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and cultural
organization

international atomic
energy agency

the
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international centre for theoretical physics

SMR/1270-32

SCHOOL ON SYNCHROTRON RADIATION

6 November – 8 December 2000

Miramare - Trieste, Italy

Supported in part by the Italian Ministry of Foreign Affairs in connection with the SESEME project

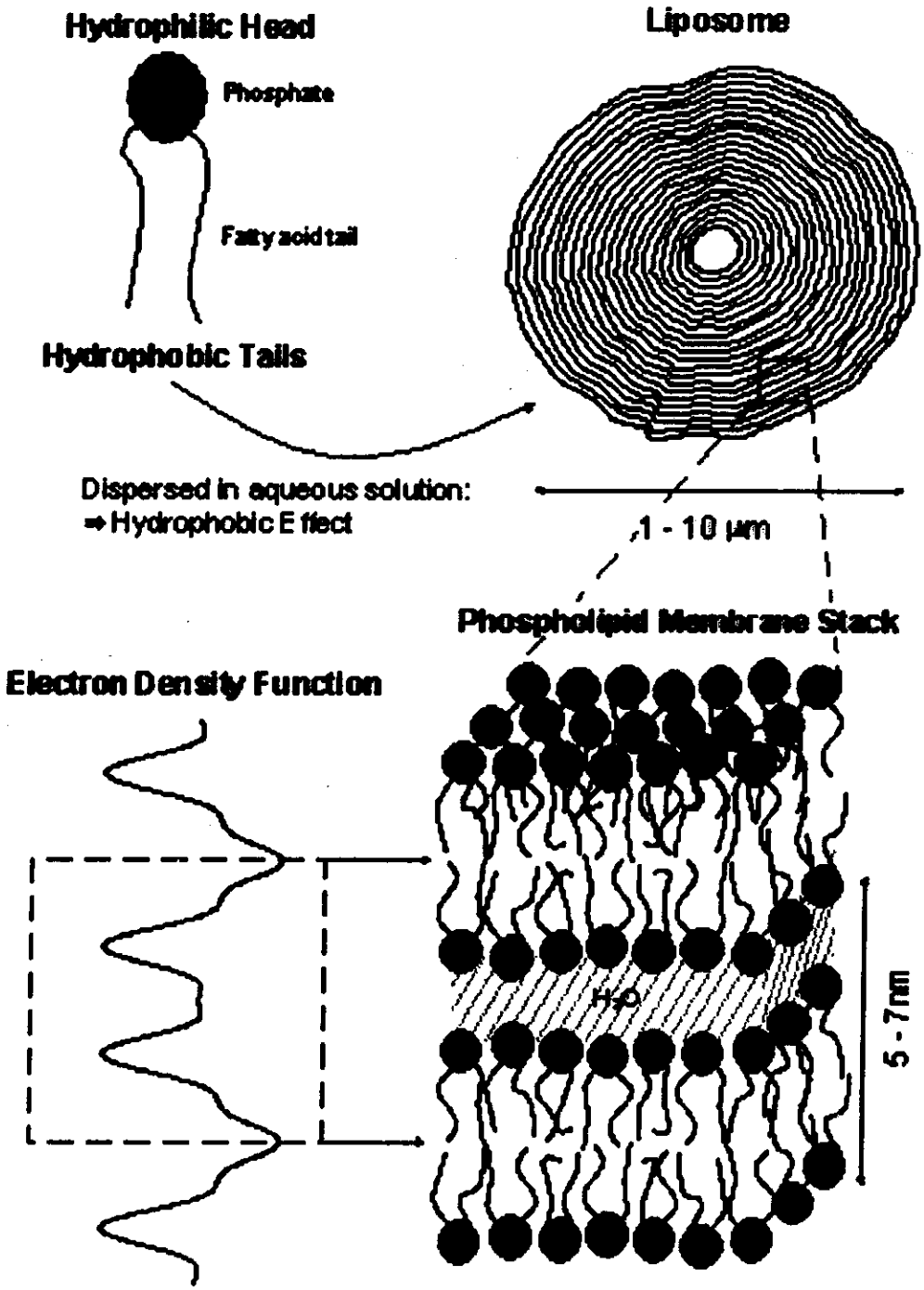
Co-sponsors: Sincrotrone Trieste, Società Italiana di Luce di Sincrotrone (SILS) and the Arab Fund for Economic and Social Development

Biological Membranes and Time Resolved experiments

P. Laggner
Akademie Der Wissenschaften
Institut Fur Biophysik Und Rontgenstrukturforschung
Graz, Austria

PHOSPHOLIPID MODEL MEMBRANES

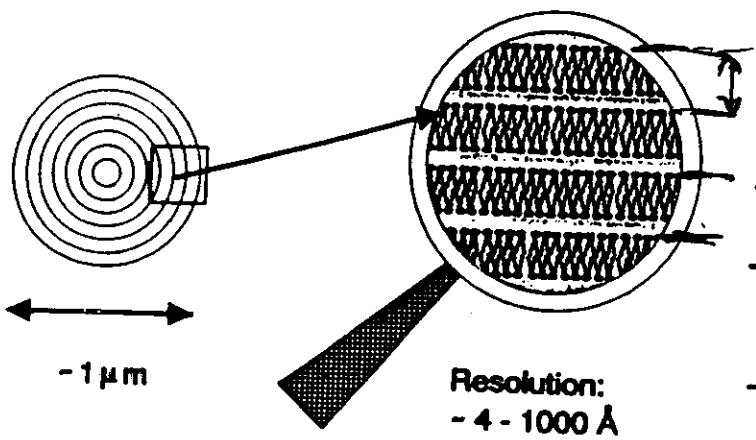
The Lamellar Liquid Crystalline Phase



Multilamellar Liposomes

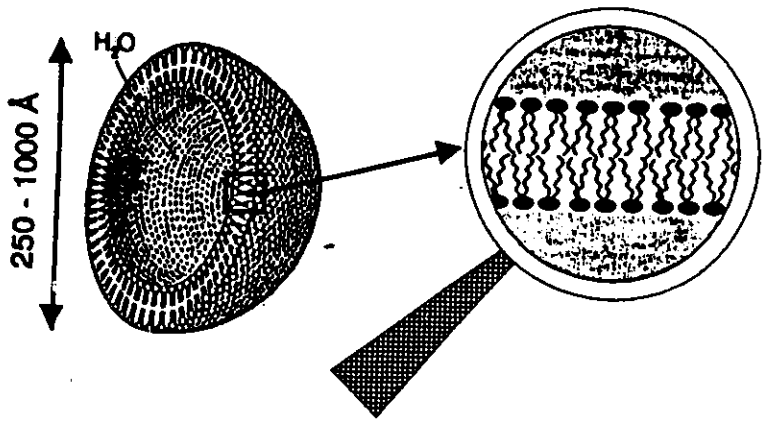
What X-Rays "see"

