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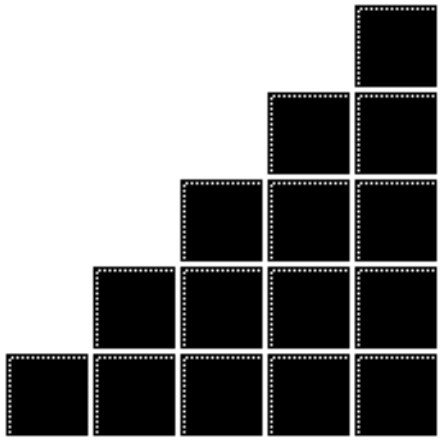
CENTER FOR FEMTOSECOND RESEARCH AND TECHNOLOGY AT HARVARD UNIVERSITY

Eric Mazur
Harvard University

Tokyo
13 March 1995



❶ Research

❷ Facilities

❸ Plans

RESEARCH AREAS

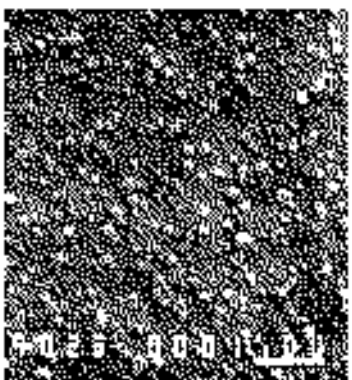
❶ semiconductors

❷ reactions at metal surfaces

❸ monolayers at liquid surfaces

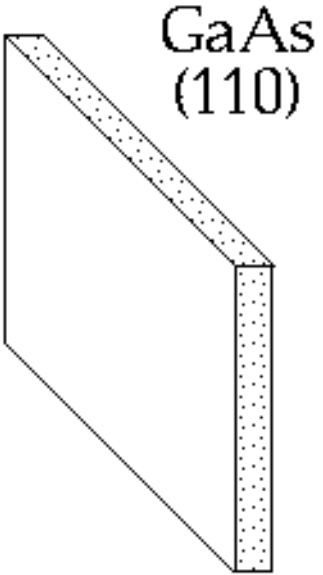
SEMICONDUCTORS

Effect of femtosecond pulses on

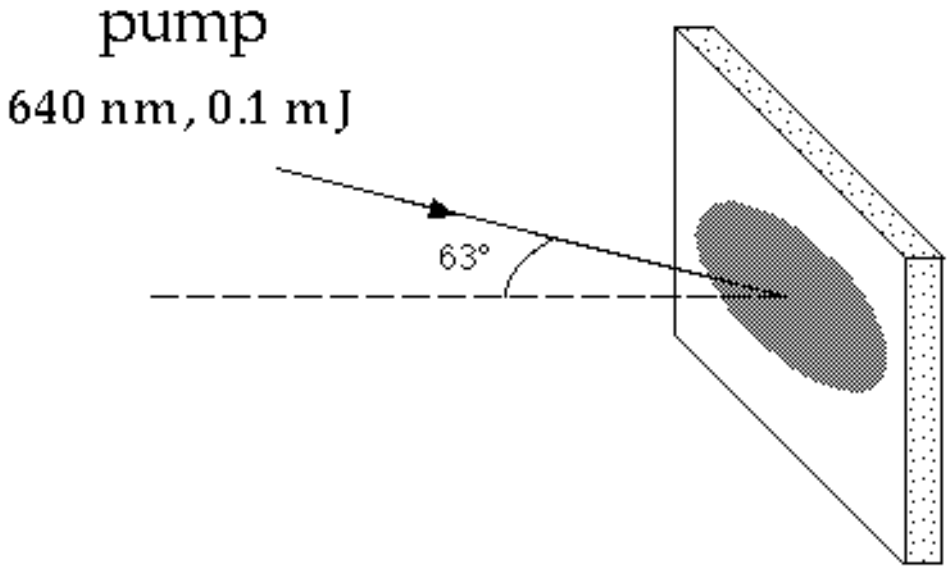


SEM picture of GaAs after femtosecond laser irradiation

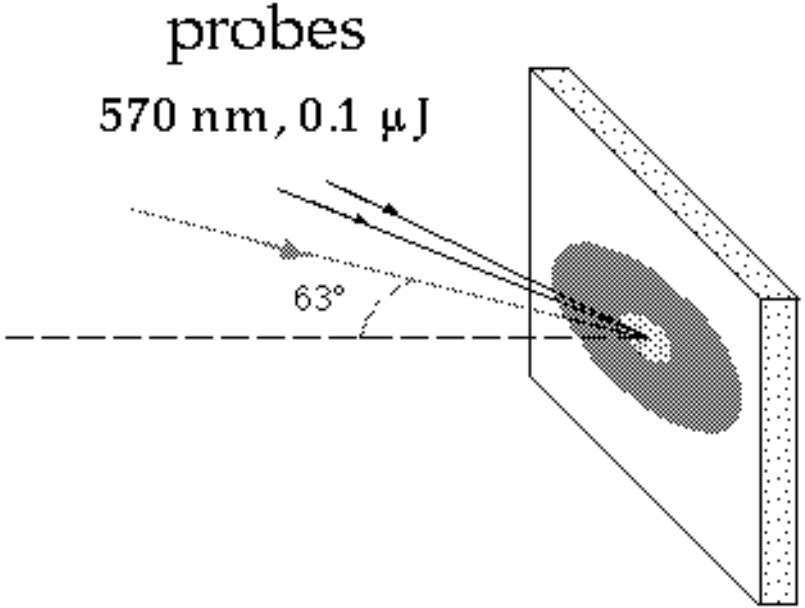
- electronic properties
- material properties


GaAs
(110)

SEMICONDUCTORS

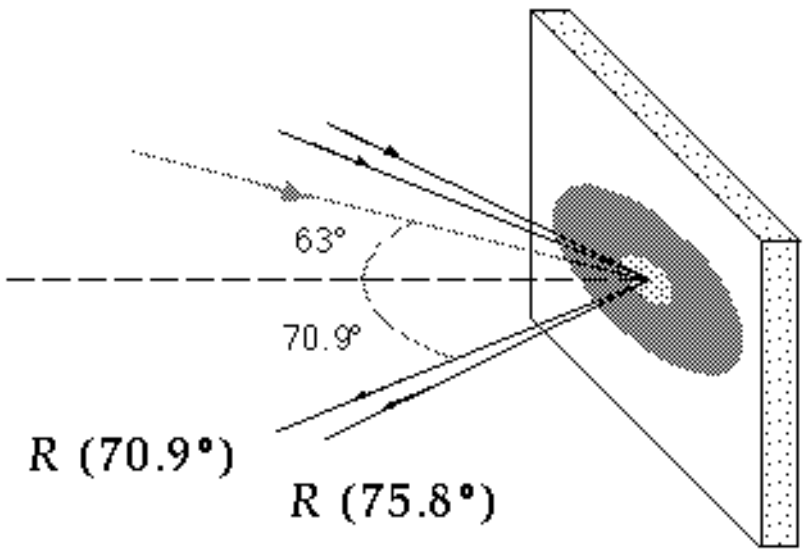


SEMICONDUCTORS



all beams
70 fs, *p*-pol

SEMICONDUCTORS



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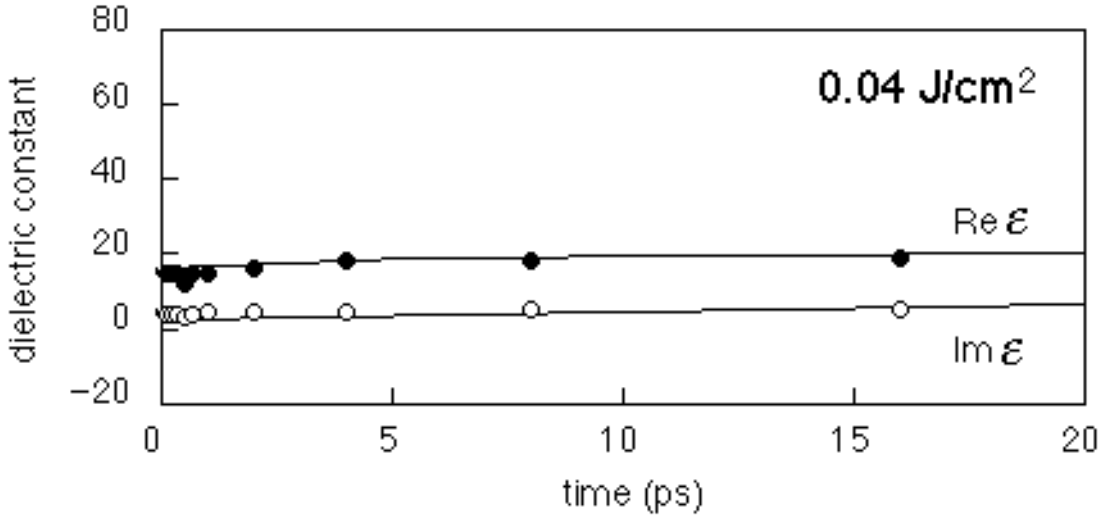
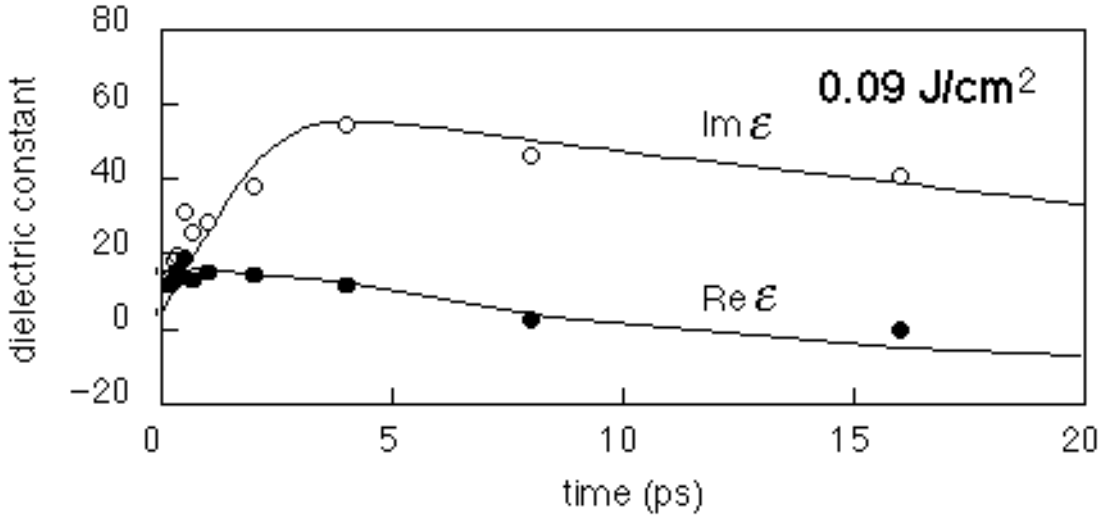


