The initial stages of epitaxial growth of Si on Si(100)-2x1

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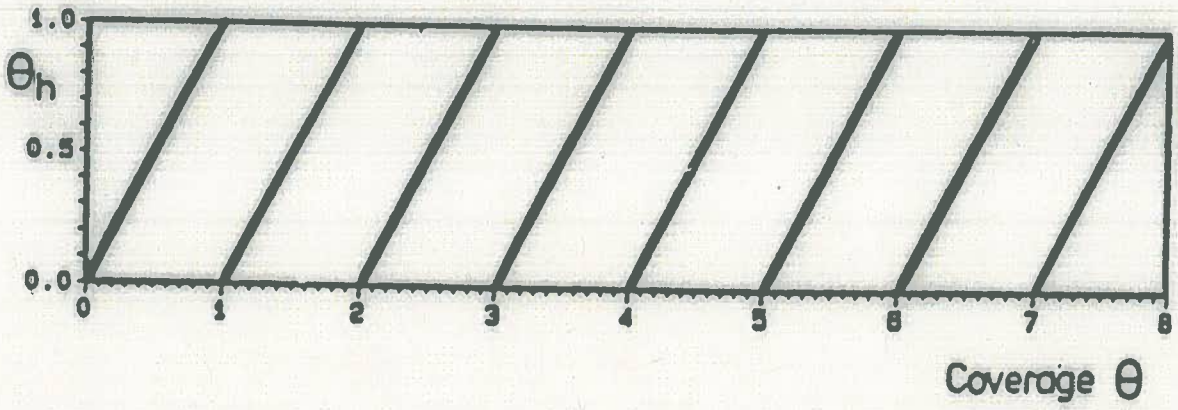
motivation:

in situ - measurement of crystal growth
quantitative analysis

method:

Spot **P**rofile **A**nalysis of LEED

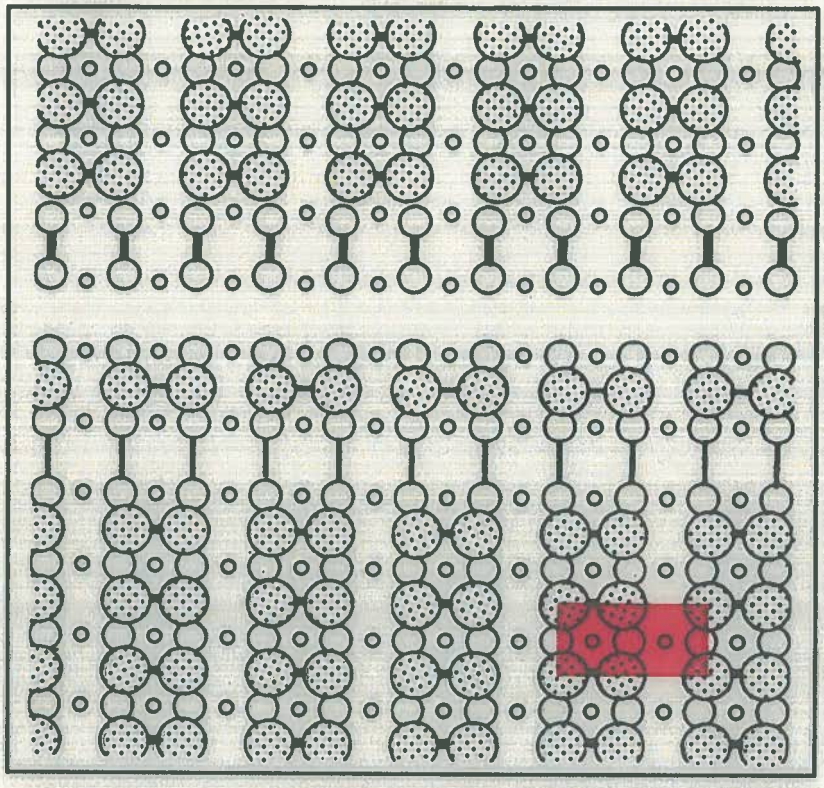
perfect layer-by-layer growth?



Outline

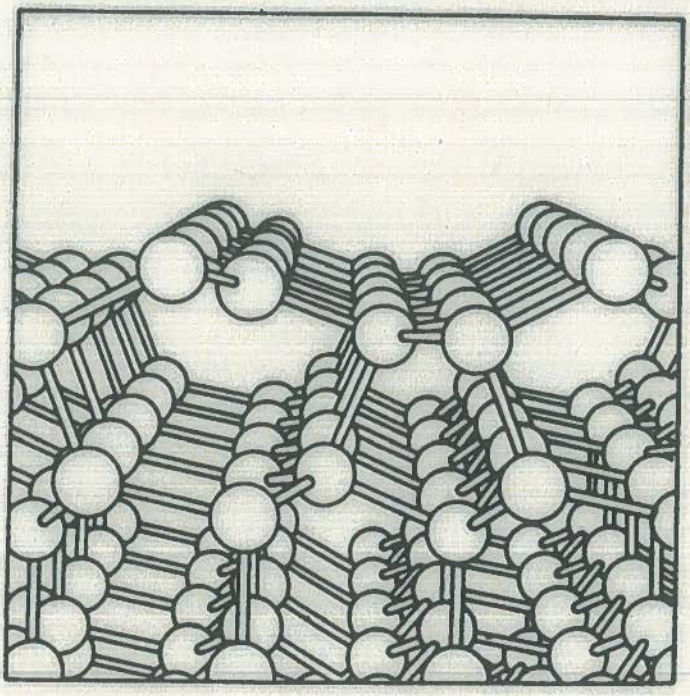
- Si(100)-2x1
- Experimental Setup
- Kinematic Approximation
- Results
  - Oscillations
  - Layer Distribution
  - Island Size Distribution
  - Reconstruction