Accessible Information



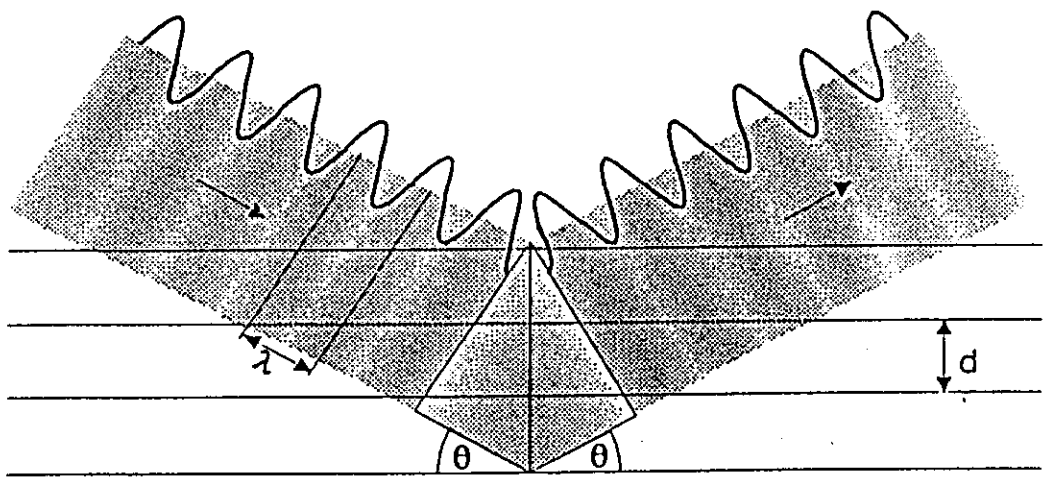
- o Bilayer Thickness
- o Waterlayer Thickness
- o Surface Area / Lipid
- o Electron Density Profile
- o Chain Packing Geometry

Unilamellar Vesicles



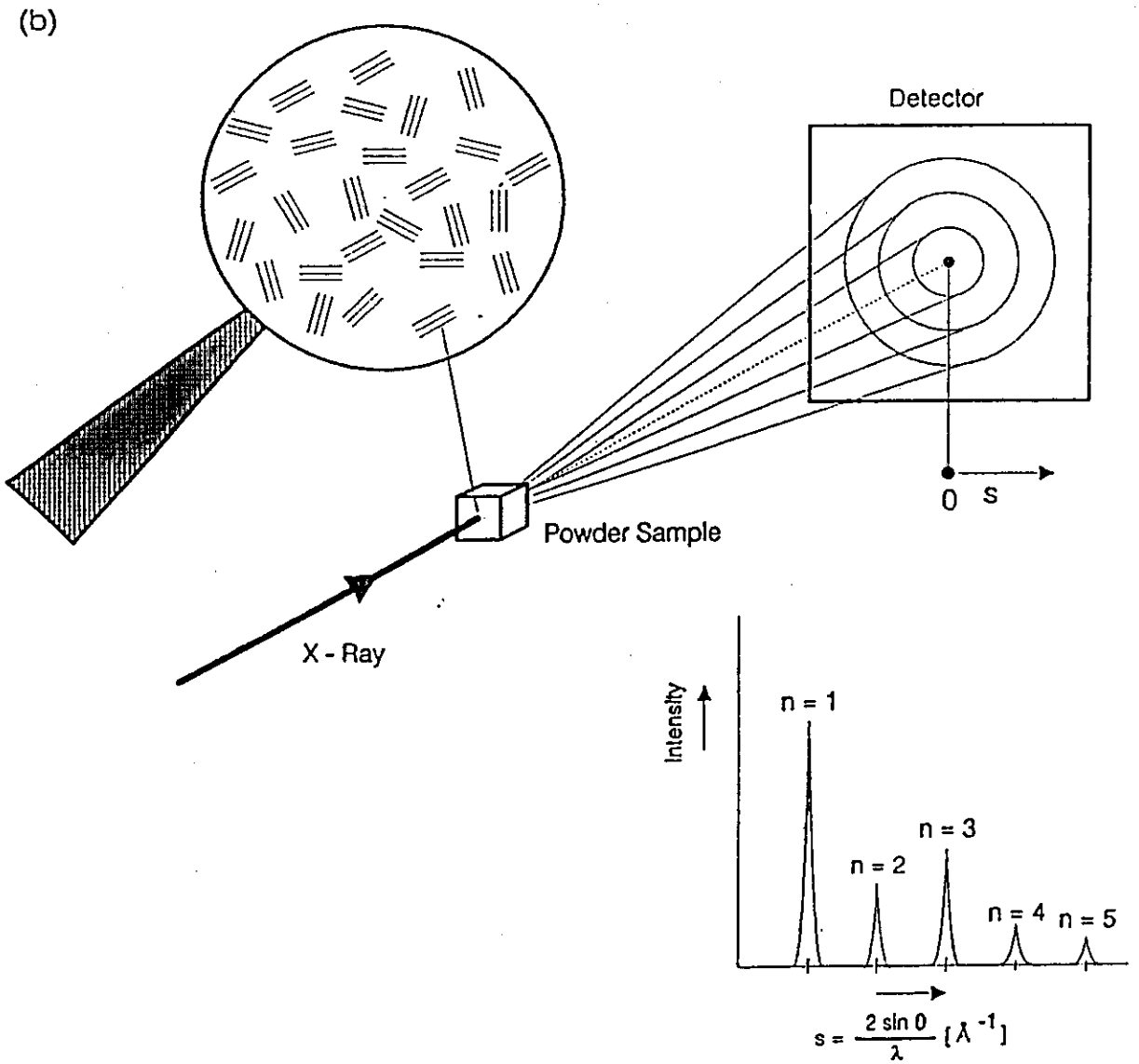
- o Bilayer Thickness
- o Surface Area / Lipid
- o Mass / Unit Area
- o Electron Density Profile

(a)



$$n\lambda = 2\,d\,\sin\theta$$

(b)



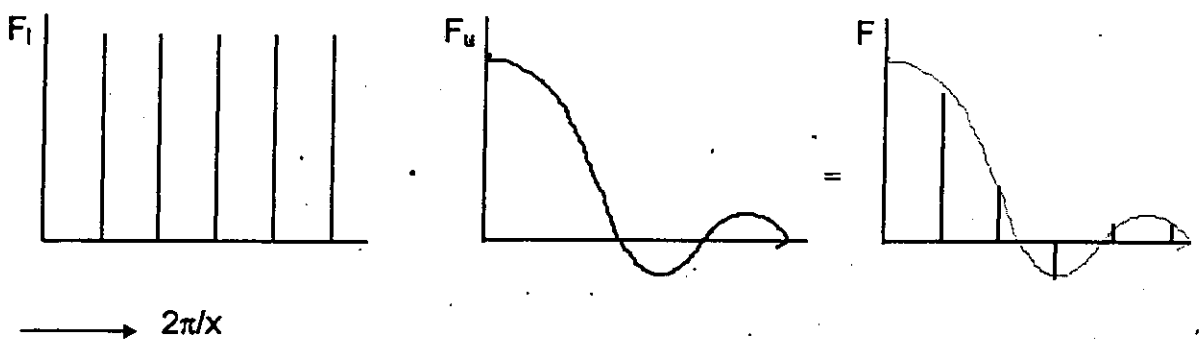
LAYERED STRUCTURES

in liquid crystals, polymers, clays etc.