E. Glezer, Y, Siegal, L. Huang, E. Mazur, Phys. Rev. B, March 15 (1995)

SEMICONDUCTORS



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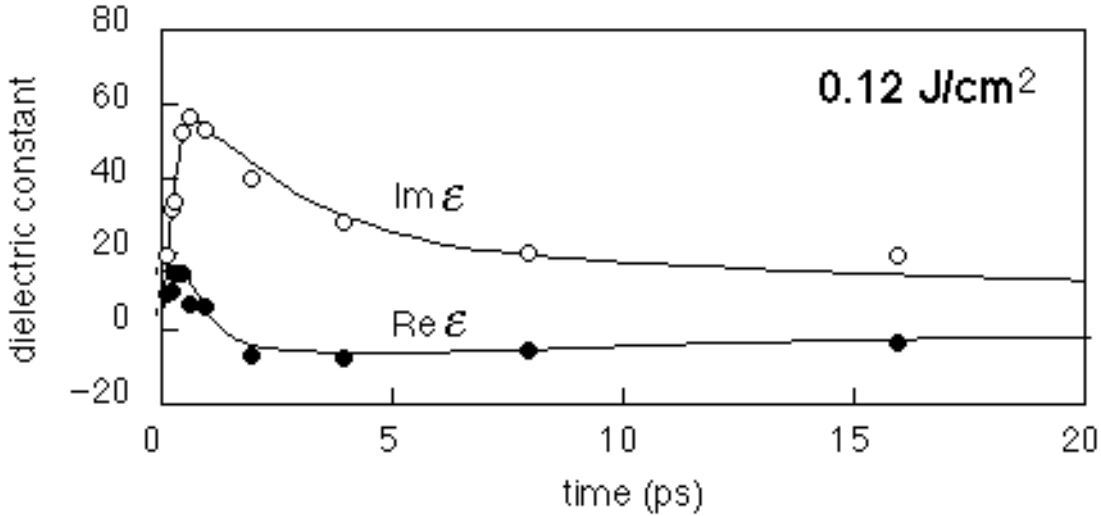

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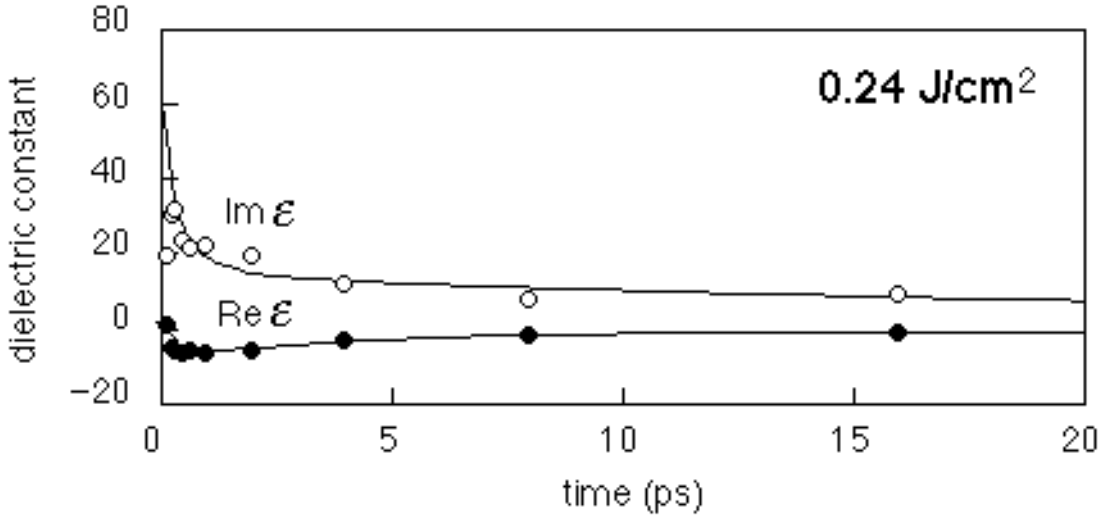

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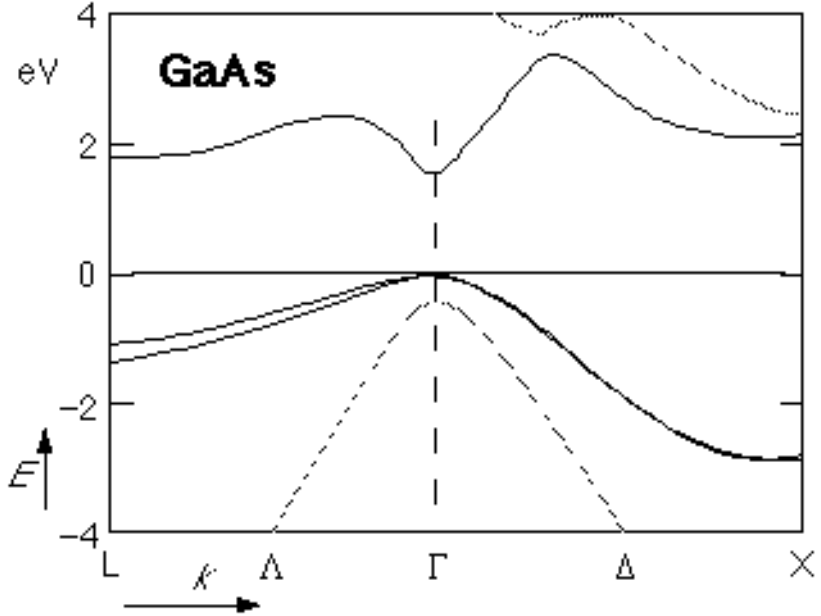

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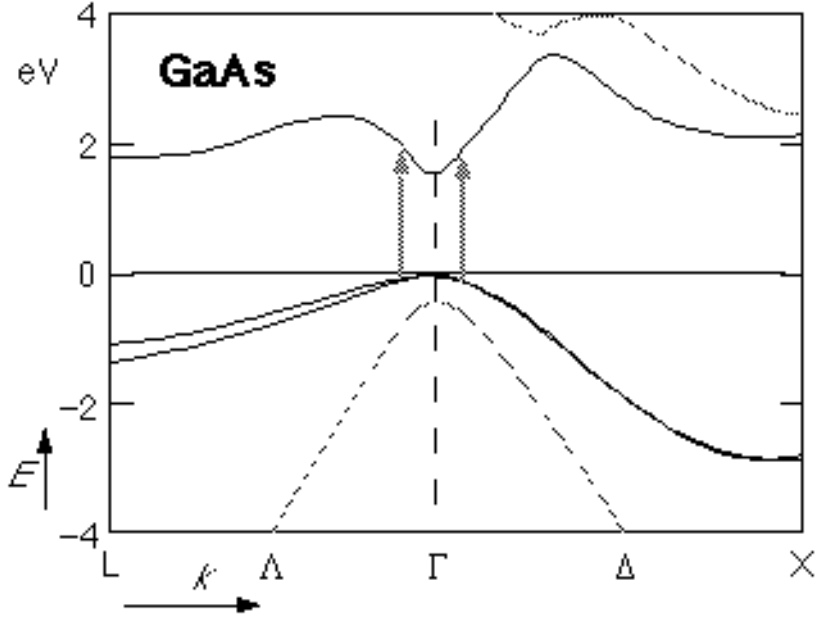
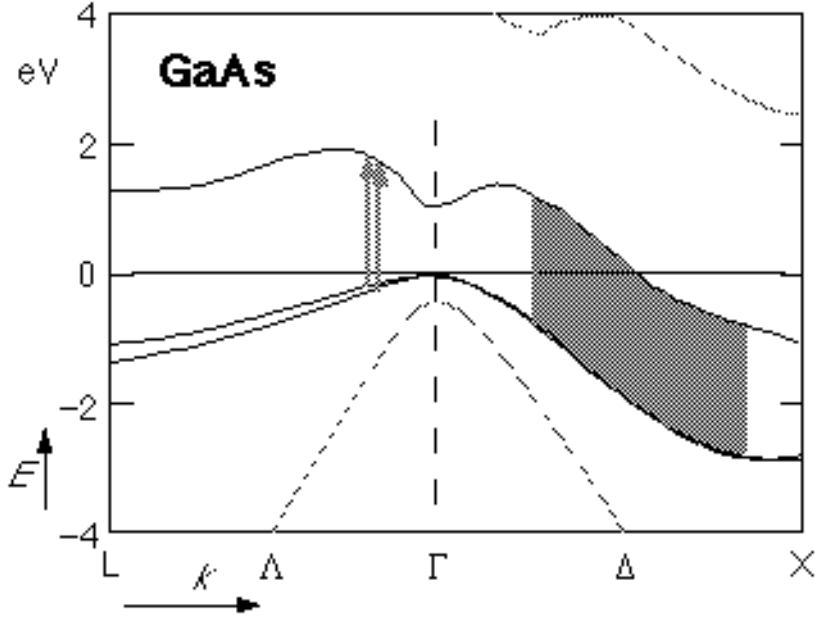
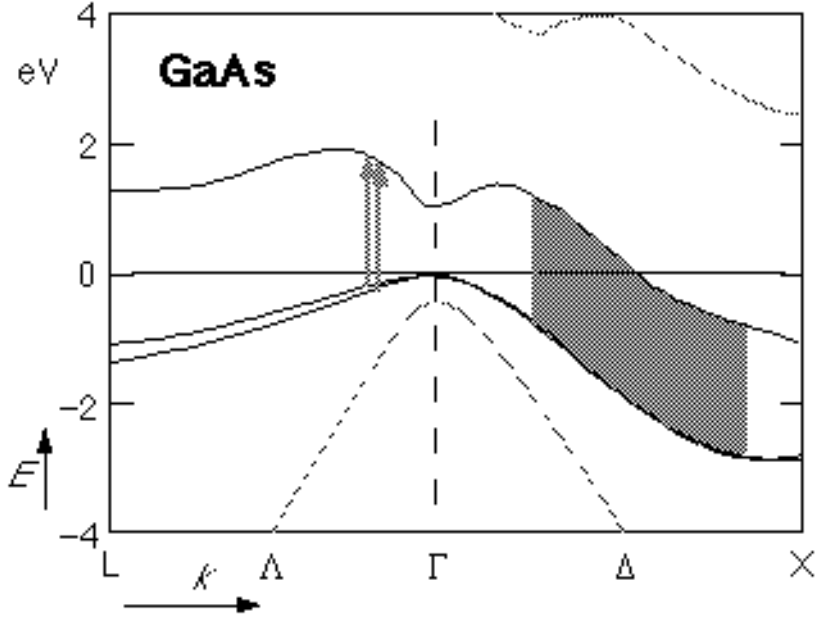