Si(100)-2x1 surface



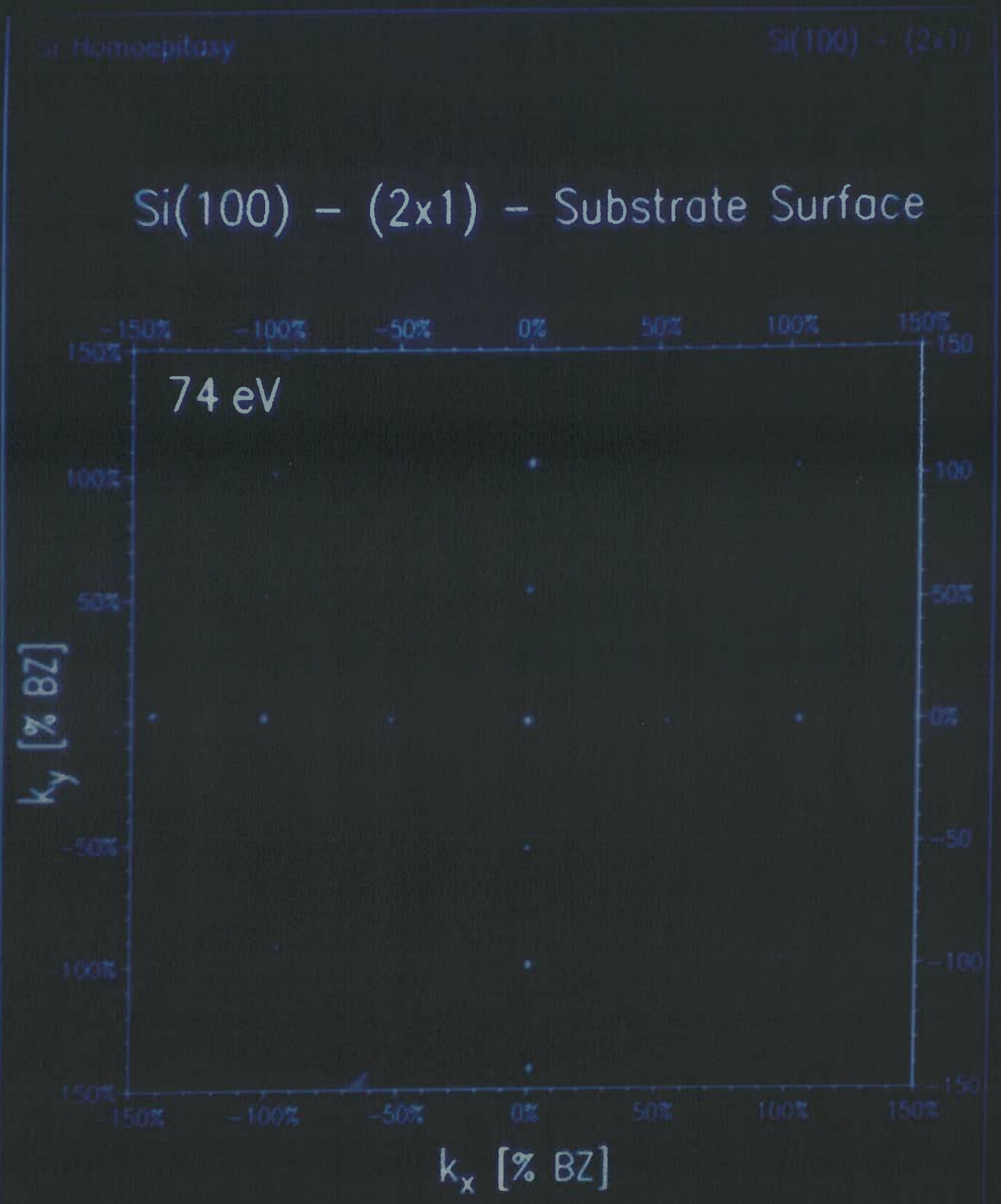
top view

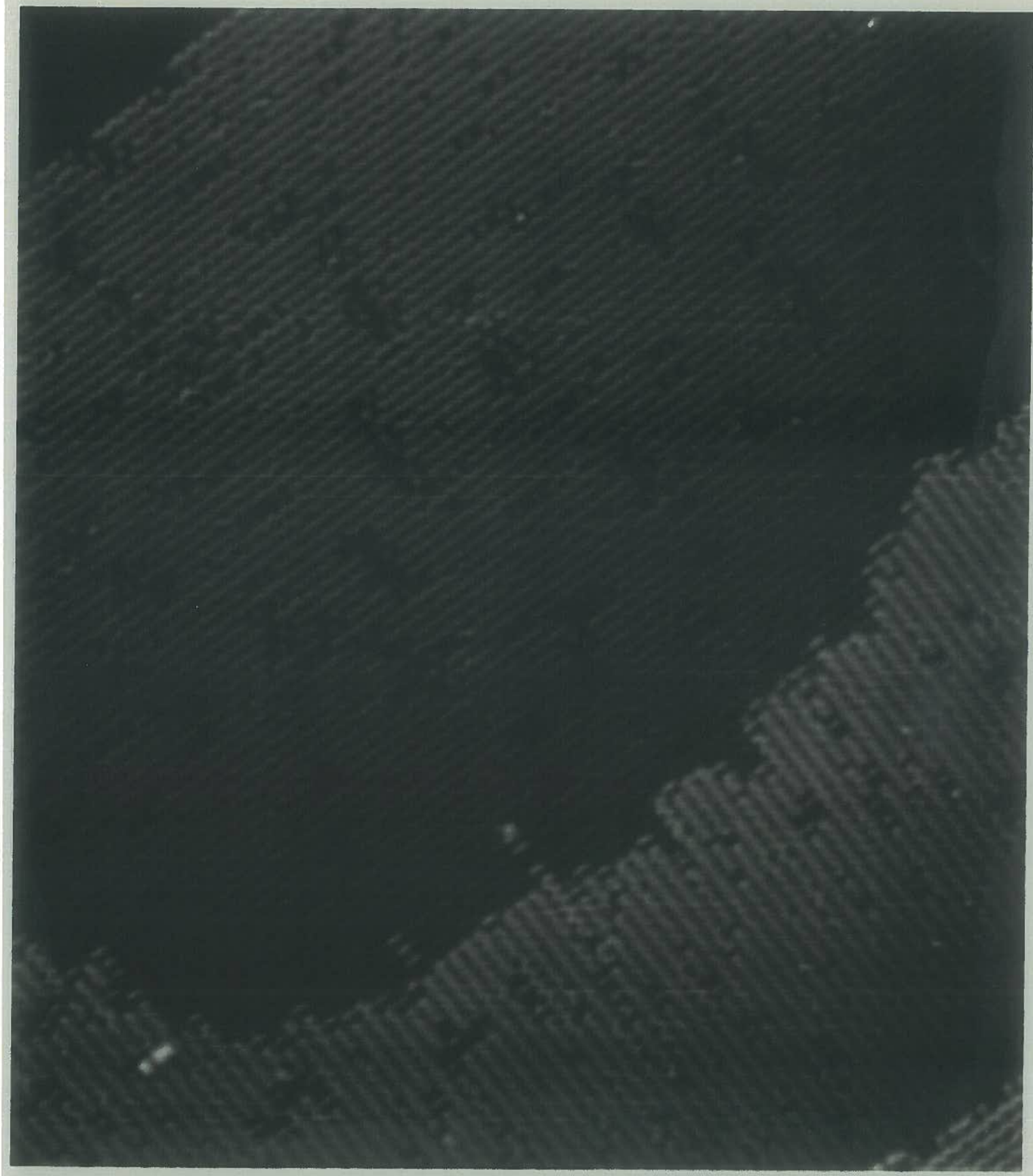
2x1 unit cell



side view

buckled dimers

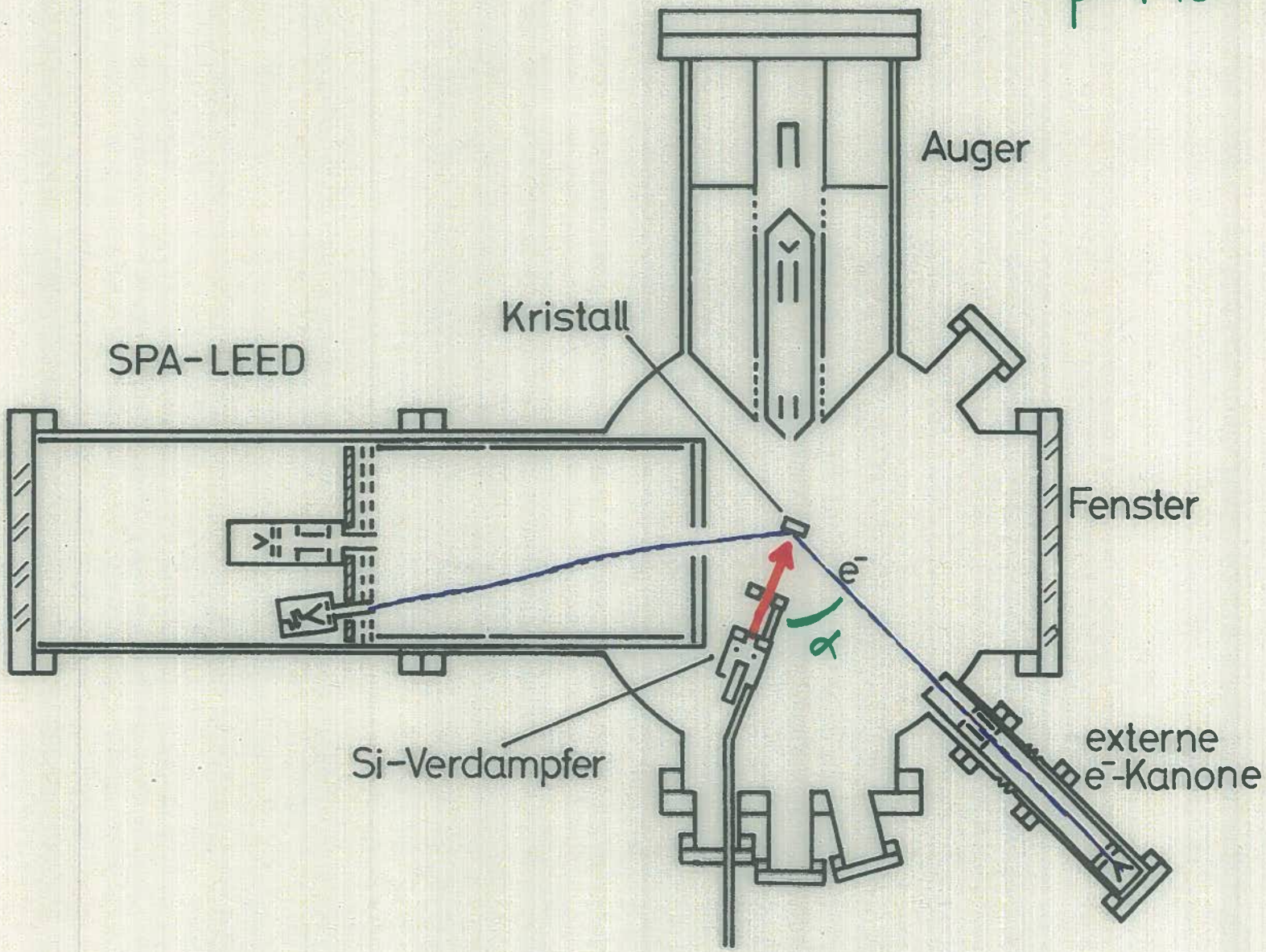

Si Homoepitaxy
Si(100) - (2x1)
Si(100) - (2x1) - Substrate Surface
74 eV
-150%
-100%
-50%
0%
50%
100%
150%
150
100
50
0
-50
-100
-150
k_y [% BZ]
k_x [% BZ]



APS 1.5 YKTAPS5 TRAVEL (1 FT 3.7 IN , 1 FT 3.7 IN) USAGE (1 FT 1.2 IN , 1 FT 1.2 IN

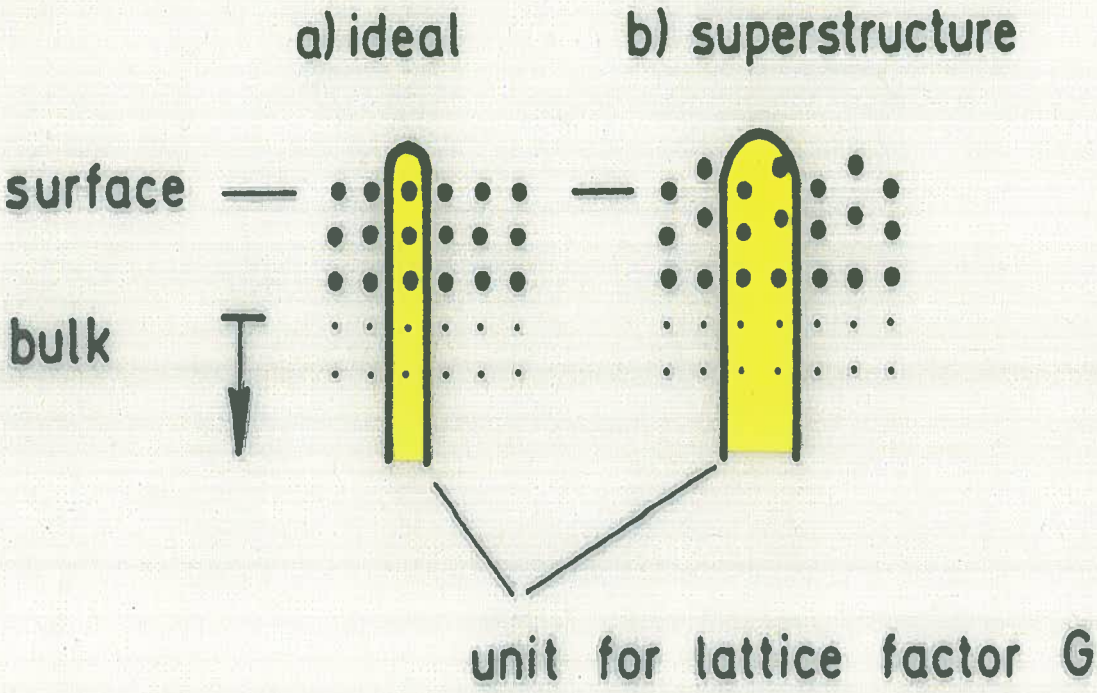
), 1987 KOEHLER DCF3I800 DEC12BF DOC.# 05297 TRAVEL 1 FT 4.7 IN USAGE 1 FT 2.2 IN