Real space

lattice unit cell 1-D crystal

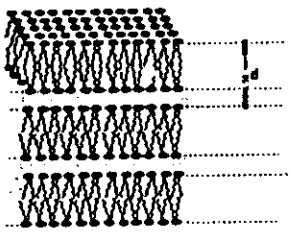
Fourier Transform



reciprocal lattice form factor structure amplitude

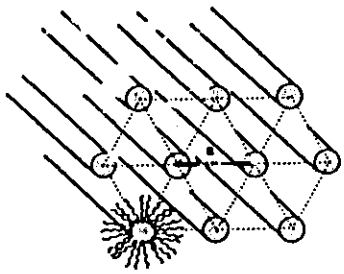
A. CLASSES OF POLYMORPHIC LIPID PHASES

Lamellar



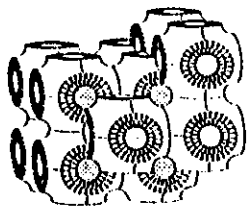
L_α

Hexagonal



H_{II}

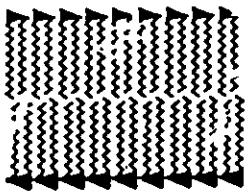
Cubic



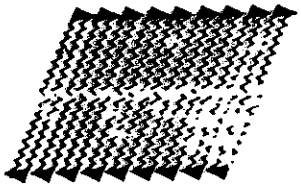
Q

B. SOME FORMS OF LOW-TEMPERATURE LAMELLAR PHASES

Crystalline

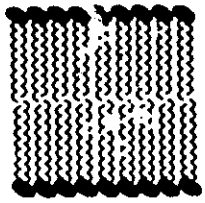


L_c

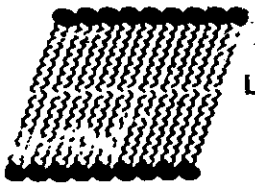


L_c'

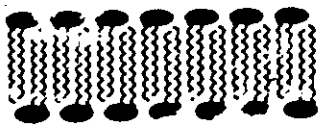
Gel



L_β

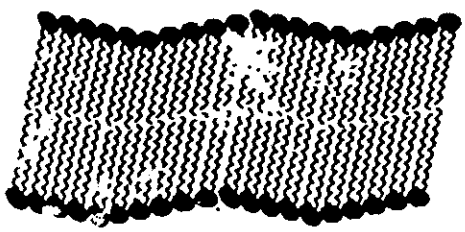


L_β'



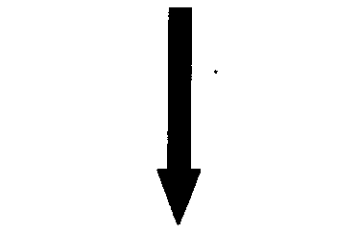
L_i

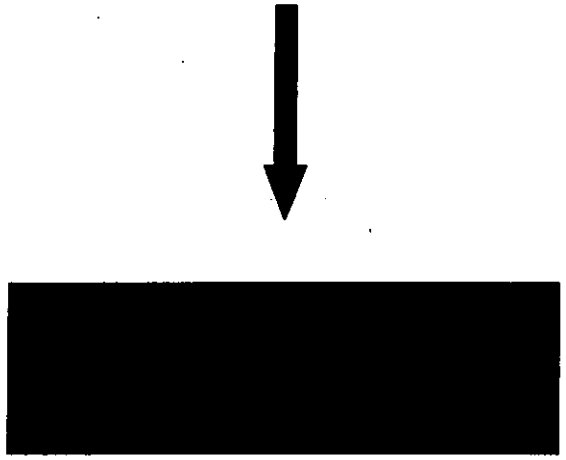
Ripple Phase

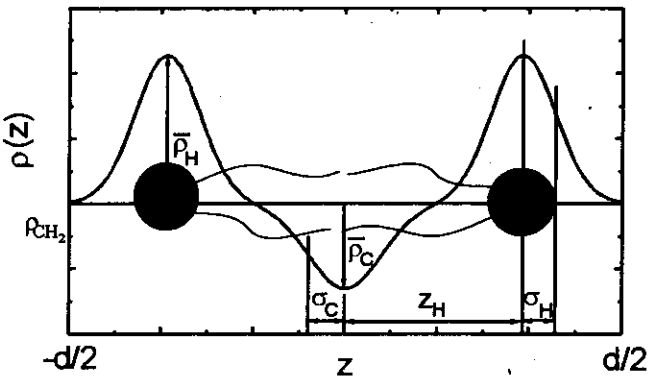


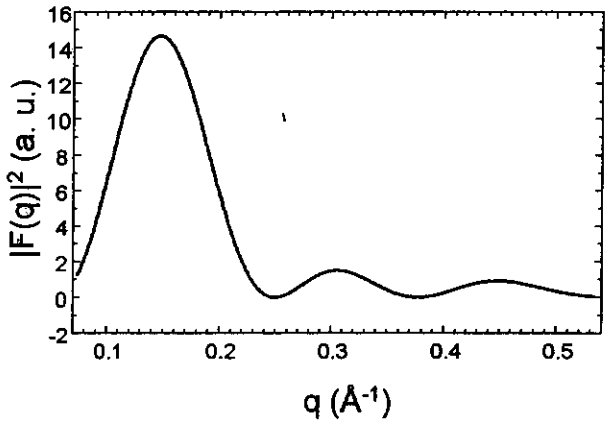
P_β'

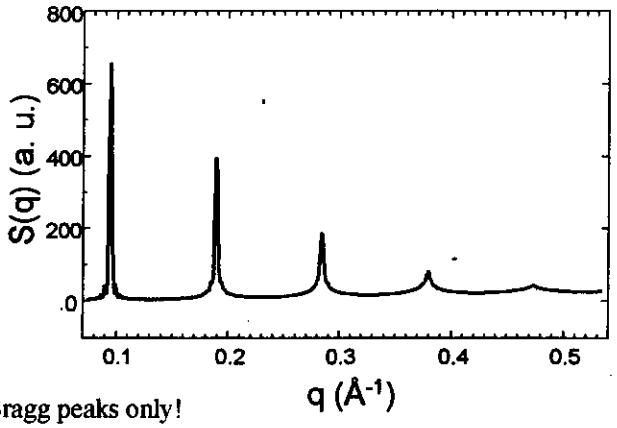
MCG: fit the diffraction patterns of fully hydrated liposomes in the full q-range



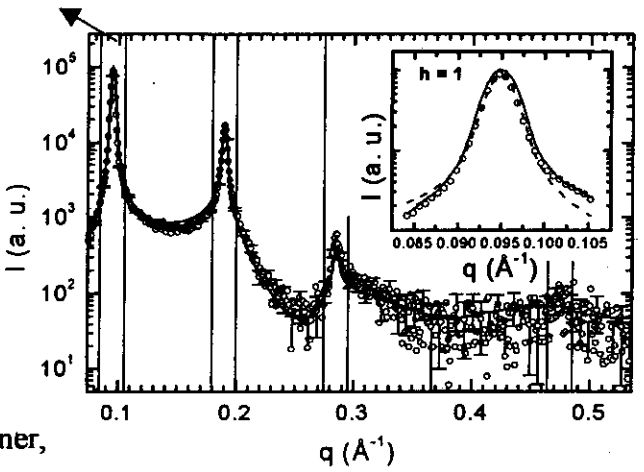








Standard methods fit Bragg peaks only!

