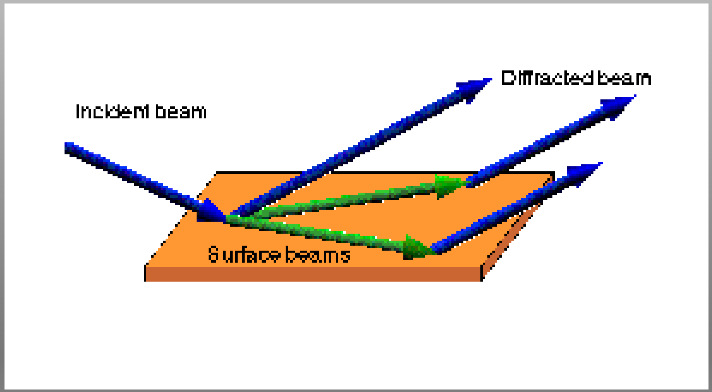


Well Annealed
Sapphire Surface

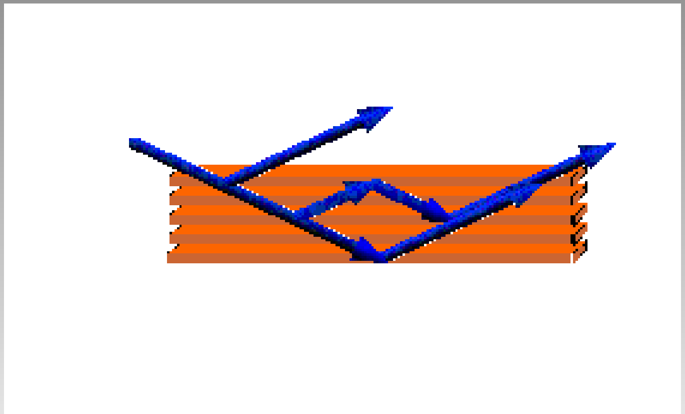


Two Laue circles
with Streaks

Surface Resonance & Kikuchi Lines

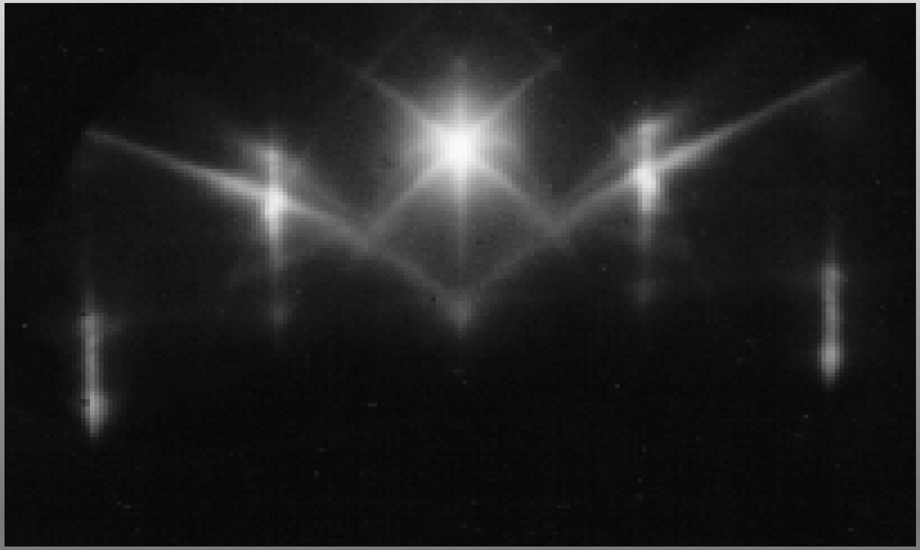


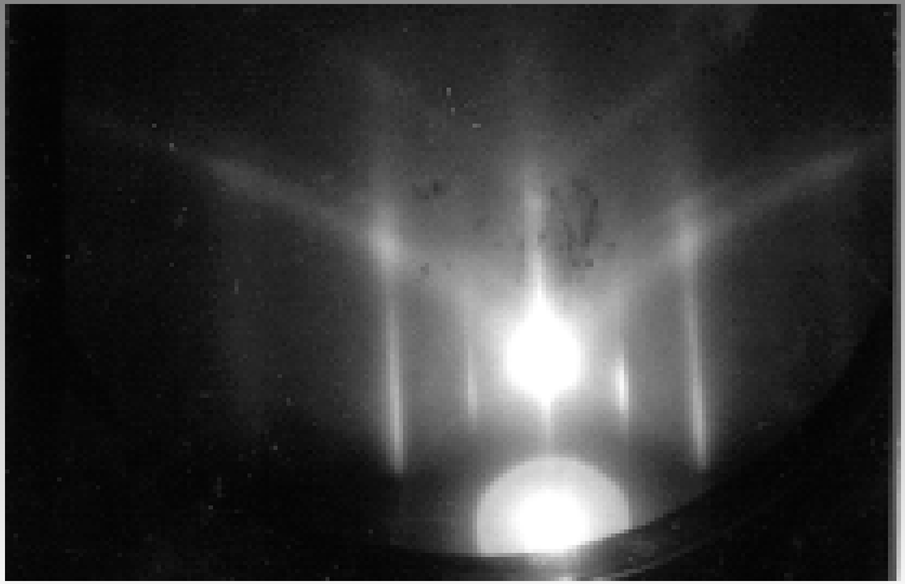
Surface Resonance



Bragg’s Diffraction Planes

Surface resonance and kikuchi lines





Conclusions

- RHEED in principle can give substantial information about crystal surface
- Kinematic theory gives little error in predicting the position of diffraction spots
- Kinematic theory does not takes into account surface resonance and inelastic collisions
- The exact measure of intensities cannot be done by kinematic theory
- In MBE systems it is used to have qualitative measure of surface perfection