$p = 7 \cdot 10^{-11}$ mbar



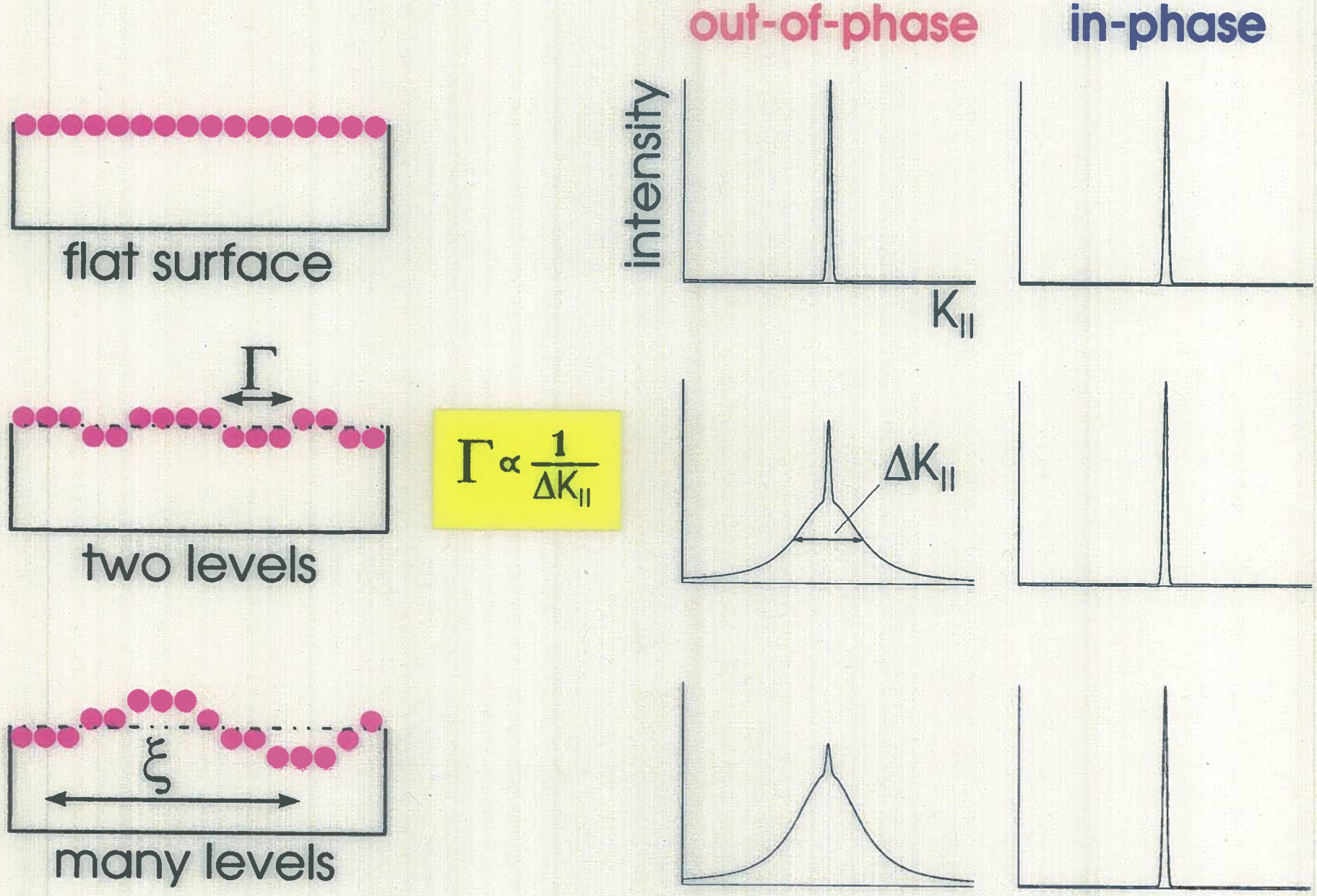
incidence angle $\alpha = 60°$

Kinematic approximation



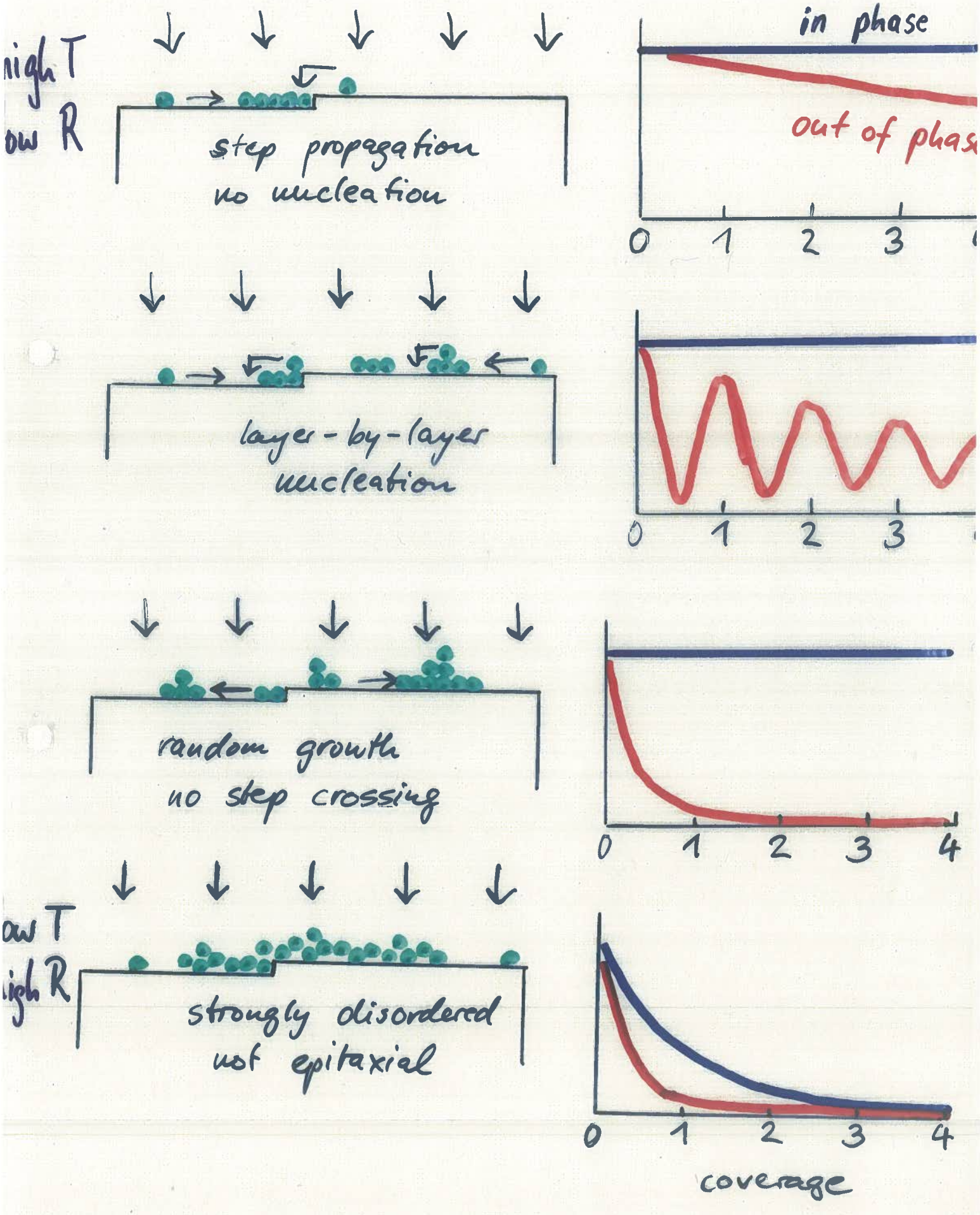
$$I = \left| \sum_{n=1}^{N} f_n e^{i\vec{k}\cdot\vec{r}_n} \right|^2 \approx |f|^2 \times \left| \sum_{n=1}^{N} e^{i\vec{k}\cdot\vec{r}_n} \right|^2 = F \cdot G$$