SEMICONDUCTORS



SEMICONDUCTORS



SEMICONDUCTORS

- ultrafast structural phase transition
- large changes in electronic properties

RESEARCH AREAS

❶ semiconductors

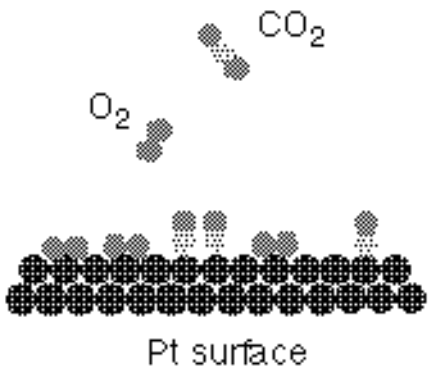
❷ reactions at metal surfaces

❸ monolayers at liquid surfaces

REACTIONS AT METAL SURFACES

Control molecular processes

- catalysis
- microelectronics
- new materials



Atomically clean platinum surface (90 K)

Pt surface

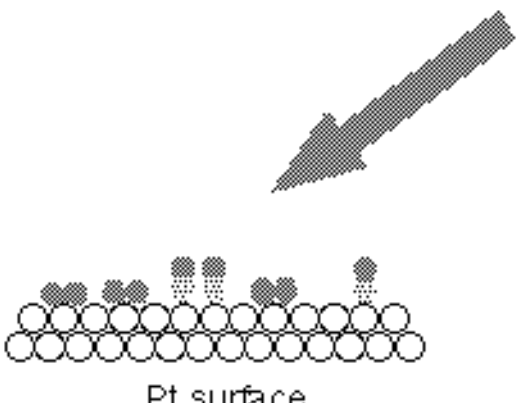
REACTIONS AT METAL SURFACES

Dose with O_2 and CO

Pt surface

REACTIONS AT METAL SURFACES

Excite substrate with
femtosecond laser pulse

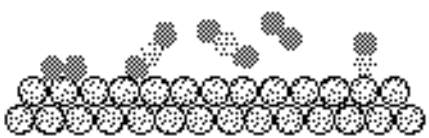


REACTIONS AT METAL SURFACES

Excited electrons initiate reactions:

O_2 desorption

$2CO + O_2 \rightarrow 2CO_2$

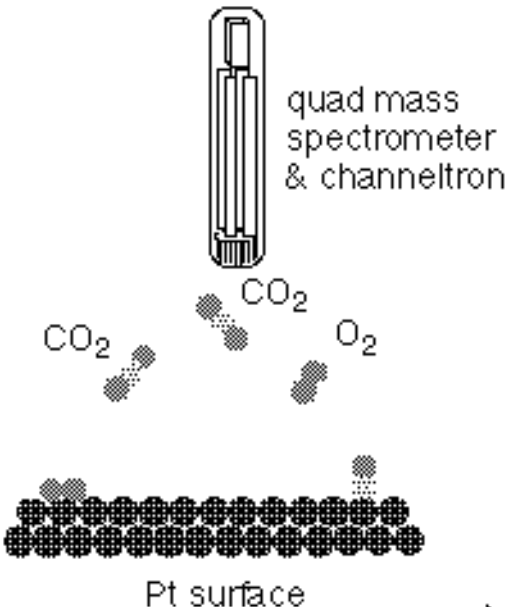


Pt surface

REACTIONS AT METAL SURFACES

Detect products:

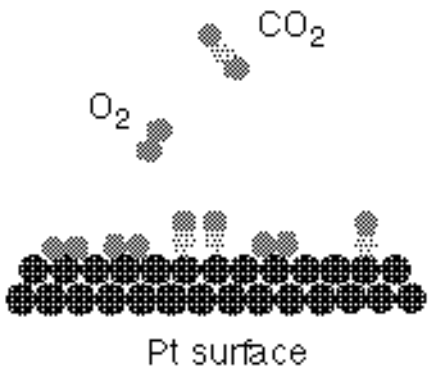
- mass spectrometer
- optically



REACTIONS AT METAL SURFACES

Control molecular processes

- catalysis
- microelectronics
- new materials



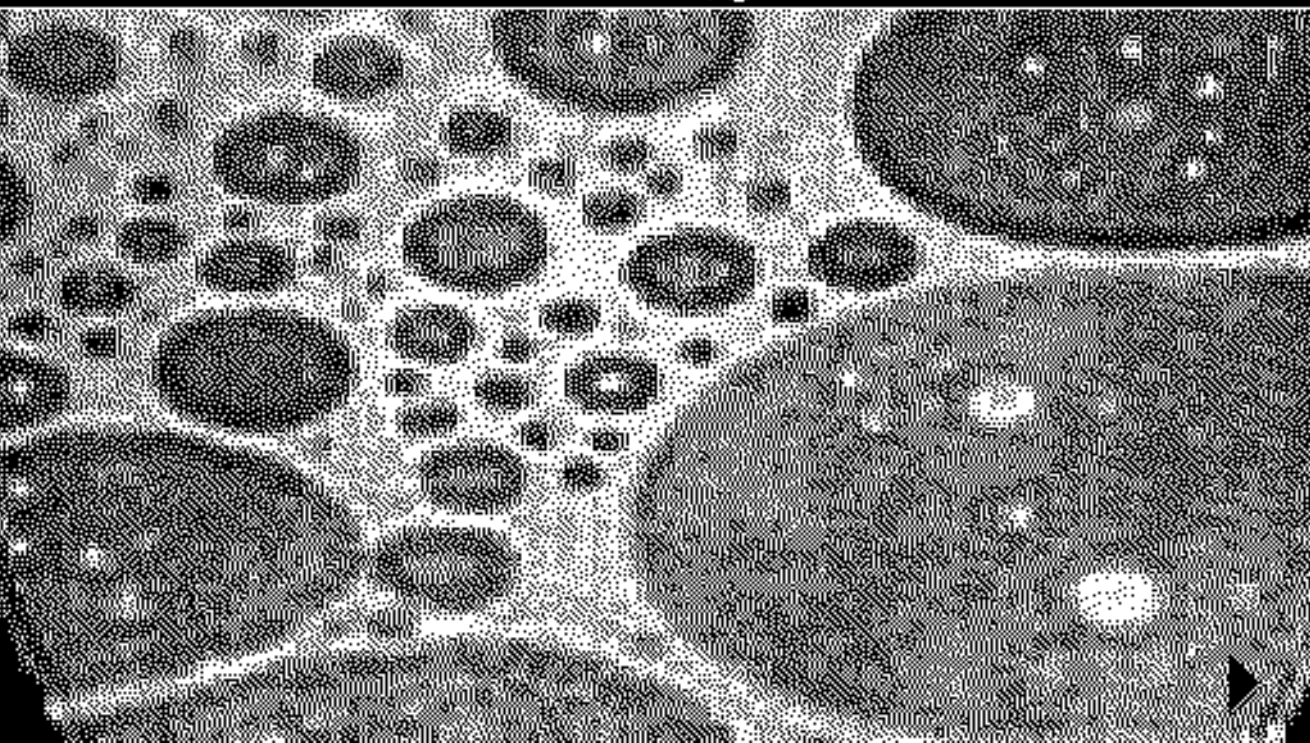
RESEARCH AREAS

❶ semiconductors

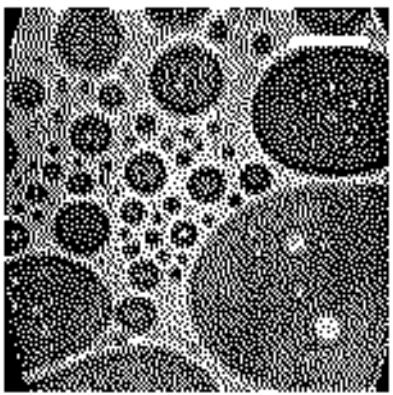
❷ reactions at metal surfaces

❸ monolayers at liquid surfaces

MONOLAYERS AT LIQUID SURFACES



MONOLAYERS AT LIQUID SURFACES



Pentadecanoic acid monolayer
on water

- industrial technology
- physics
- biology

MONOLAYERS AT LIQUID SURFACES

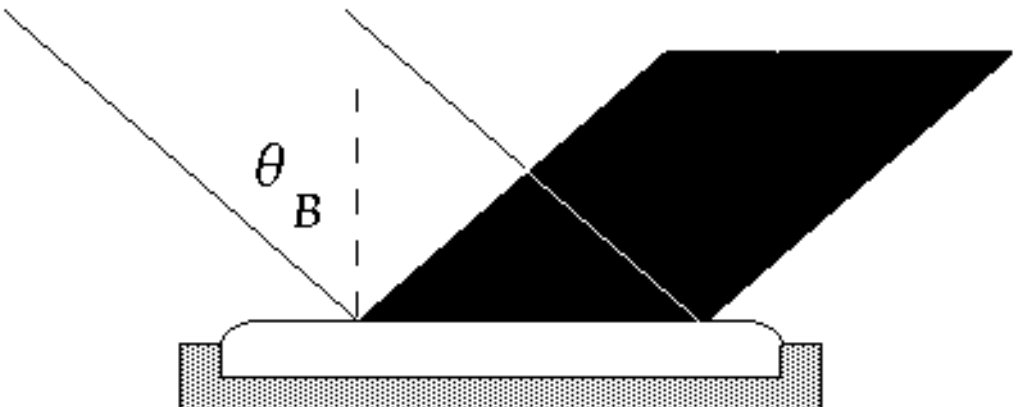
- heterodyne light scattering
- Brewster angle microscopy
- surface second harmonic generation