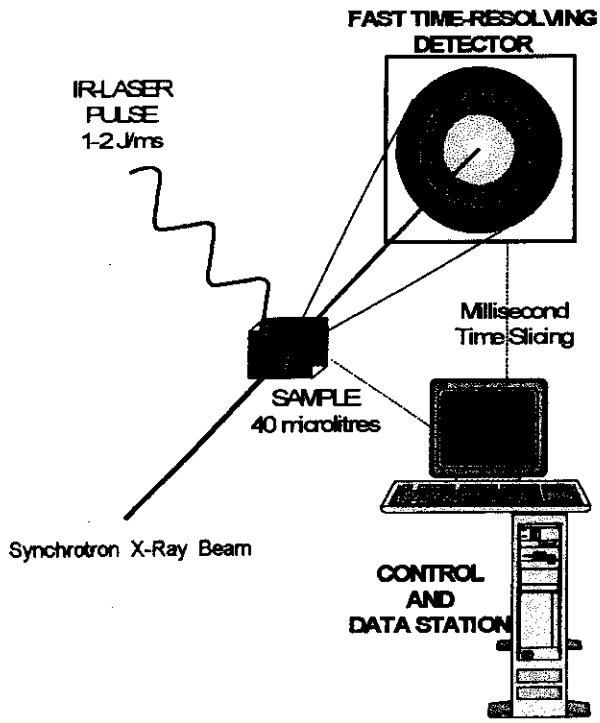


Fit the total scattered intensity in the full q-range

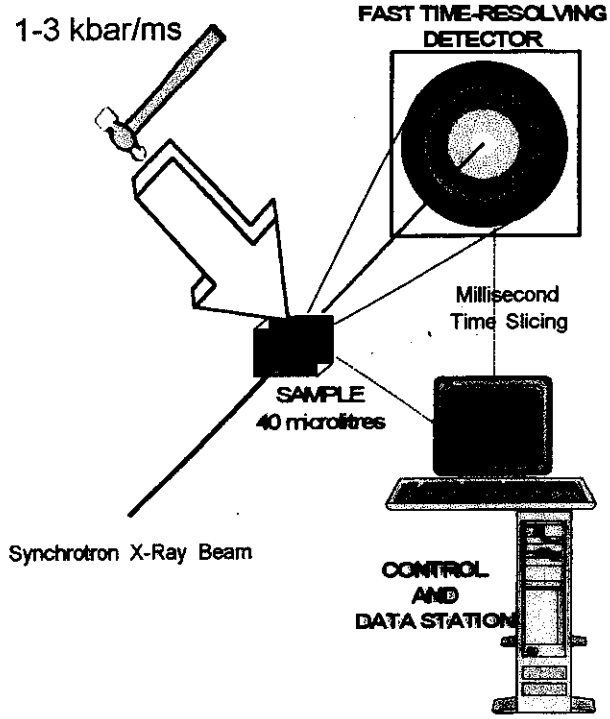
G. Pabst, M. Rappolt, H. Amenitsch, and P. Laggner, *Phys. Rev. E*, in press.