All scattering amplitudes f_n are identical

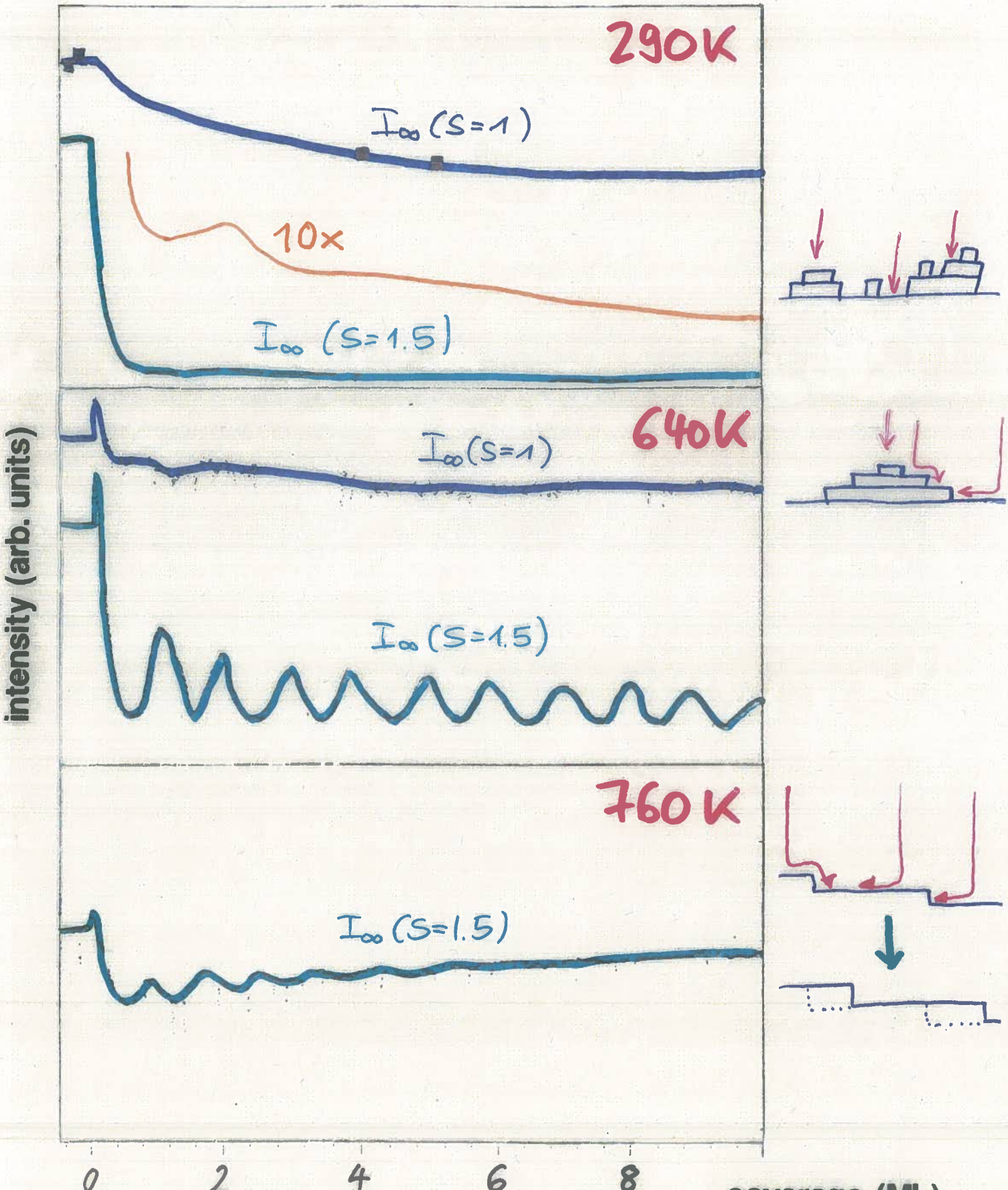

out-of-phase
in-phase
flat surface
intensity
$K_{||}$
Γ
two levels
$\Gamma \propto \frac{1}{\Delta K_{||}}$
$\Delta K_{||}$
ξ
many levels