BREWSTER ANGLE MICROSCOPY

clean water surface

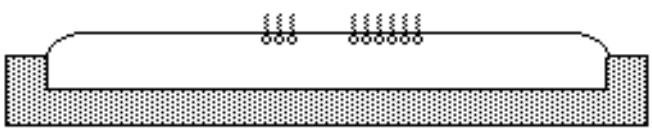
BREWSTER ANGLE MICROSCOPY

no reflection at Brewster angle



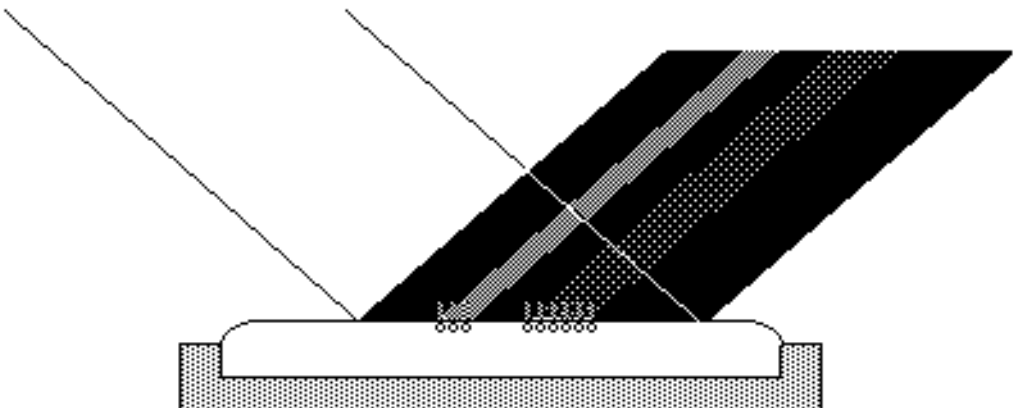
BREWSTER ANGLE MICROSCOPY

Add surfactant monolayer

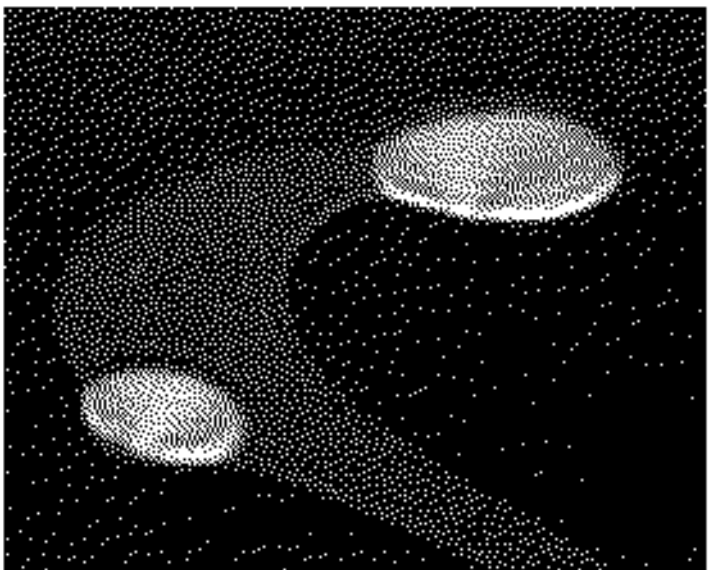


BREWSTER ANGLE MICROSCOPY

reflection due to changes in index

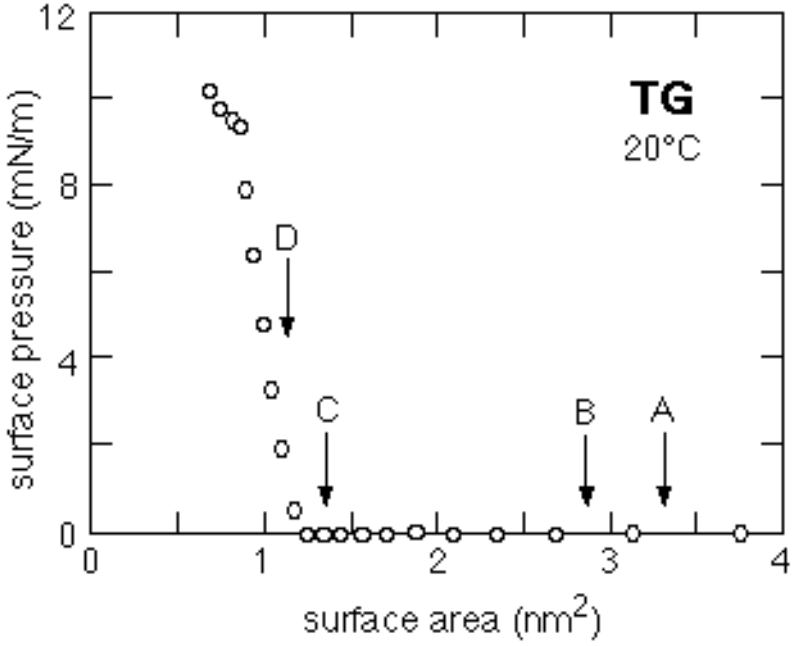


BREWSTER ANGLE MICROSCOPY

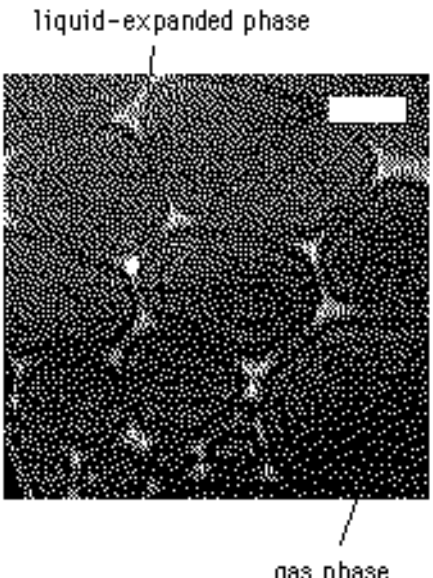


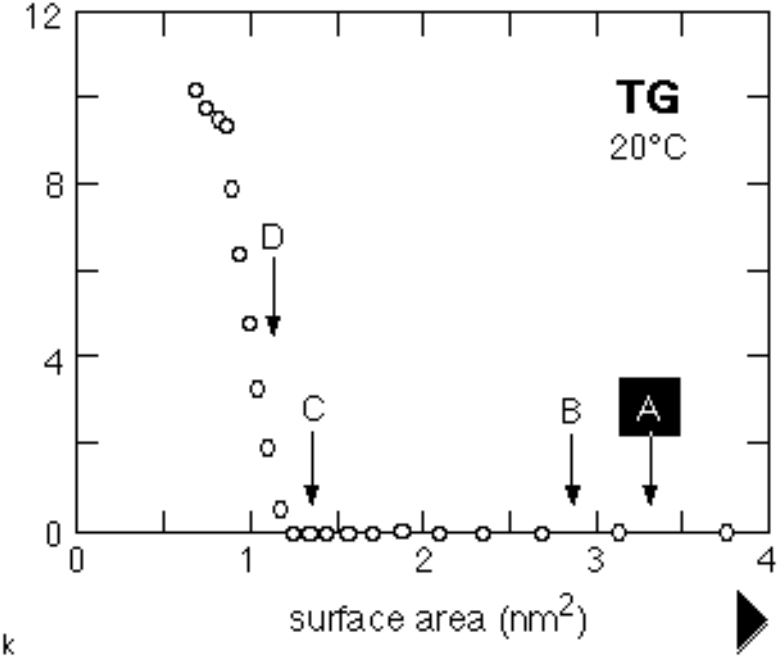
BREWSTER ANGLE MICROSCOPY

isotherm



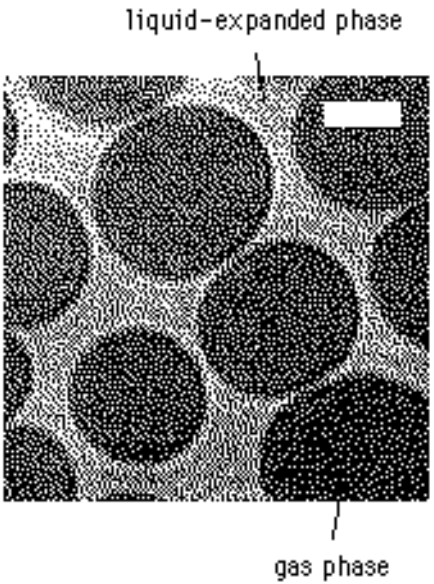
BREWSTER ANGLE MICROSCOPY

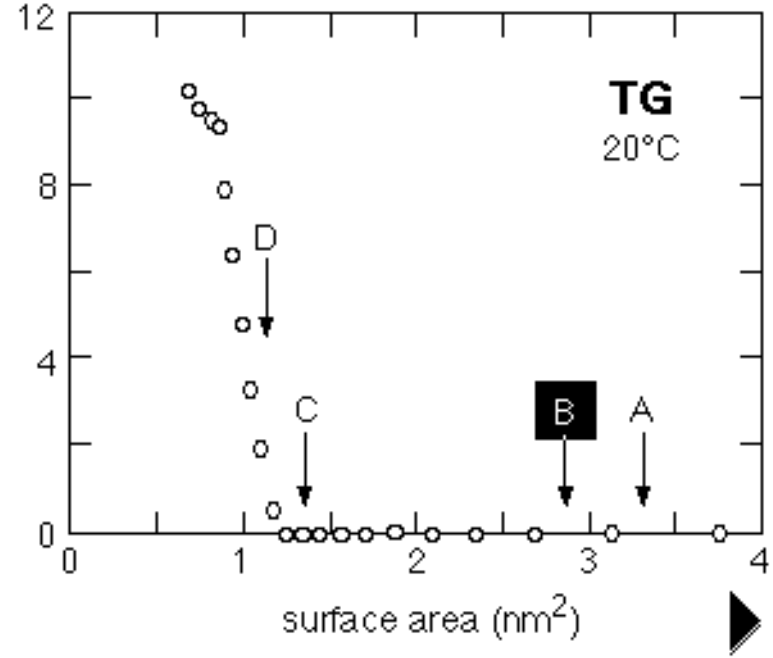




reference to our own work

BREWSTER ANGLE MICROSCOPY





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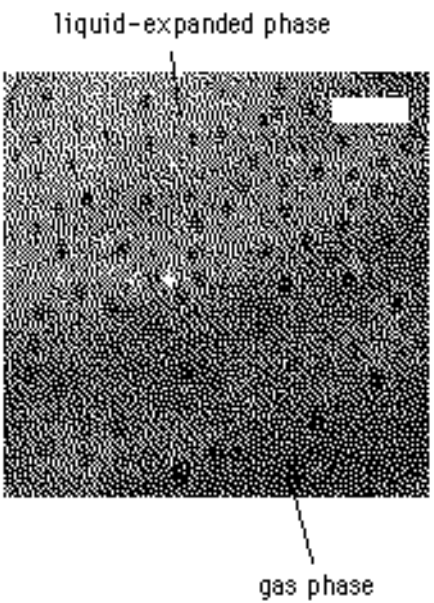
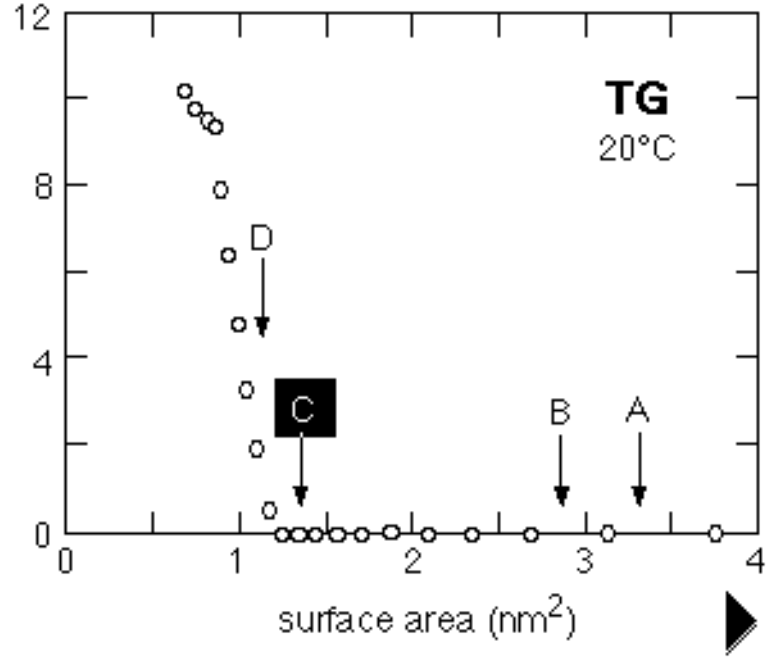
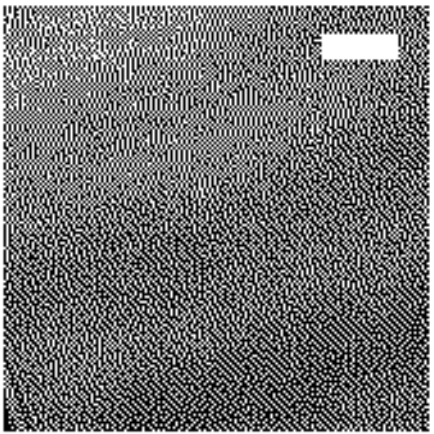
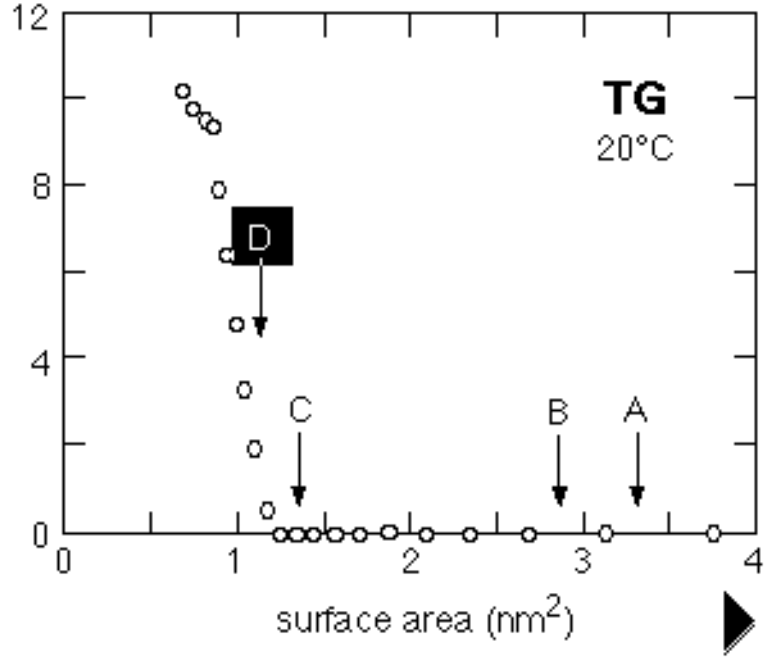




BREWSTER ANGLE MICROSCOPY

all liquid-expanded phase





RESEARCH AREAS

❶ semiconductors

❷ reactions at metal surfaces

❸ monolayers at liquid surfaces

RELEVANCE TO MACHINING

Knowledge of the dynamics of

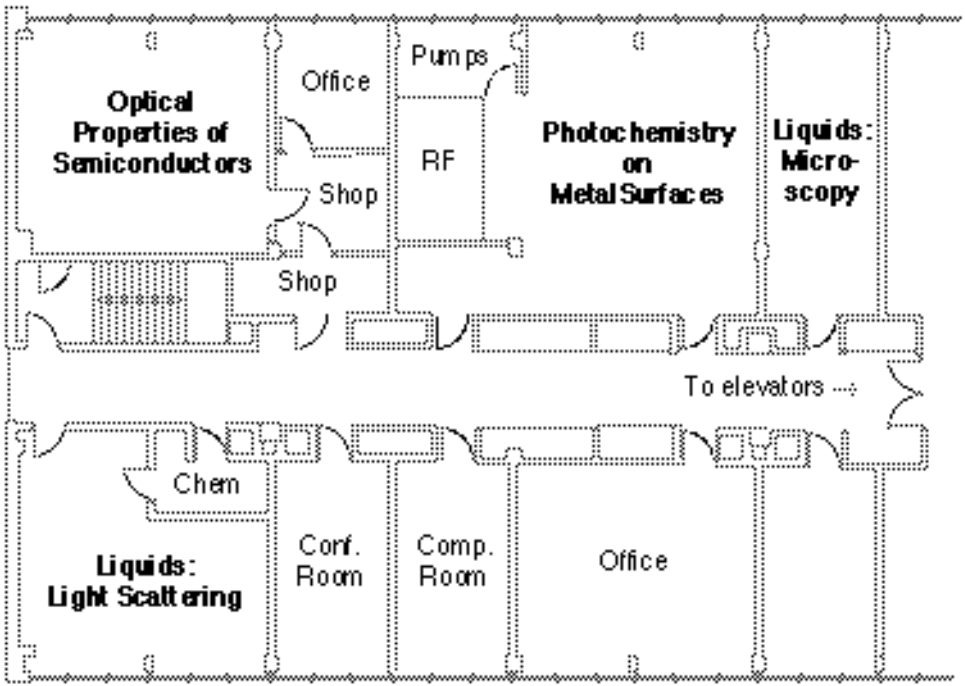
- nonequilibrium lattice/electrons
- plasma effects
- lattice and surface bonding
- photoinduced reactions