SOME EXAMPLES OF JUMP-RELAXATION APPROACHES

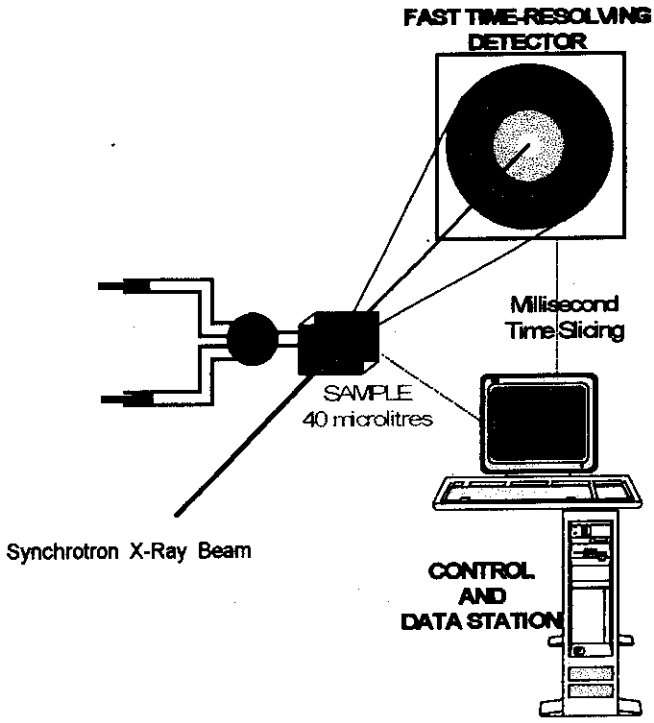
T-Jump SWAX



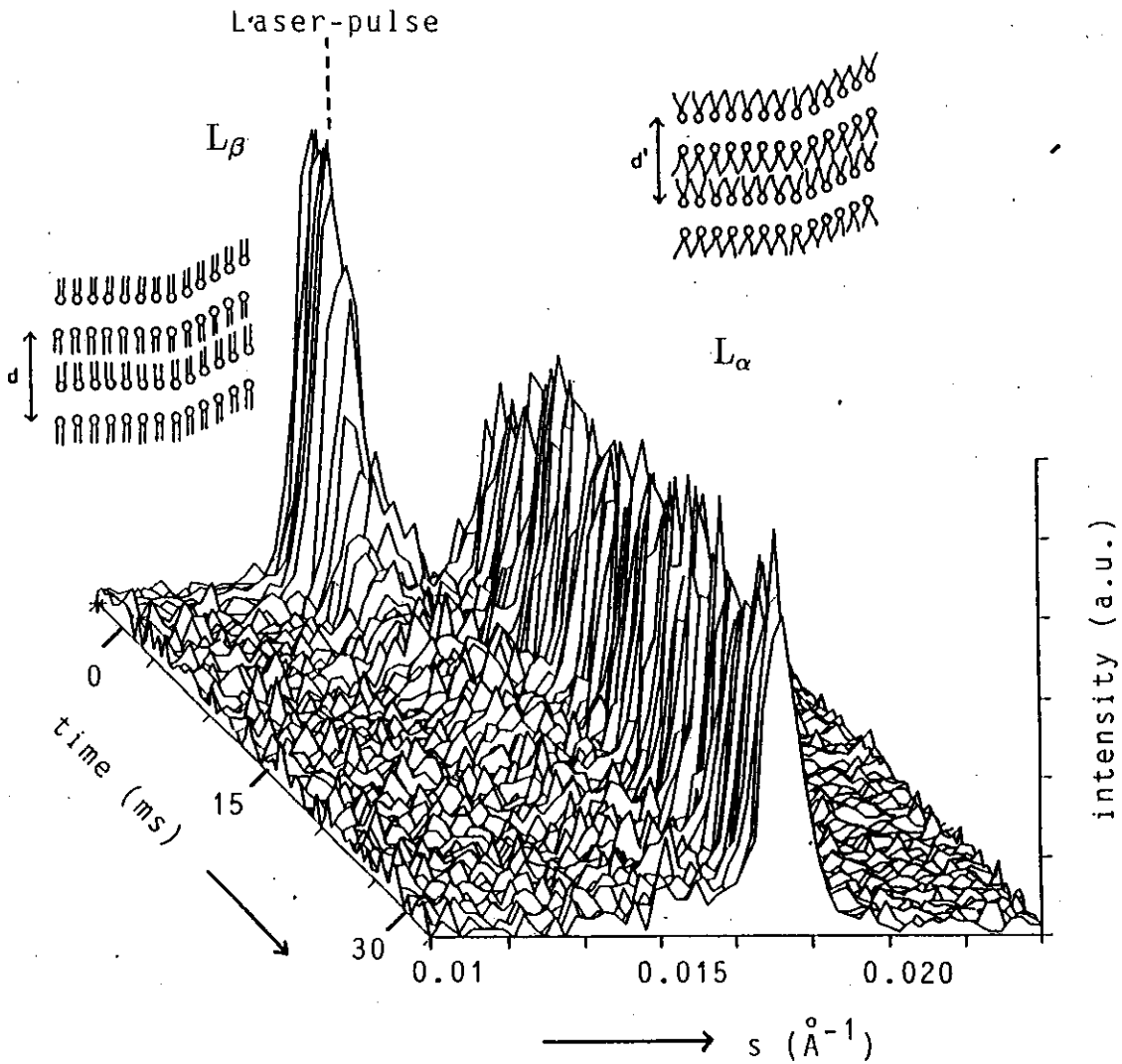
p-Jump SWAX



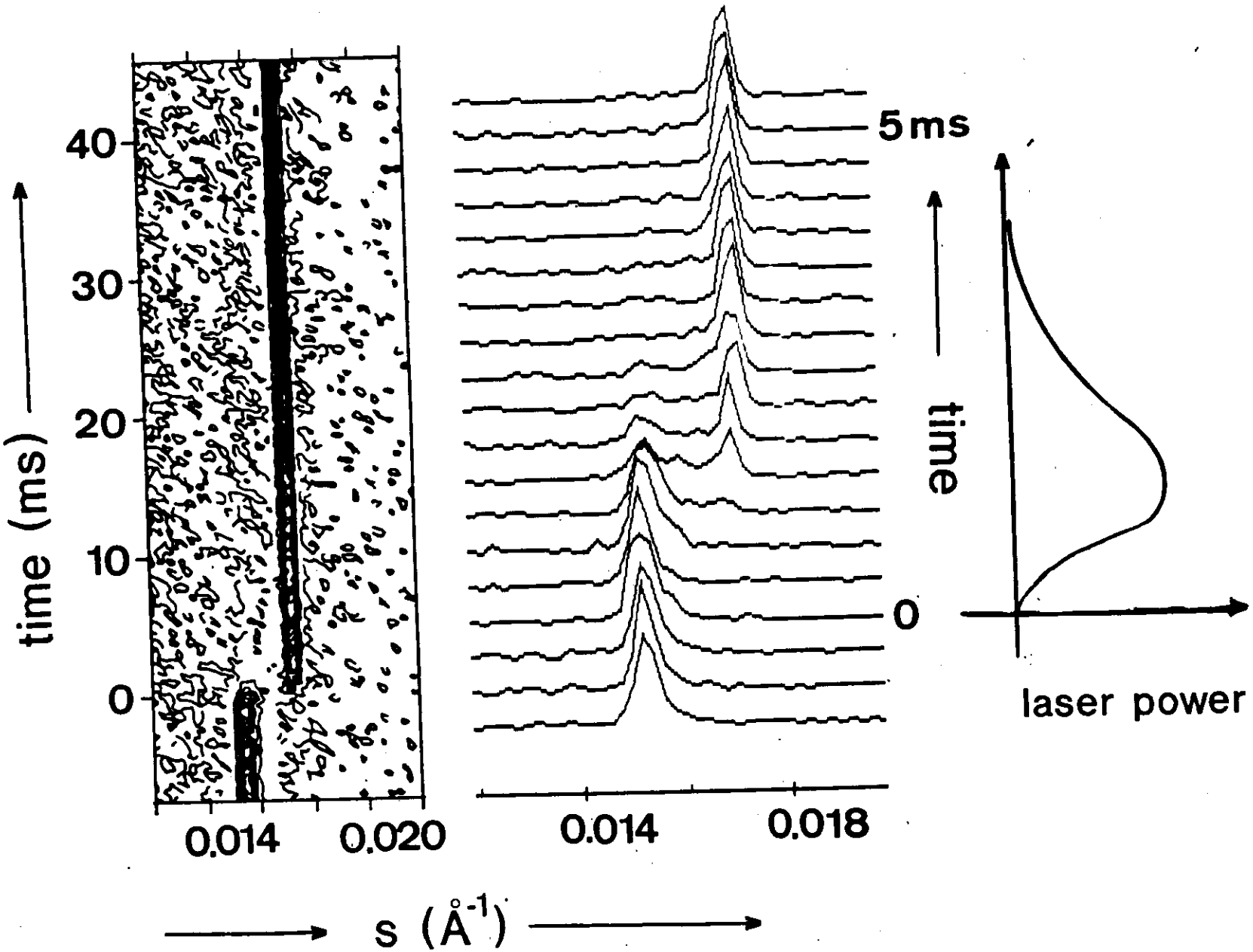
Stopped-Flow SWAX



other triggering techniques, e.g. mechanical, electrical, magnetic, or photonic excitation, are possible


Laser-pulse
L_β
L_α
d
d'
0
15
30
time (ms)
0.01
0.015
0.020
s (Å^{-1})
intensity (a.u.)

POPE


40
30
20
10
0
time (ms)
0.014
0.020
0.014
0.018
5ms
0
time
laser power
s (Å^{-1})

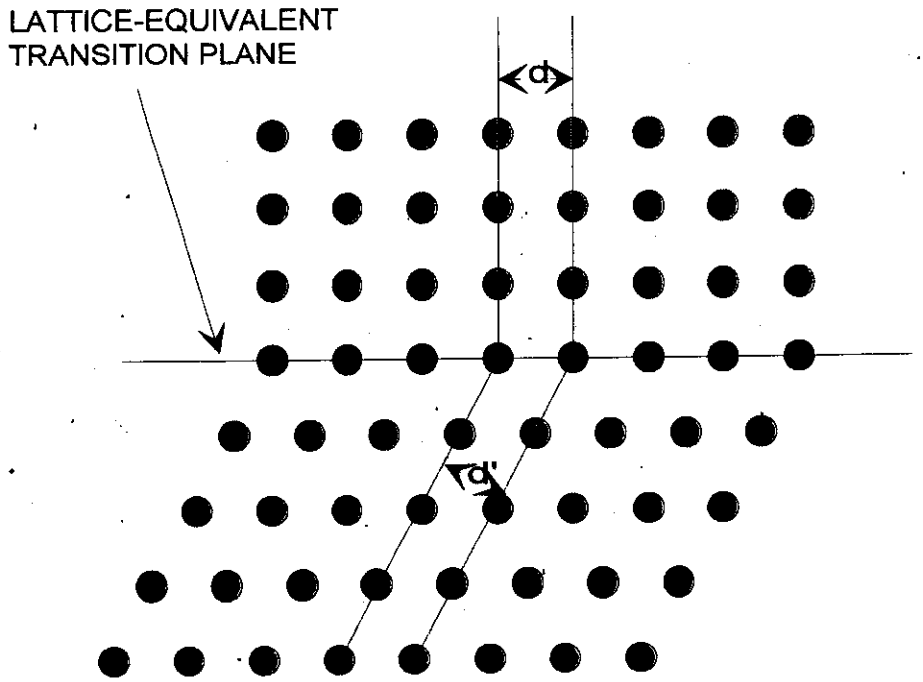
AFFINE TRANSFORMATIONS :