model

observed peak-intensity

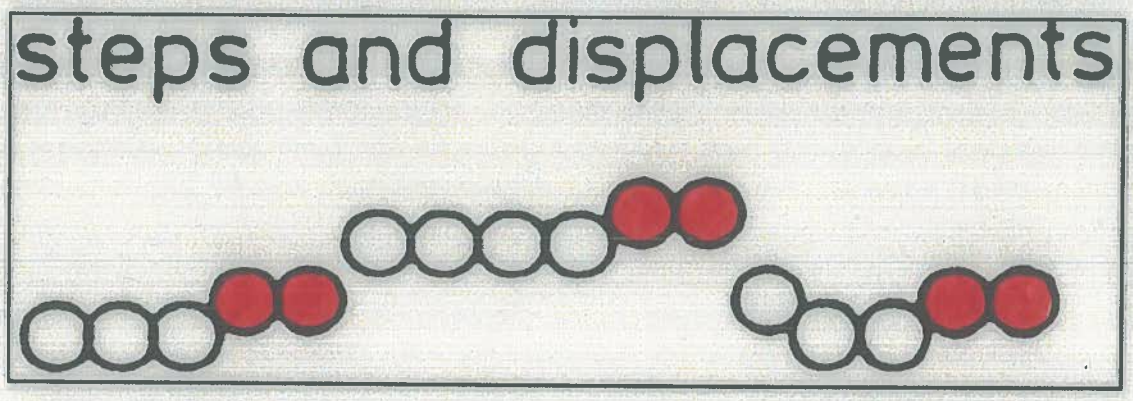


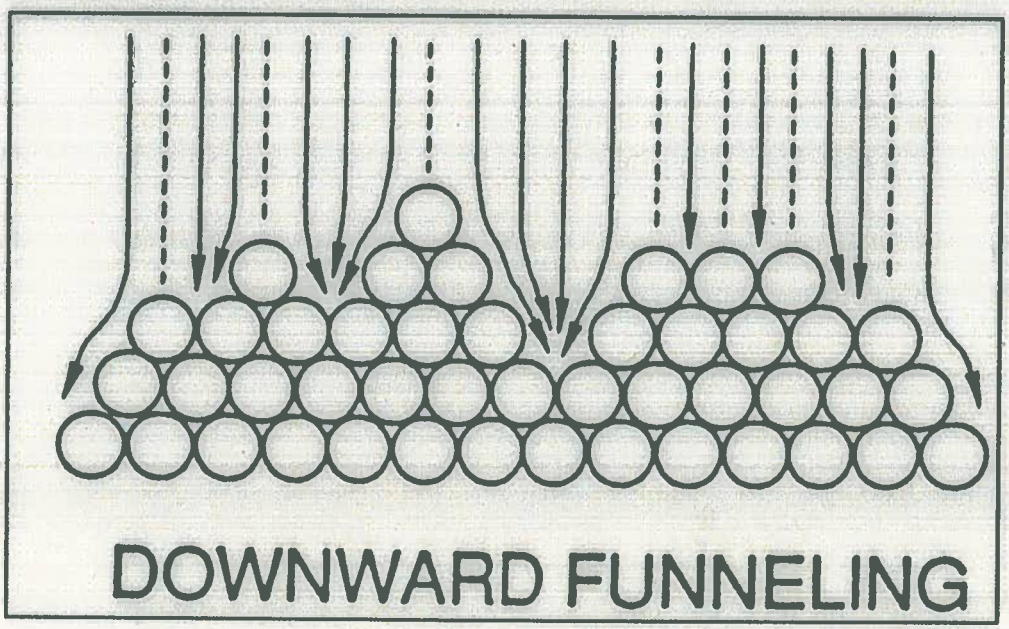
GROWTH MODES



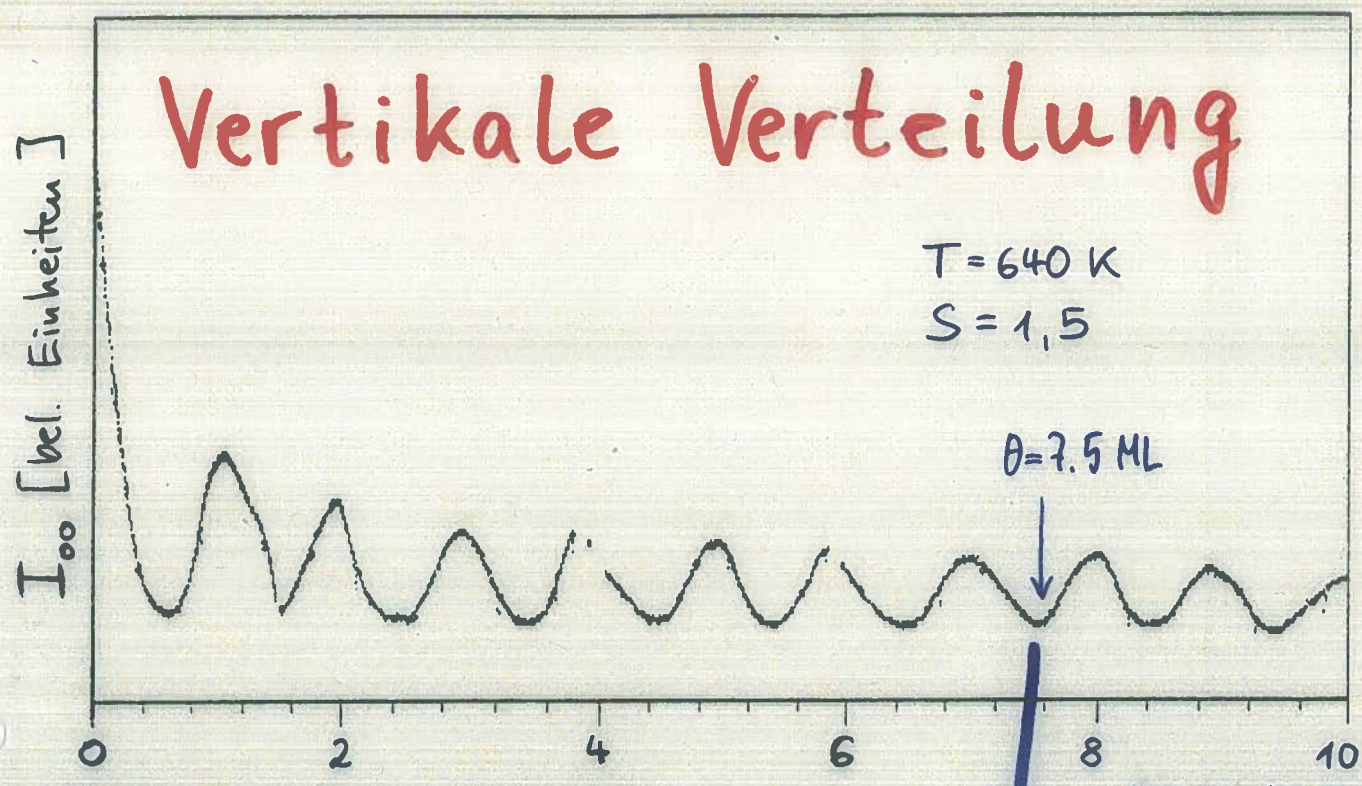
Low Temperature Epitaxy

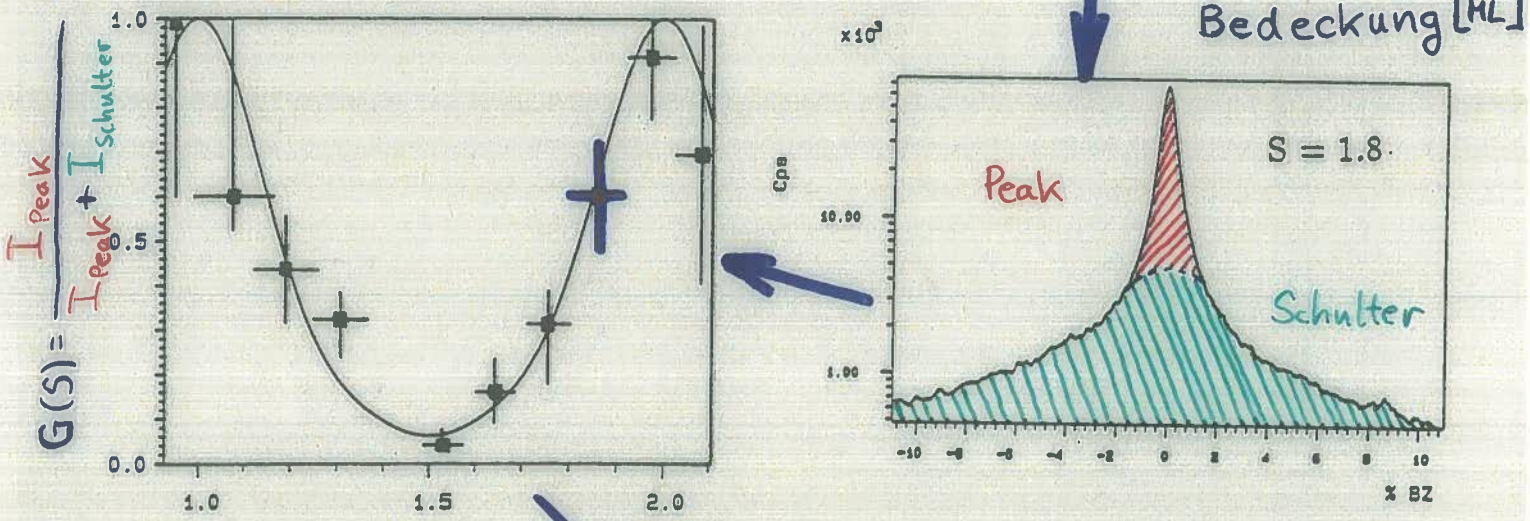
J. Falta and M. Henzler: Surf. Sci. 269/270 (1992) 14