❶ Research

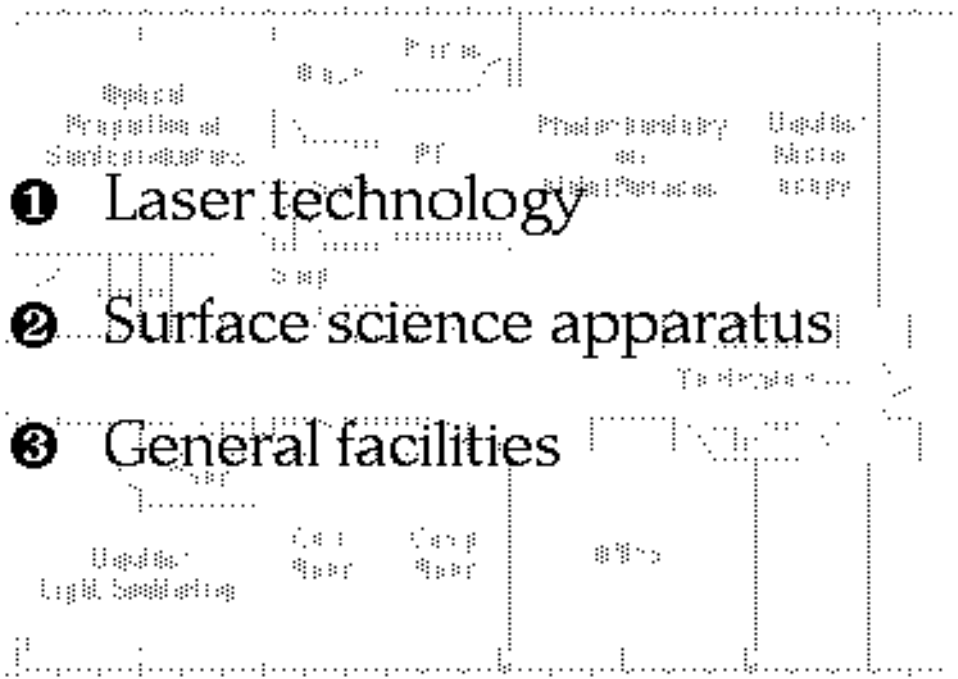
❷ Facilities

❸ Plans

FACILITIES


Optical Properties of Semiconductors
Office
Shop
Shop
Pumps
RF
Photochemistry on Metal Surfaces
Liquids: Micro-scopy
To elevators
Chem
Liquids: Light Scattering
Conf. Room
Comp. Room
Office

FACILITIES



❶ Laser technology

❷ Surface science apparatus

❸ General facilities

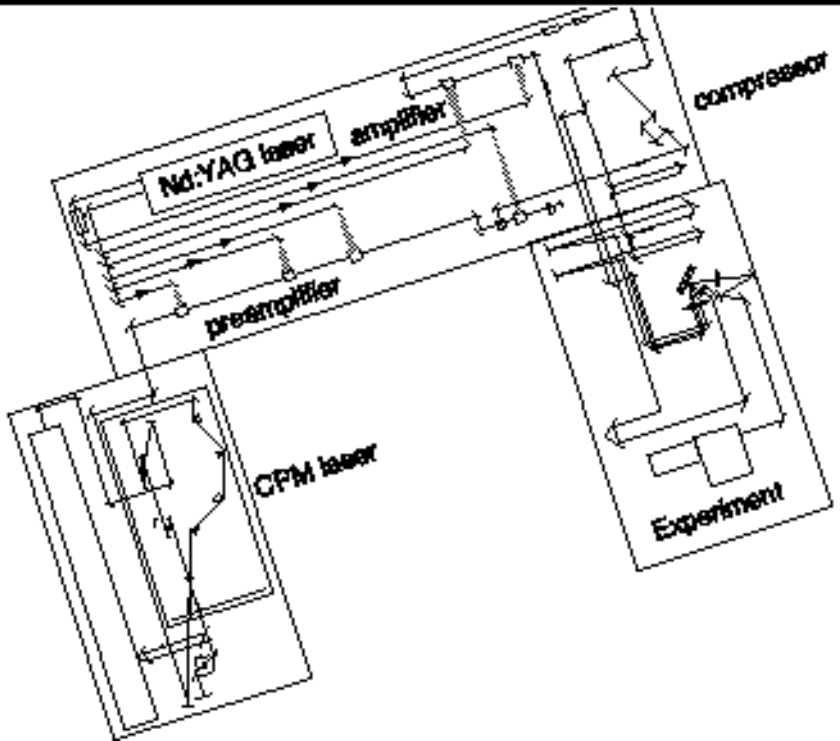
LASER TECHNOLOGY

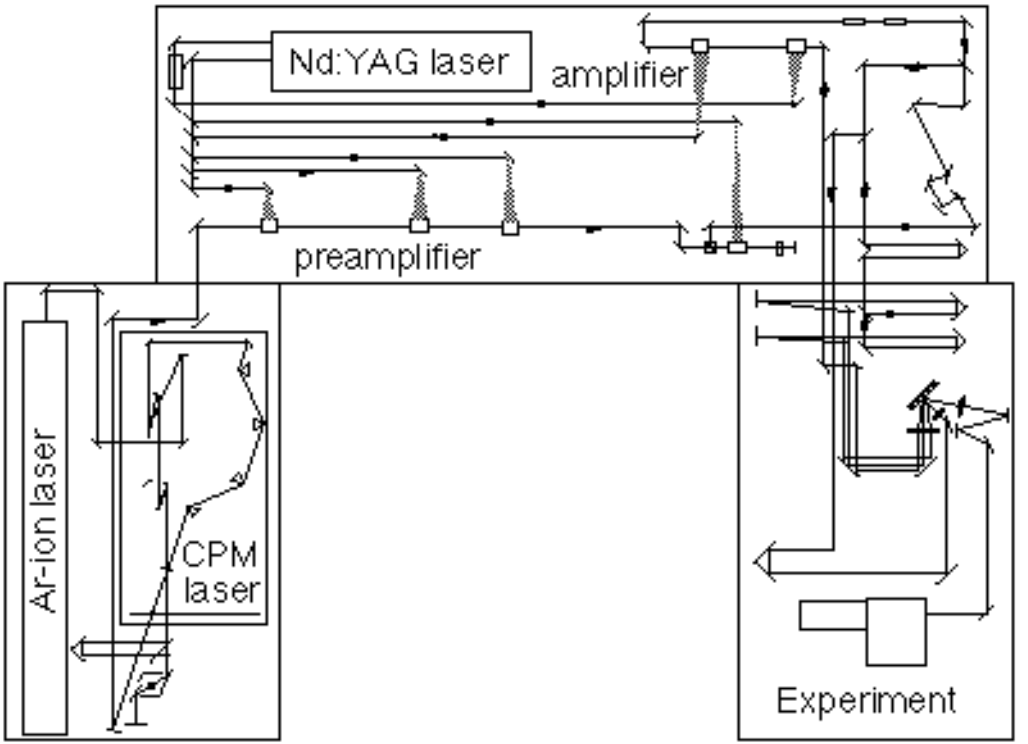
❶ CPM femtosecond facility

❷ Ti:Sap femtosecond facility

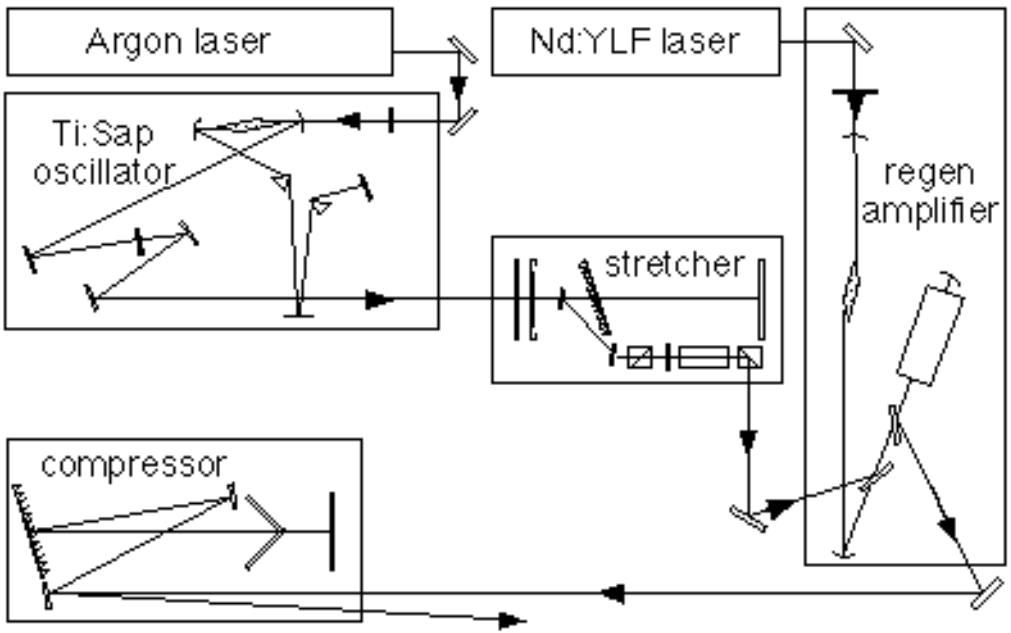
❸ other...