conservation of order

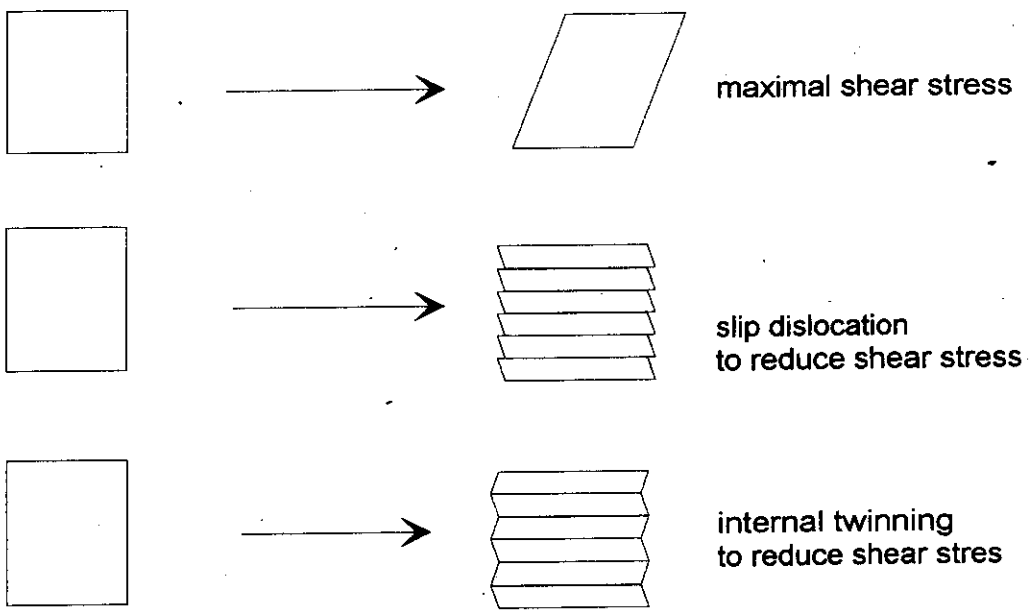
martensitic
"umklapp" - transformations

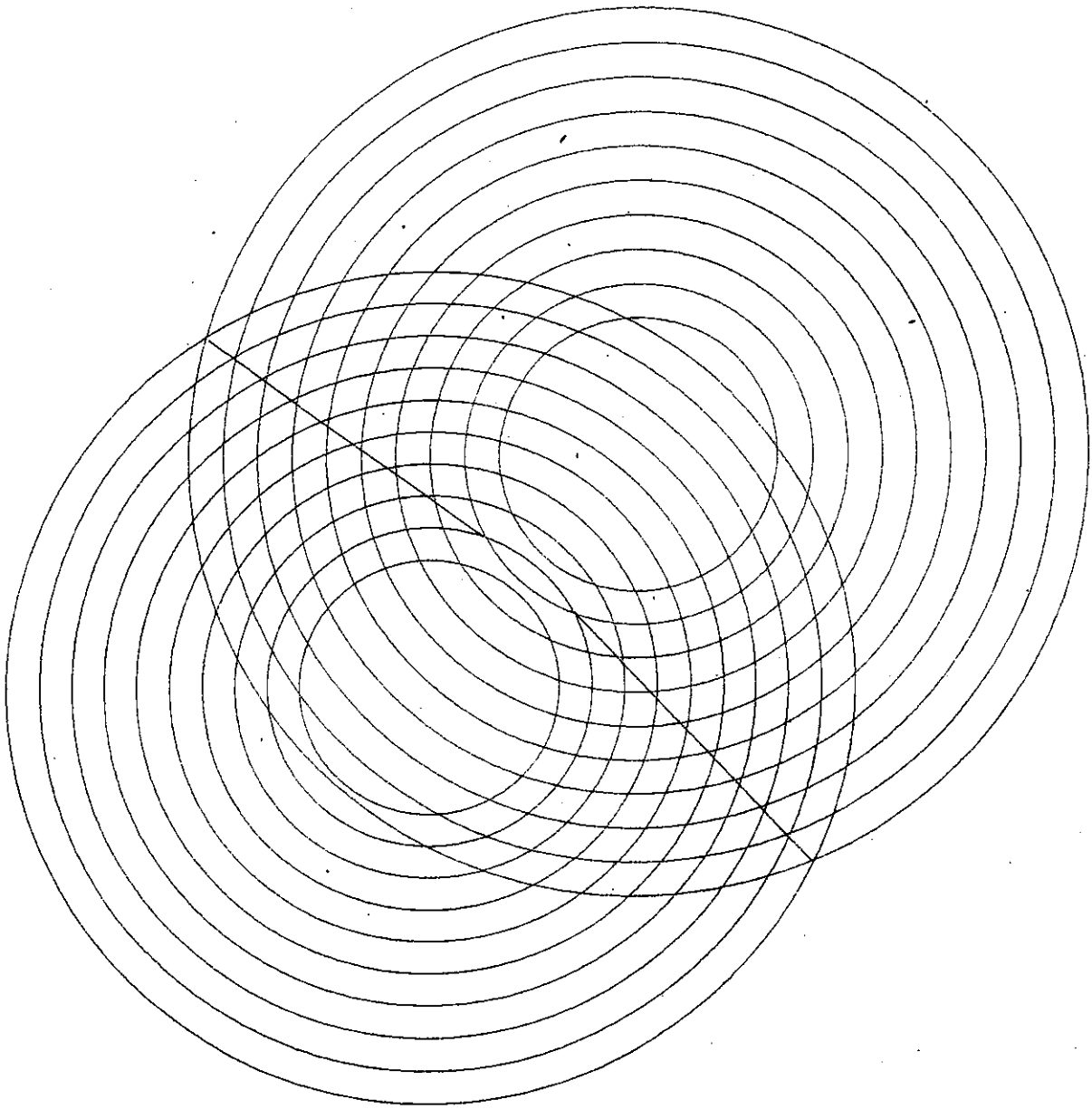
MARTENSITIC LATTICE TRANSFORMATION

LOCAL :