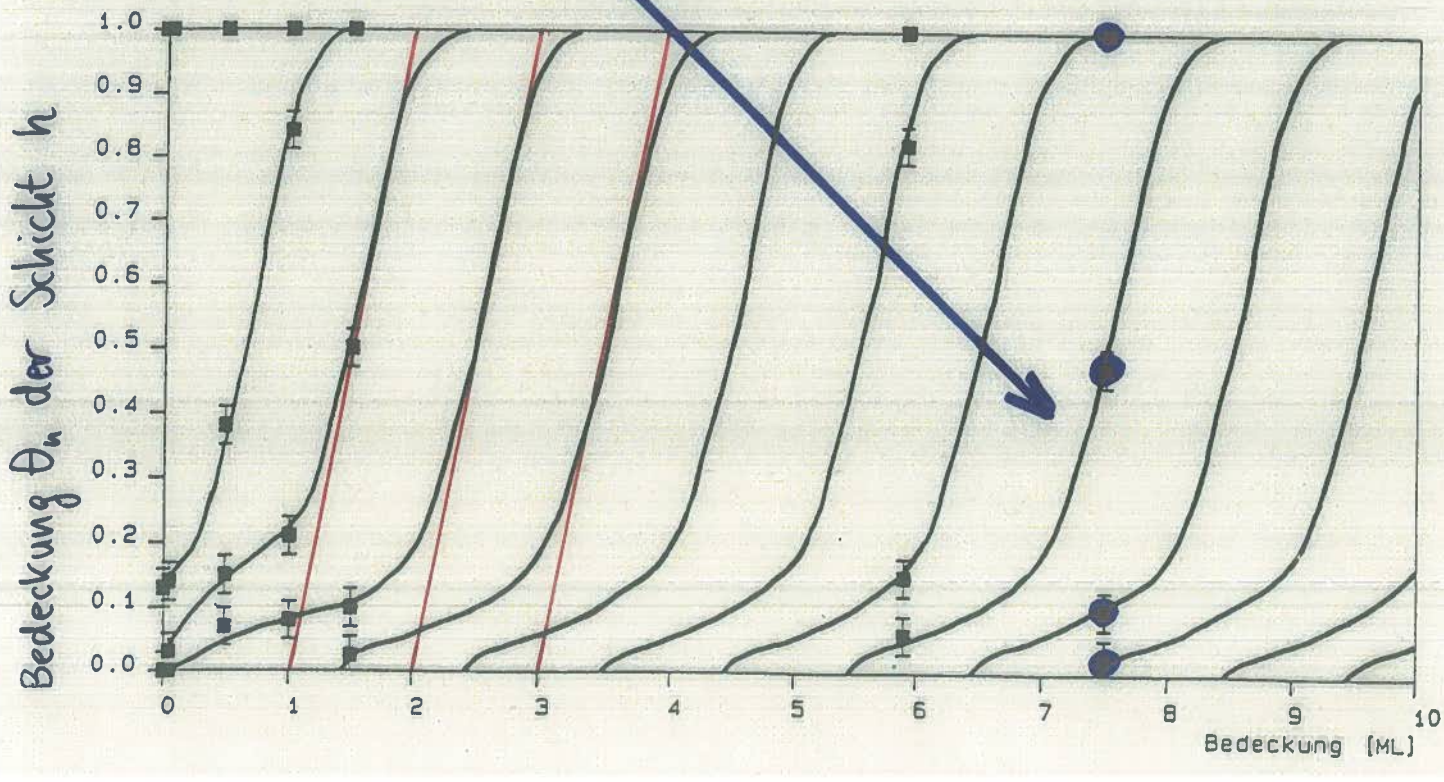




Vertikale Verteilung







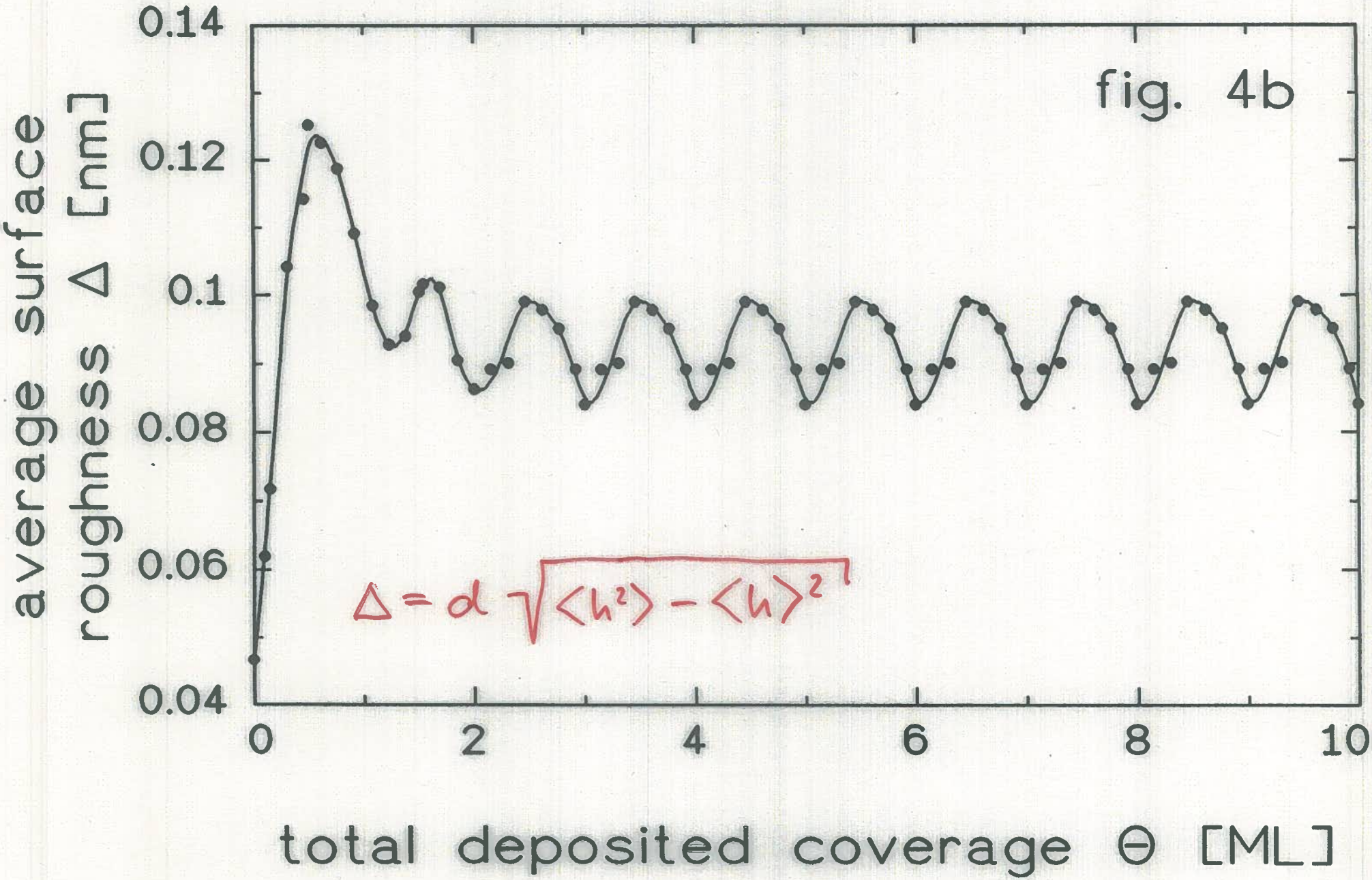
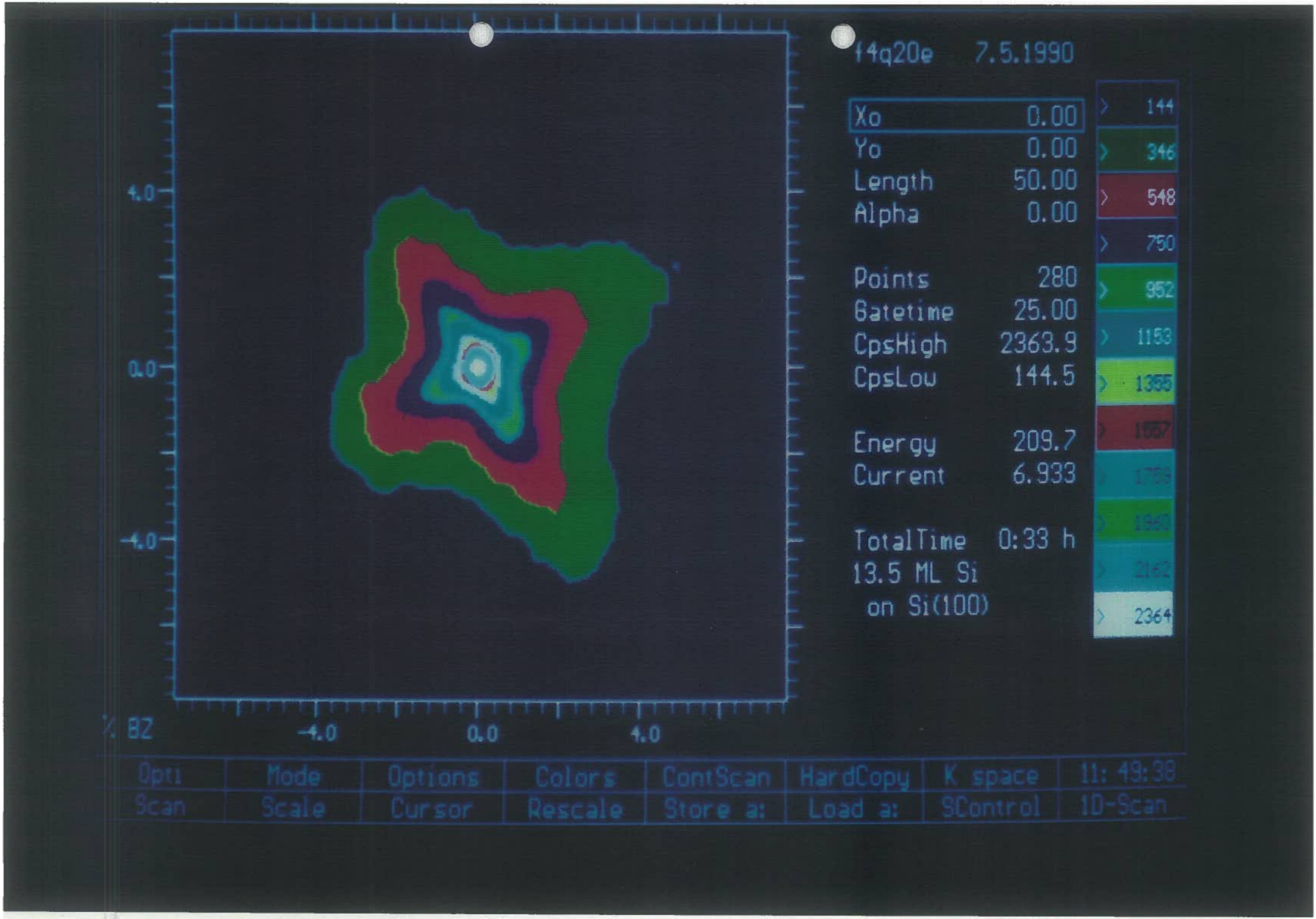
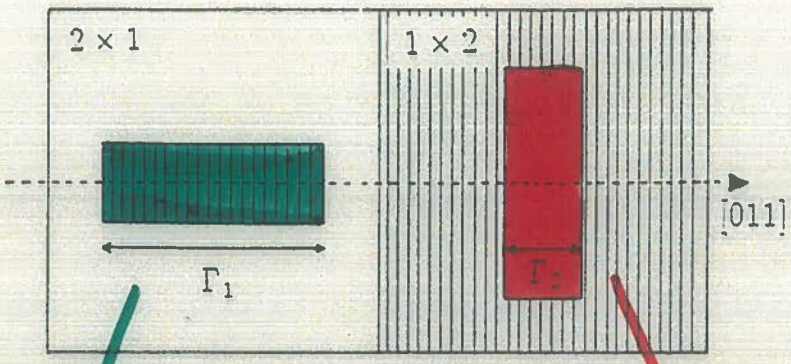


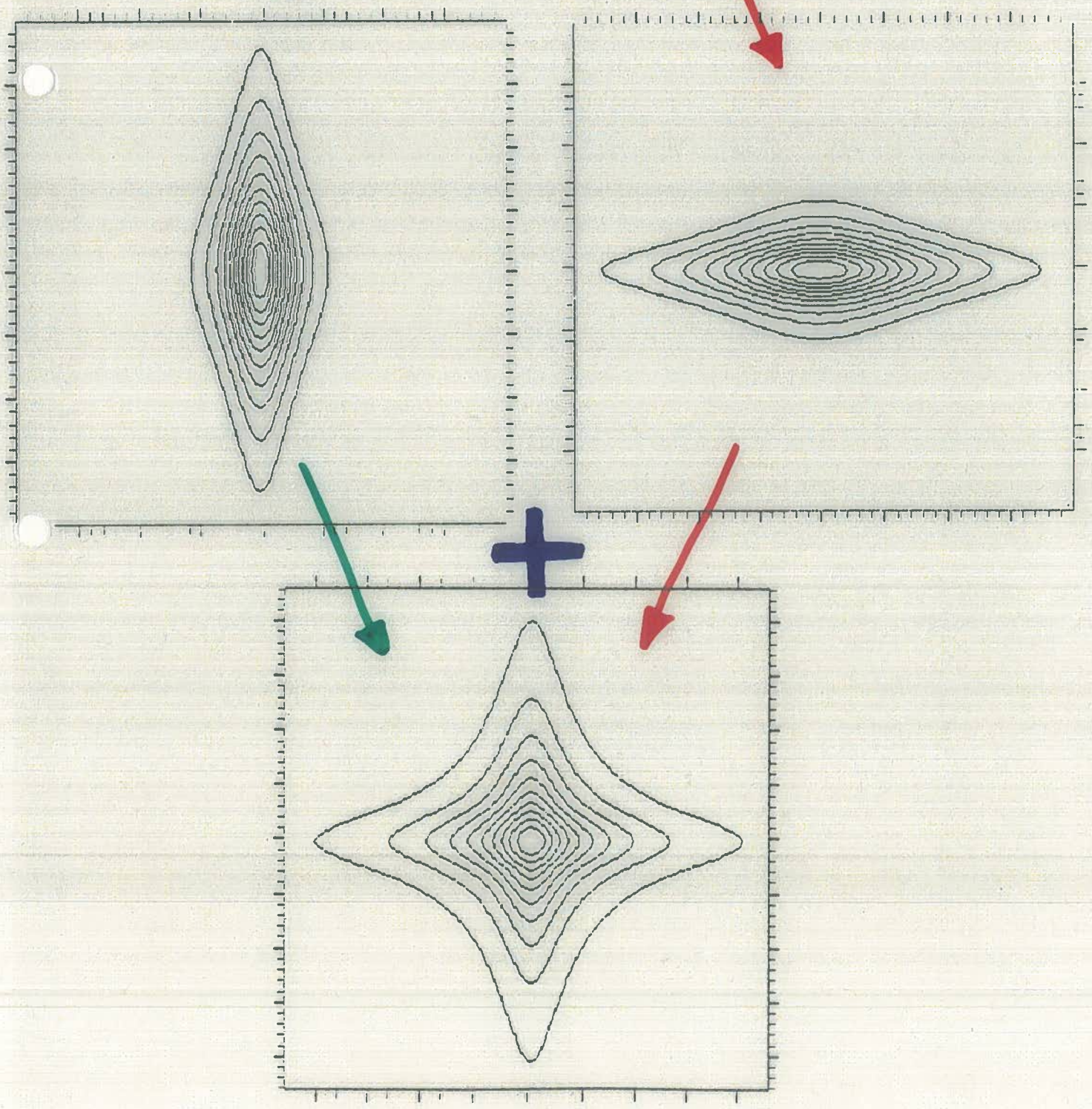
fig. 4b
average surface roughness Δ [nm]
0.14
0.12
0.1
0.08
0.06
0.04
0
2
4
6
8
10
total deposited coverage Θ [ML]
$\Delta = d\sqrt{\langle h^2\rangle - \langle h\rangle^2}$


f4q20e 7.5.1990
Xo 0.00
Yo 0.00
Length 50.00
Alpha 0.00
Points 280
Gatetime 25.00
CpsHigh 2363.9
CpsLow 144.5
Energy 209.7
Current 6.933
TotalTime 0:33 h
13.5 ML Si
on Si(100)
144
346
548
750
952
1153
1355
1557
1759
1960
2162
2364
4.0
0.0
-4.0
-4.0
0.0
4.0
BZ
Opti
Mode
Options
Colors
ContScan
HardCopy
K space
11: 49:38
Scan
Scale
Cursor
Rescale
Store a:
Load a:
SControl
1D-Scan