CPM FEMTOSECOND LASER FACILITY



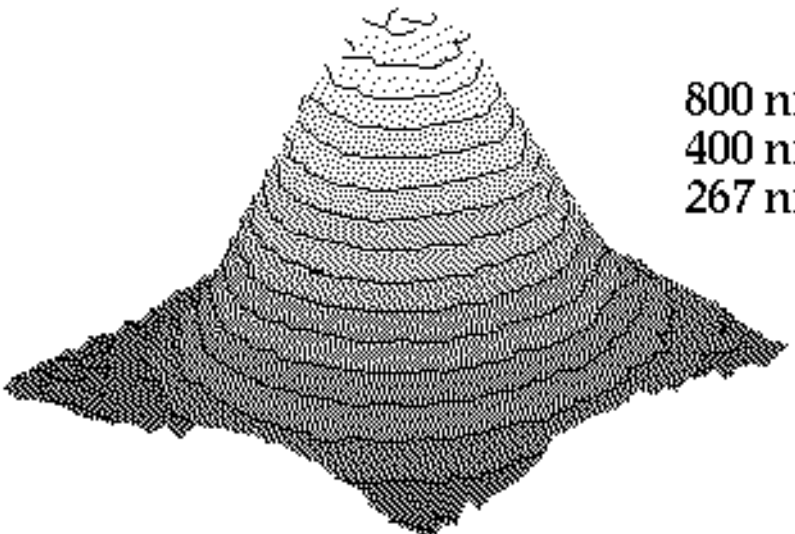

Nd:YAG laser
amplifier
preamplifier
Ar-ion laser
CPM
laser
Experiment

Ti:Sap FEMTOSECOND LASER FACILITY



Ti:Sap FEMTOSECOND LASER FACILITY

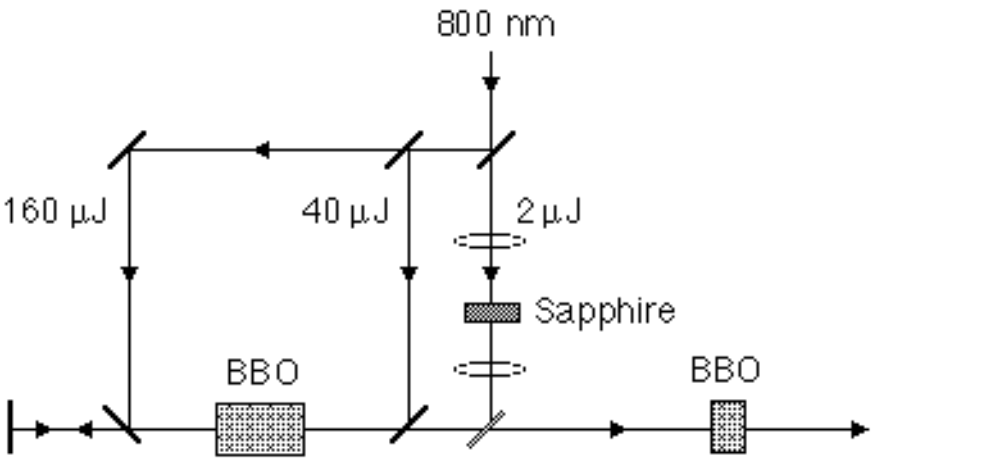
Pure Gaussian profile



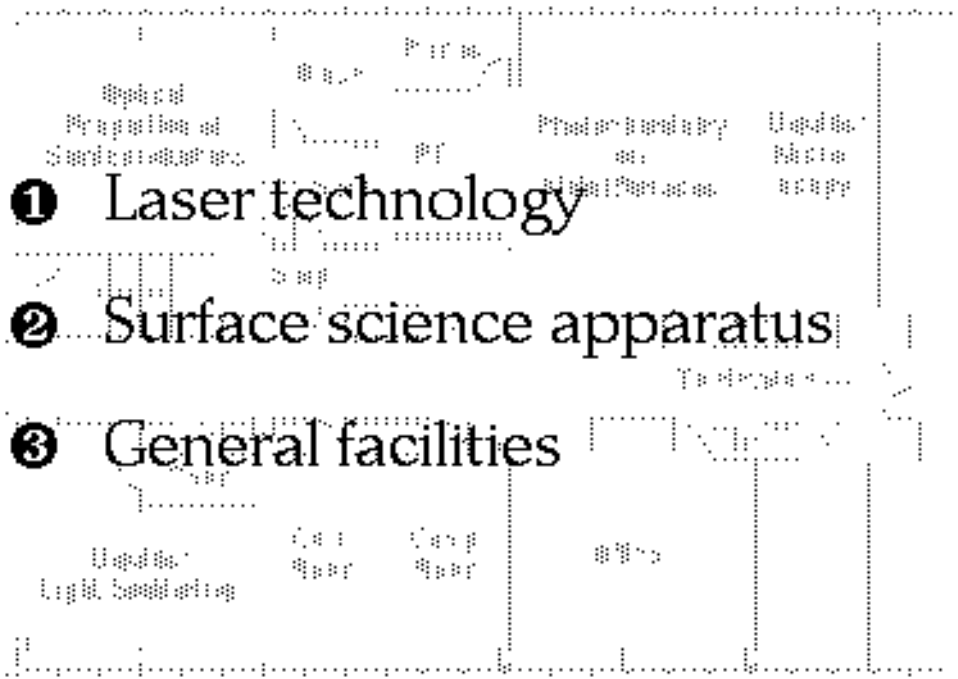
1 kHz
800 nm: 70 fs, 500 μJ
400 nm: 200 fs, 100 μJ
267 nm: 250 fs, 15 μJ