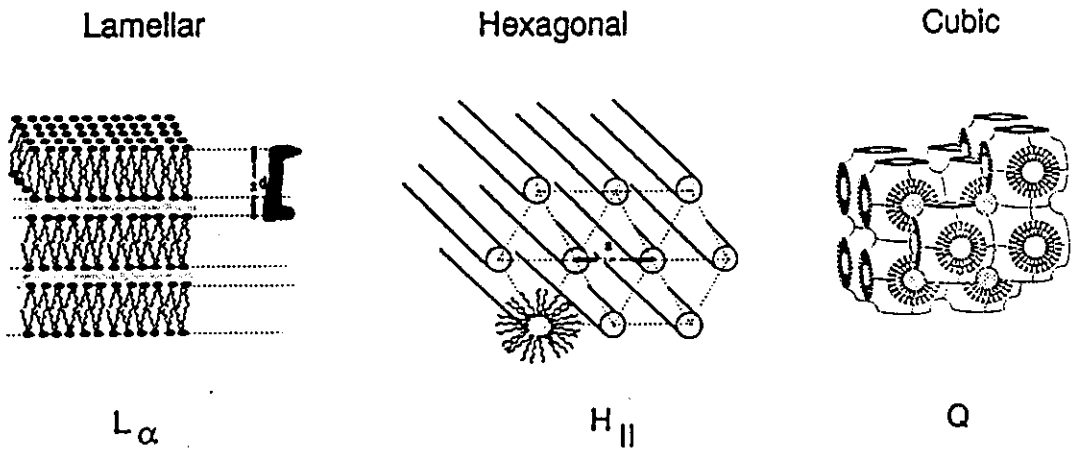


GLOBAL : lattice deformation to relieve shear stress

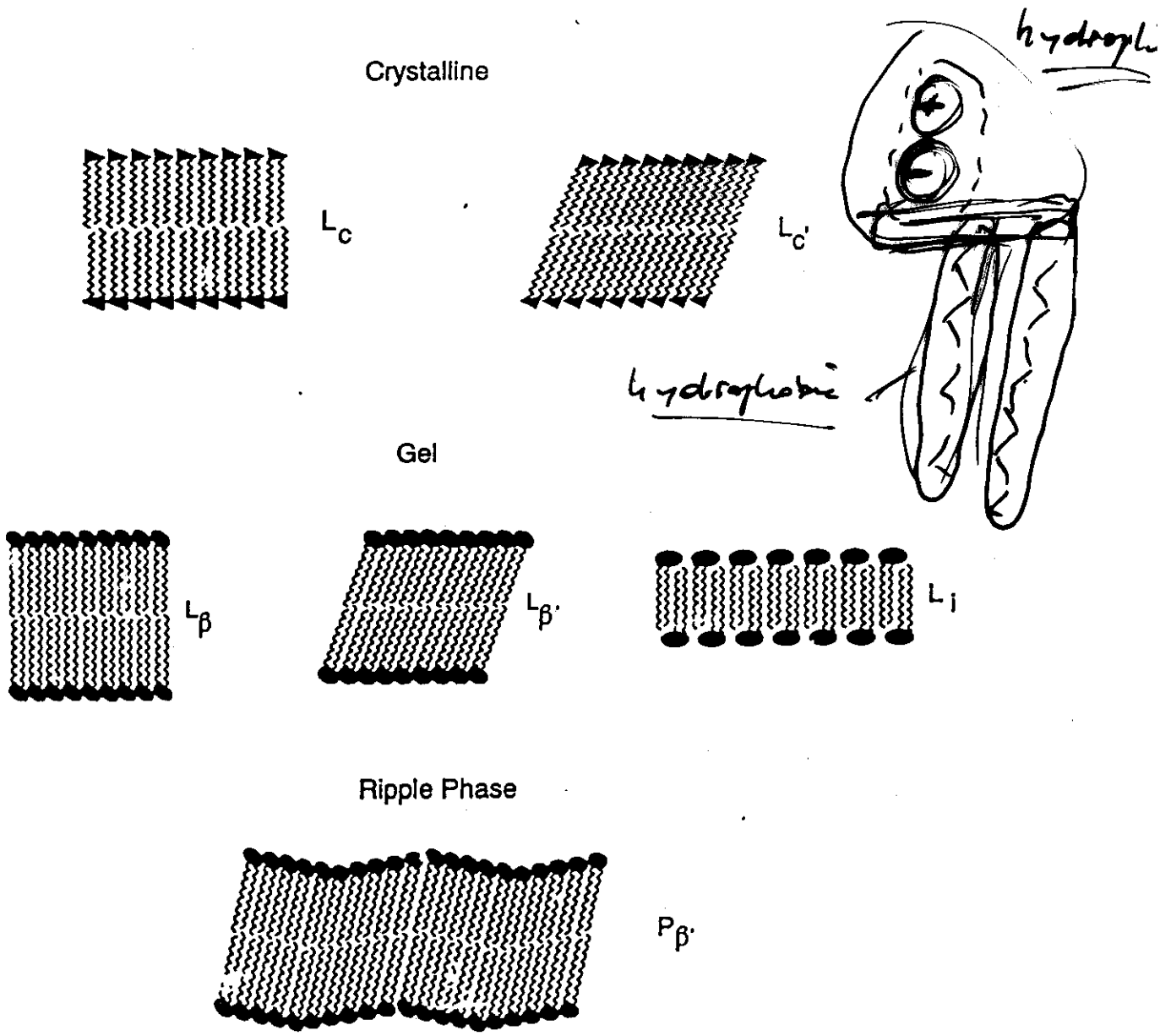


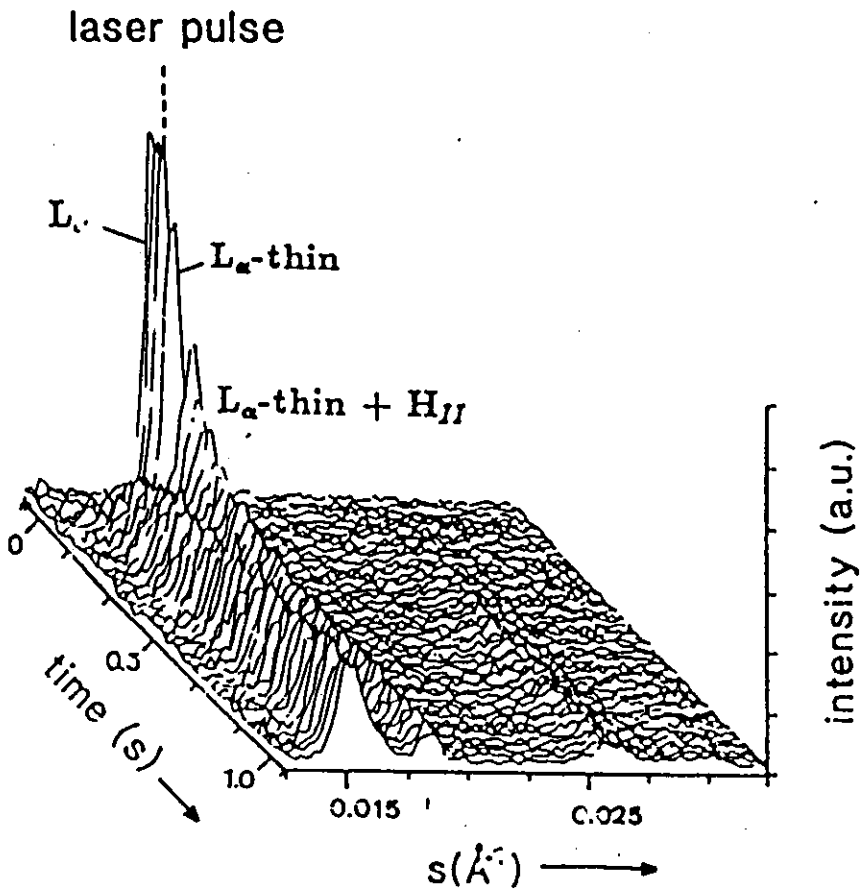


A. CLASSES OF POLYMORPHIC LIPID PHASES

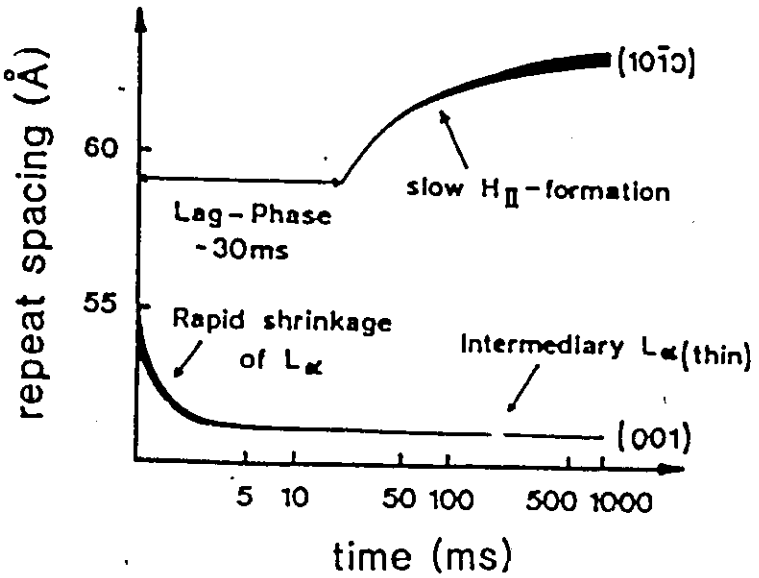


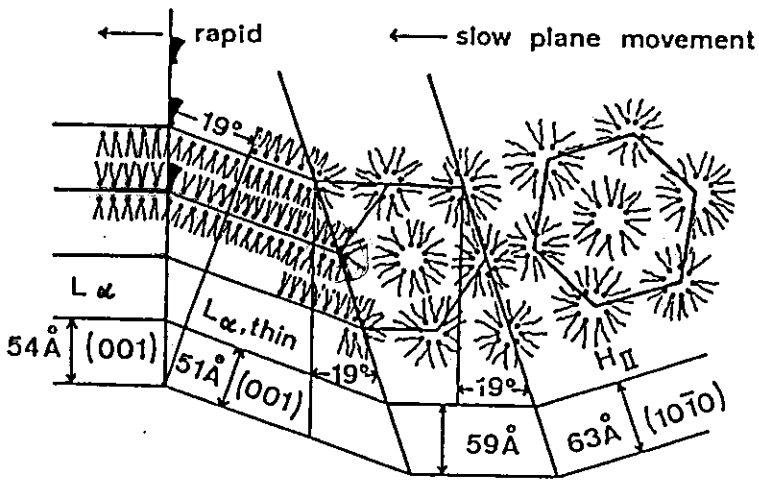
B. SOME FORMS OF LOW-TEMPERATURE LAMELLAR PHASES





BIPHASIC TIME-PATTERN OF $L_\alpha \rightarrow H_{II}$ TRANSITION

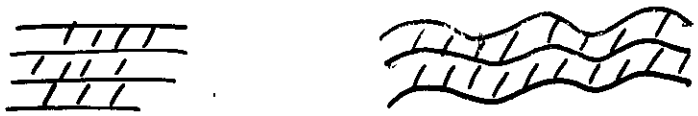




SAXS - APPLICATIONS

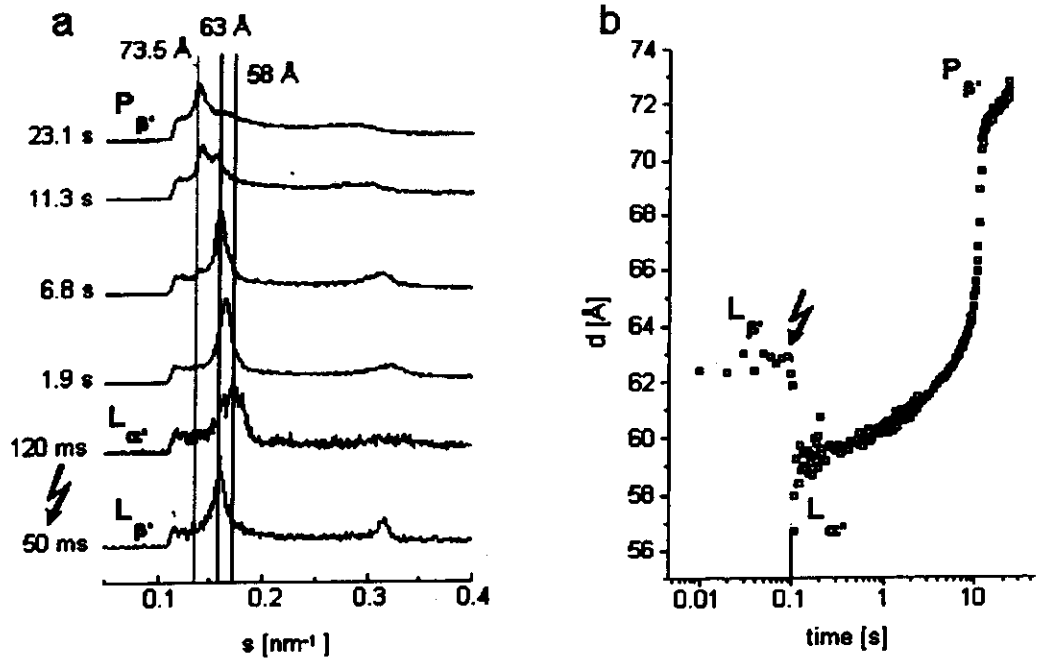
T-jump system

EXAMPLE: T-jump on the pretransition of Lecithin. (a) Extract of typical diffraction pattern and (b) time course of mean d-spacing.