2×1

1×2





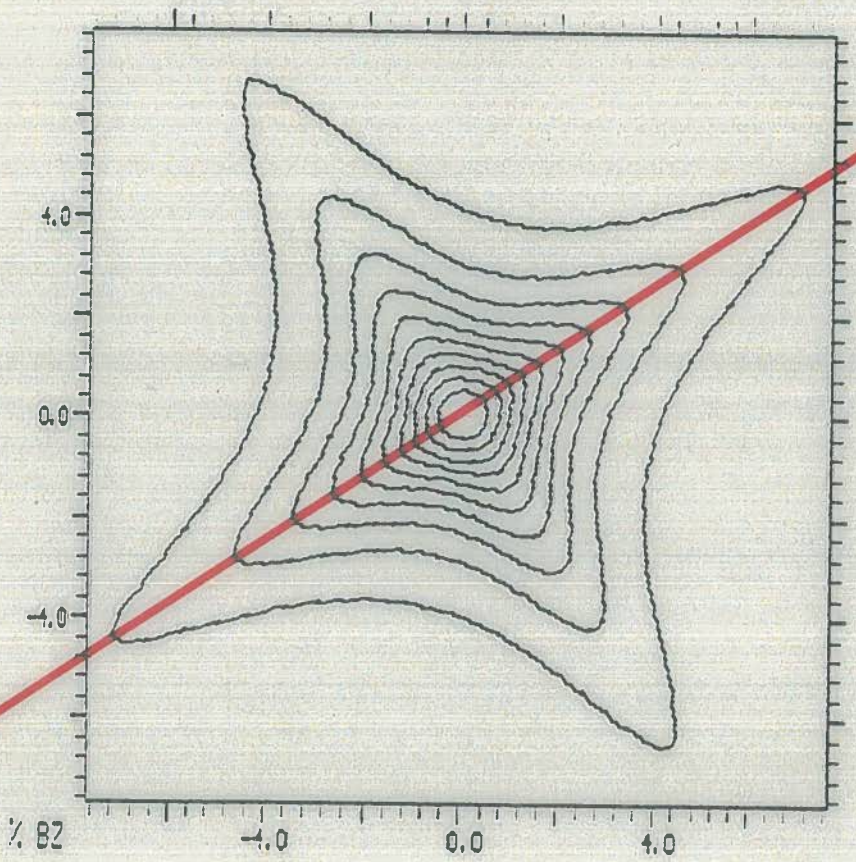
Theorie

Spadacini et.al.: Surf.Sci 133 (1983) 216

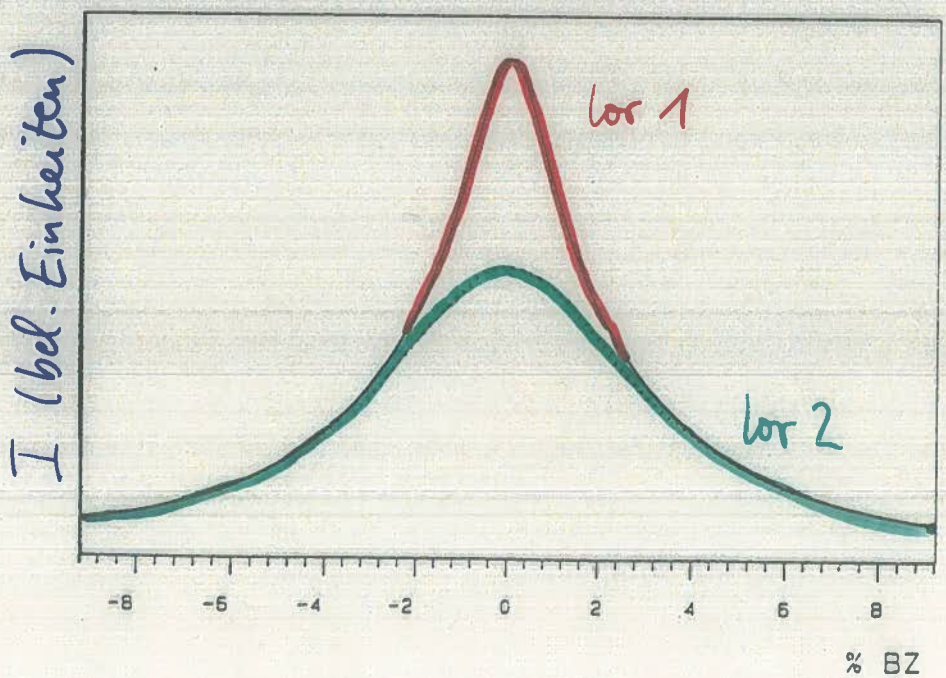
geometrische Stufenverteilung

aber: $w_1 \neq w_2$

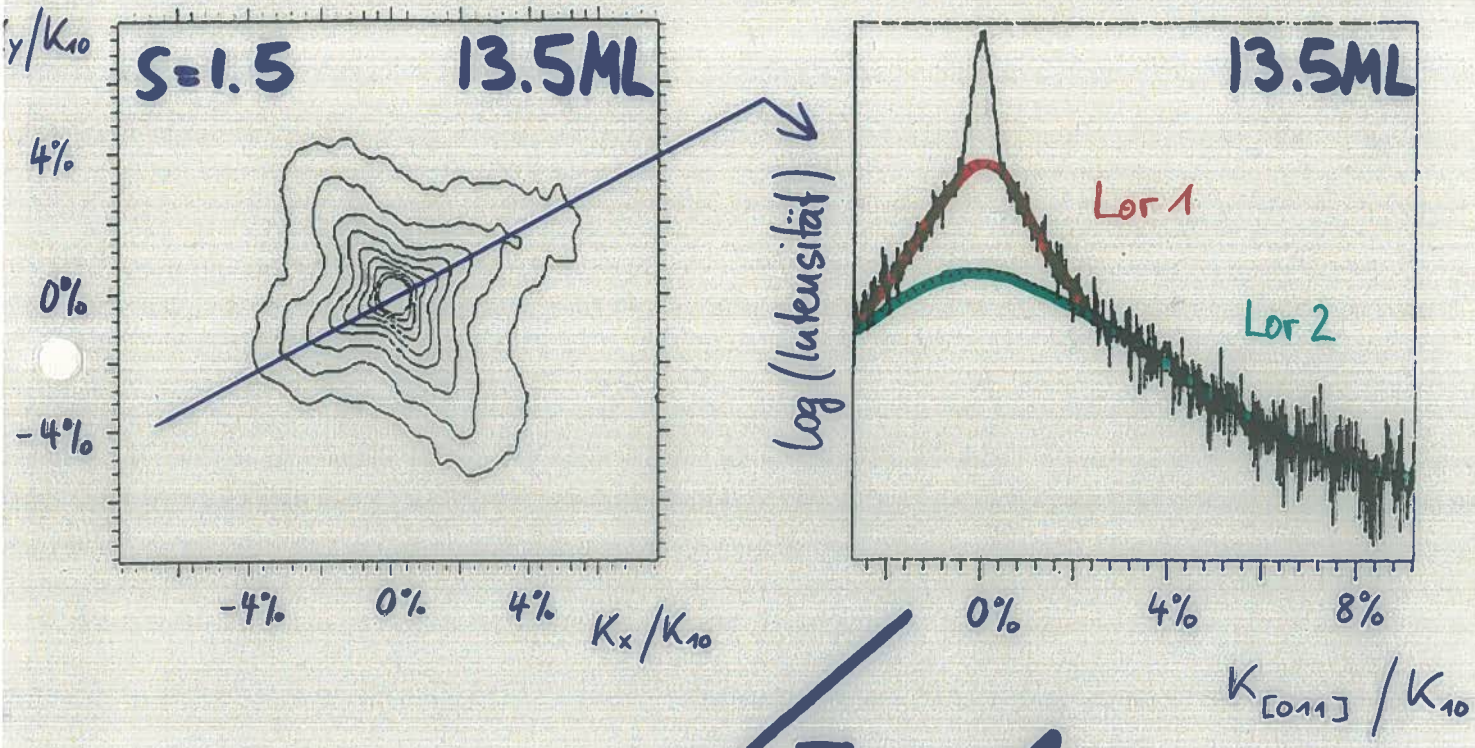
$$I = Lor1 + Lor2$$



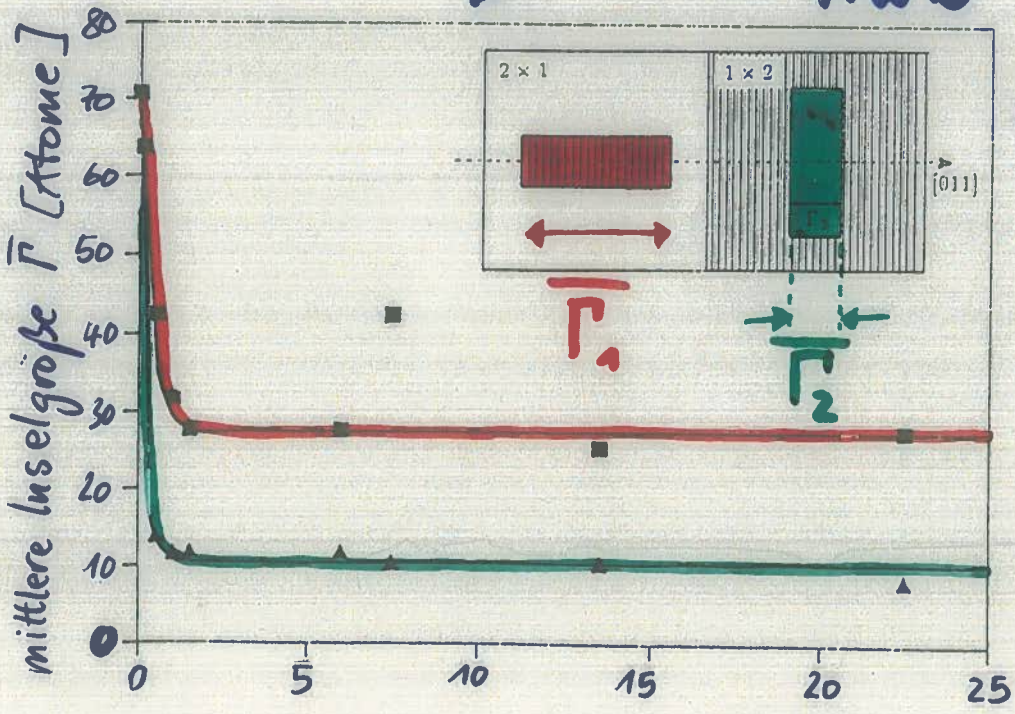
Simulationen für 13.5 ML



Laterale Verteilung

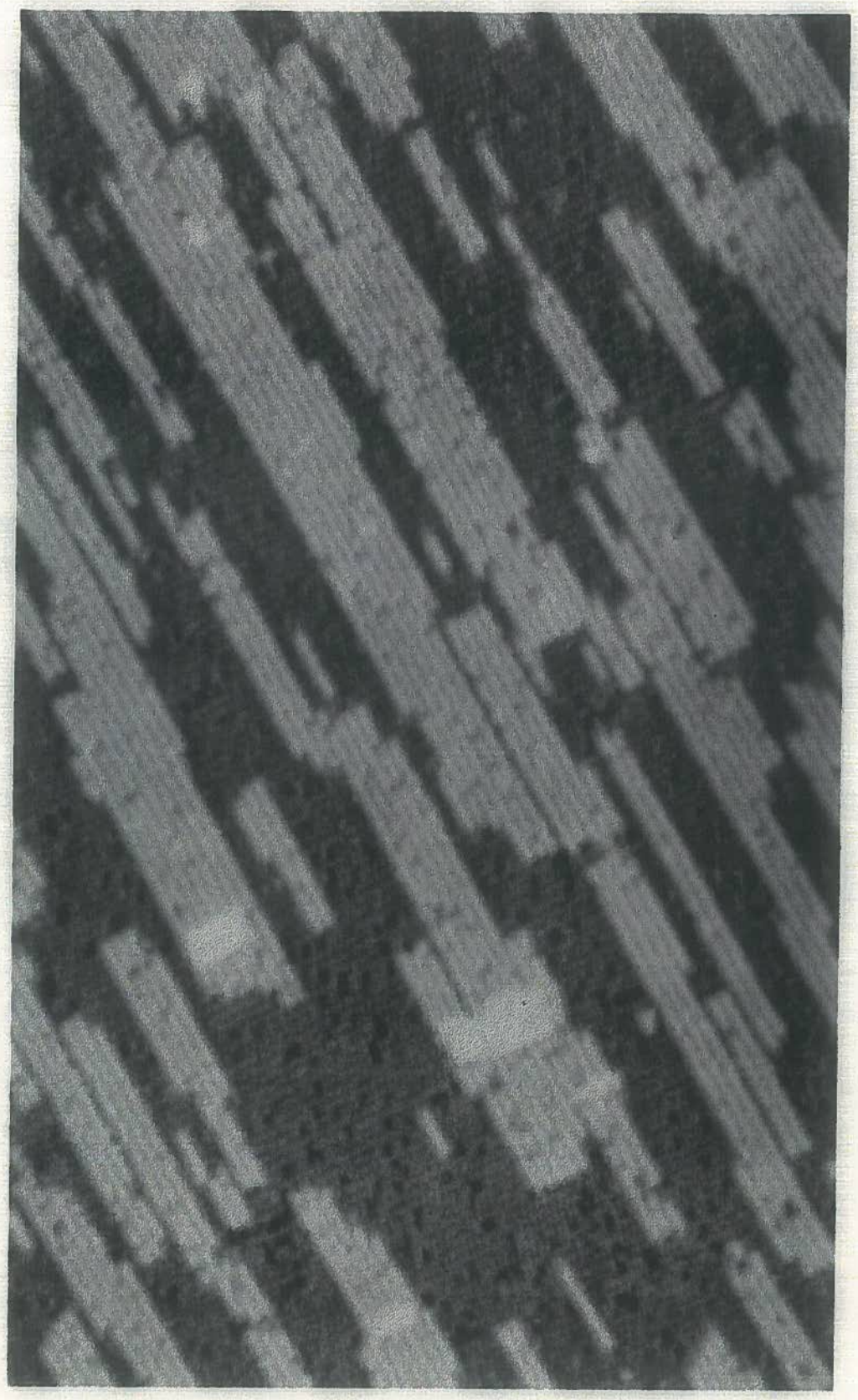


$$\bar{\Gamma} \propto \frac{1}{HWB}$$