G. Pabst, H. Amenitsch, S. Bernstorff,C. Krenn, M. Rappolt & P. Laggner



Near equilibrium: $L_{\beta'} \Rightarrow P_{\beta'}$ (rippled gel-phase)

Non-equilibrium: $L_{\beta'} \Rightarrow (L_{\beta'} + L_{\alpha^*}) \Rightarrow P_{\beta'}$

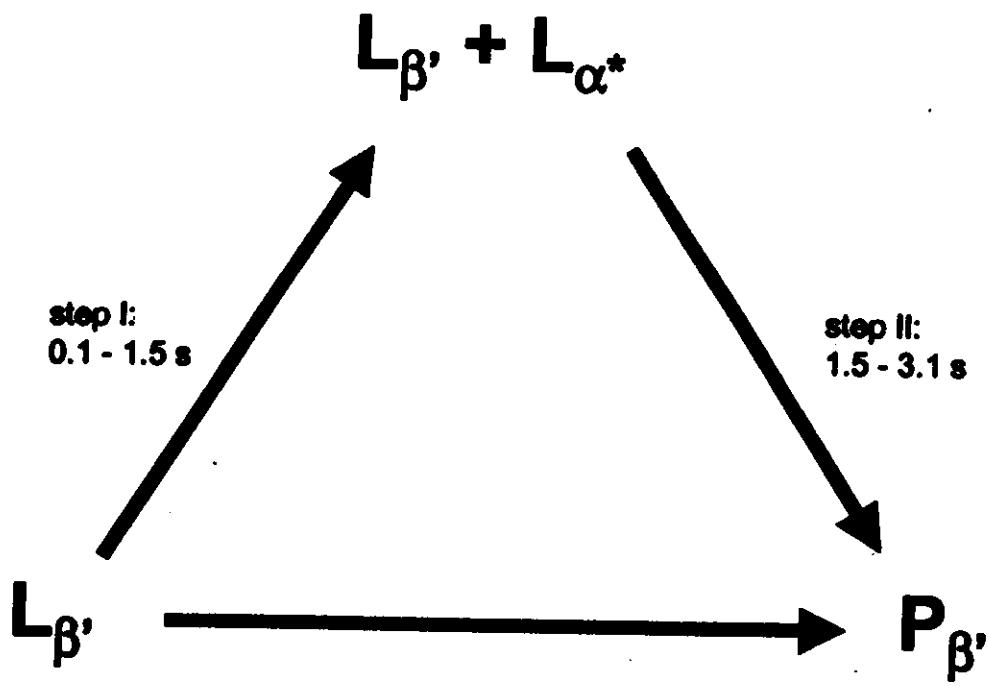


AUSTRIAN SAXS - BEAMLINE AT ELETTRA
H. Amenitsch, S. Bernstorff, P. Dubcek,
R. Menk, G. Pabst, M. Rappolt & P. Laggner

THE PRETRANSITION OF DPPC DURING A T-JUMP

The formation of an intermediate

Jump-Relaxation
heat rate > 5 °C/ms



Near-Equilibrium
heat rate < 0.1 °C/min

NONAFFINE TRANSFORMATIONS

ordered intermediate states form

topological links

(if the system is pushed far away from equilibrium)