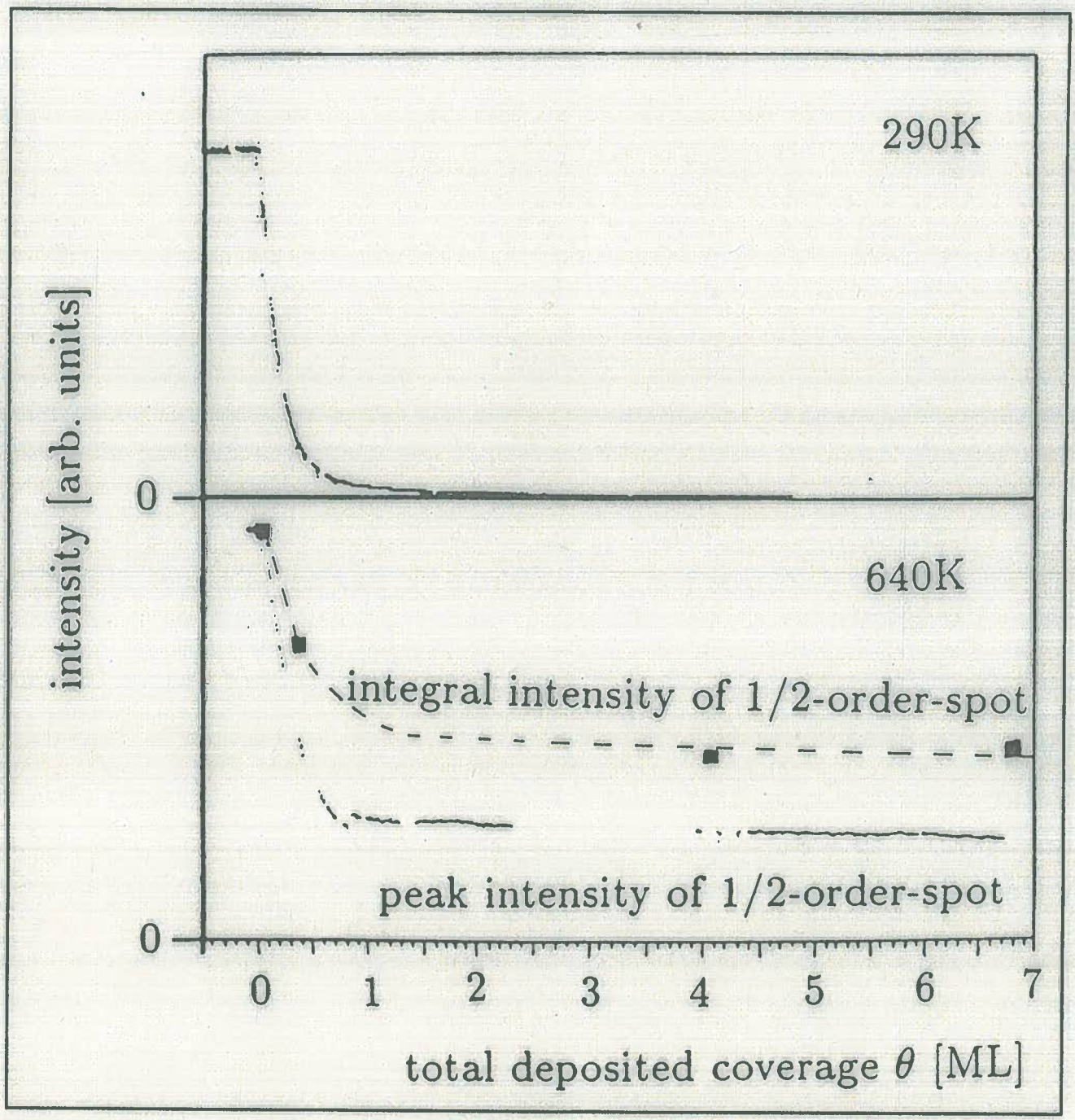


T = 640K

0.4 ML Si on Si(100), 370°C



Reconstruction



half-order spots: peak intensity ↓, FWHM ↑,
but integral intensity ↓

conclusion

Si on Si(100) model system for MBE

different growth modes:
- 290 K - 400 K: random growth
- 400 K - 750 K: layer-by-layer growth
- 750 K - 820 K: step flow

growth at 640 K:
- 4 layers growing simultaneously
- layer-by-layer growth to at least 23 ML
- elongated islands, length : width = 3 : 1