Ti:Sap FEMTOSECOND LASER FACILITY

Optical Parametric Amplifier



FACILITIES



❶ Laser technology

❷ Surface science apparatus

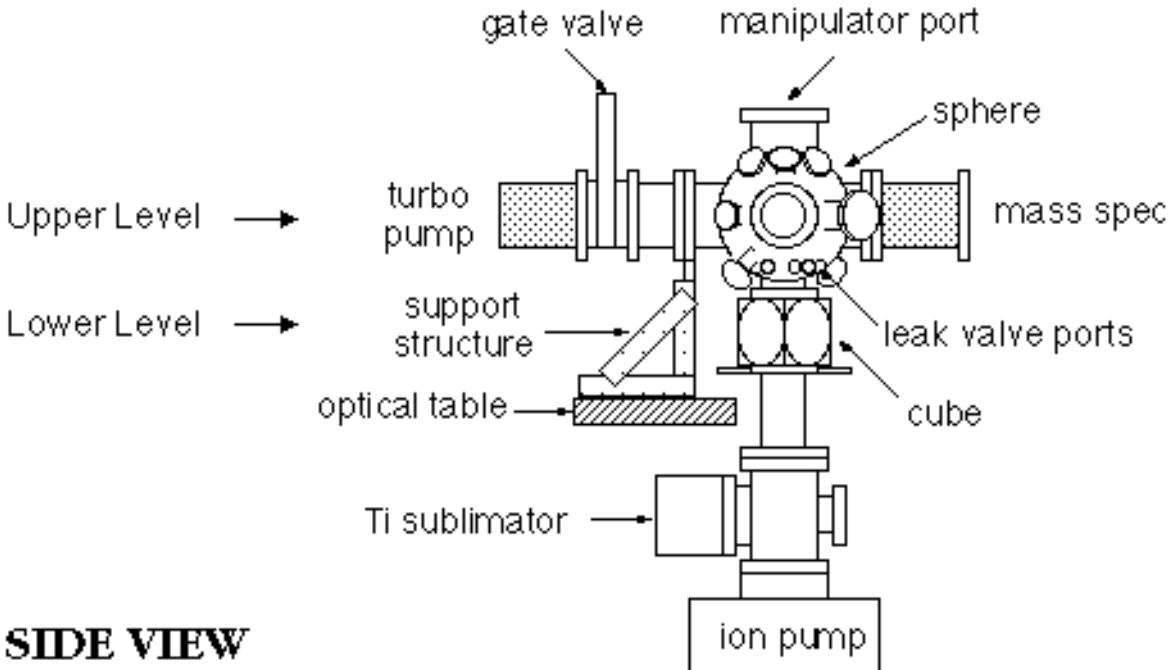
❸ General facilities

SURFACE SCIENCE APPARATUS

❶ UHV surface science chamber

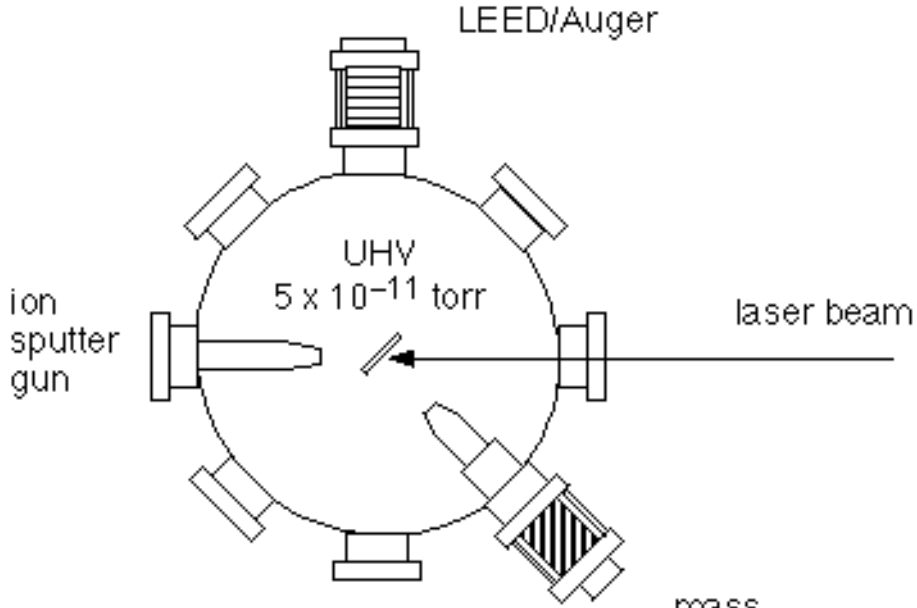
❷ Langmuir troughs

UHV SURFACE SCIENCE CHAMBER



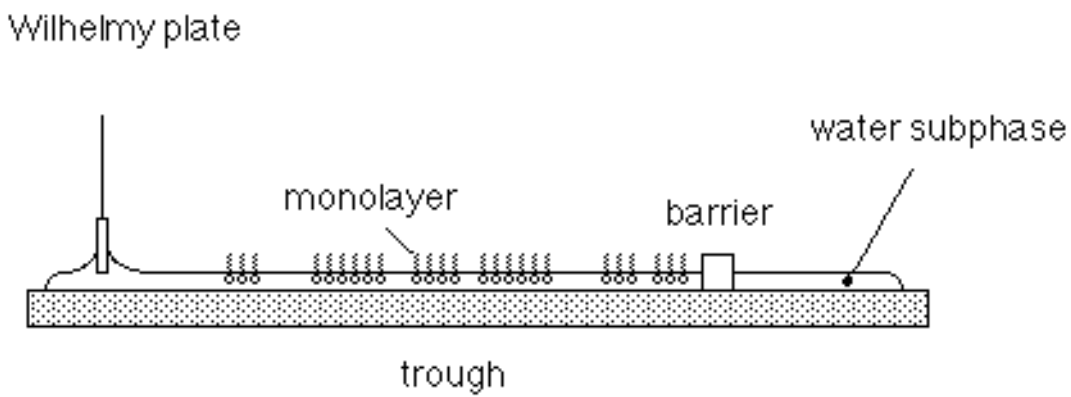
SIDE VIEW

UHV SURFACE SCIENCE CHAMBER



TOP VIEW

LANGMUIR TROUGHS



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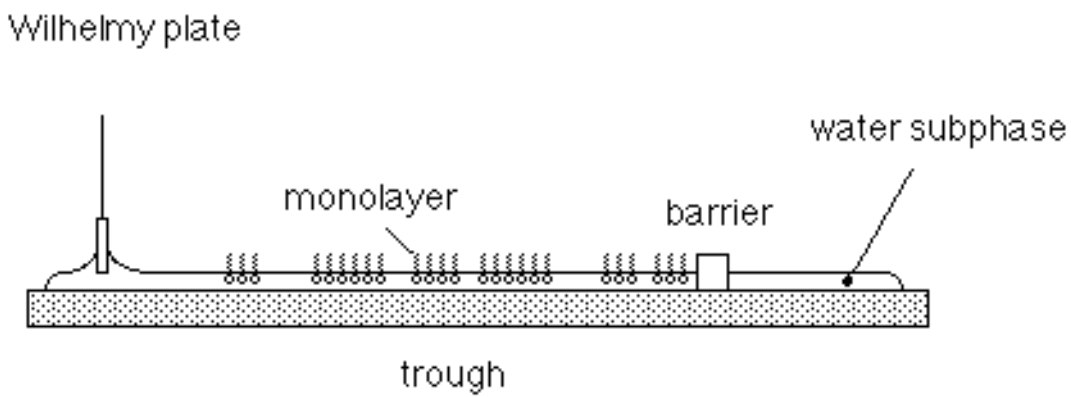

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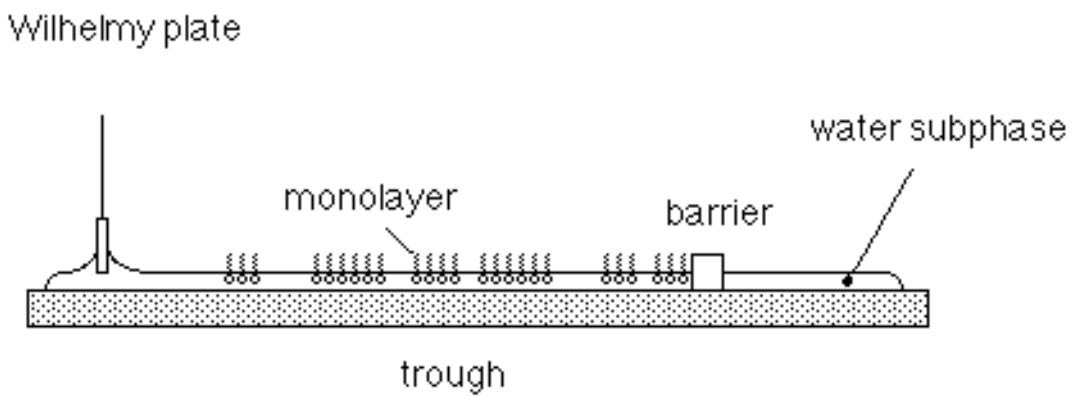

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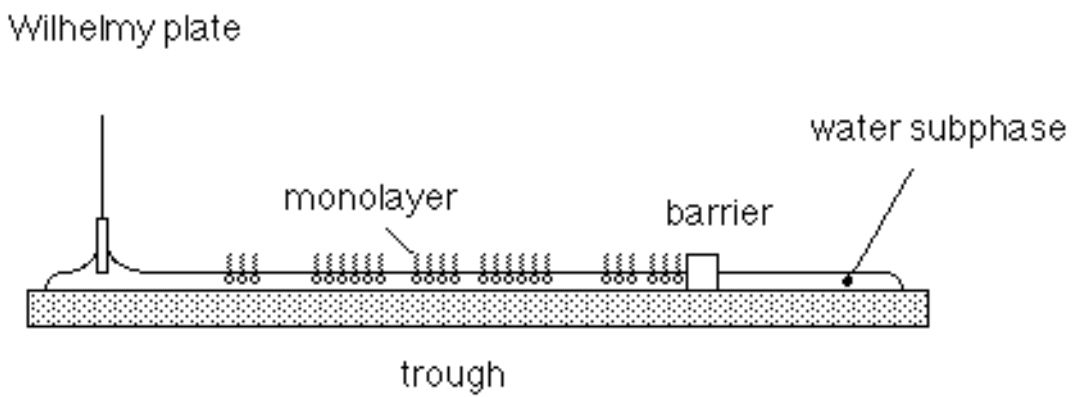

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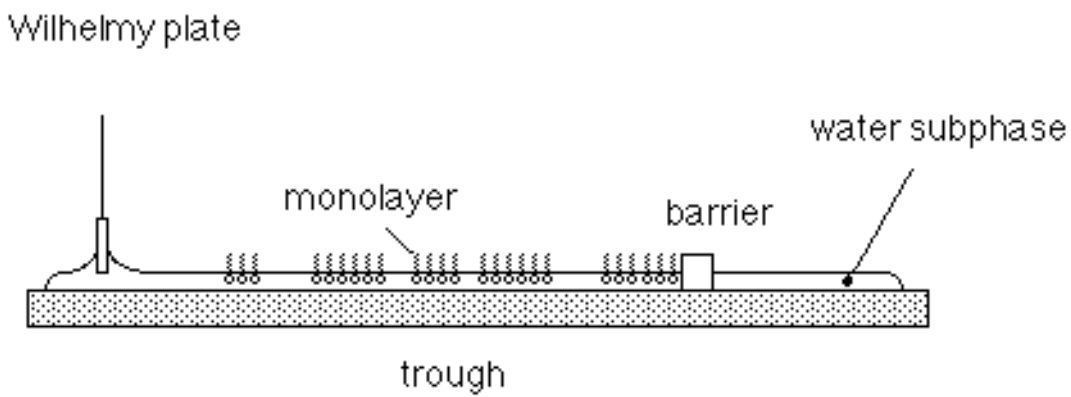

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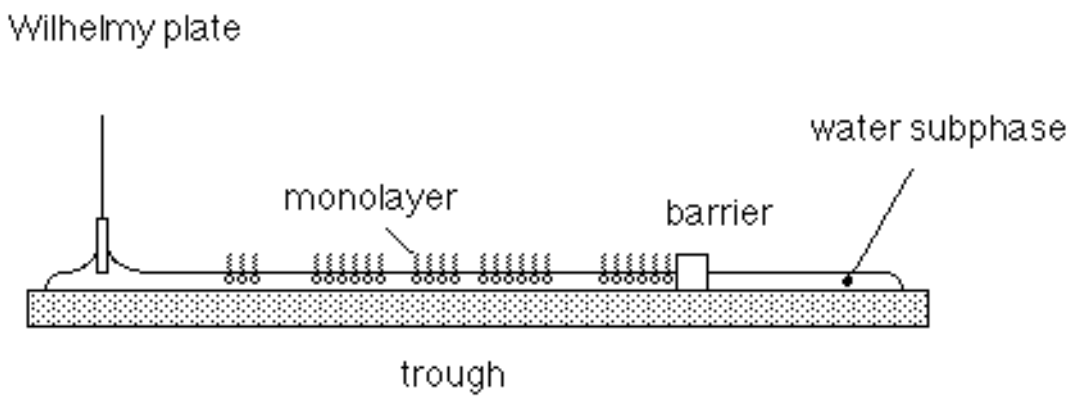

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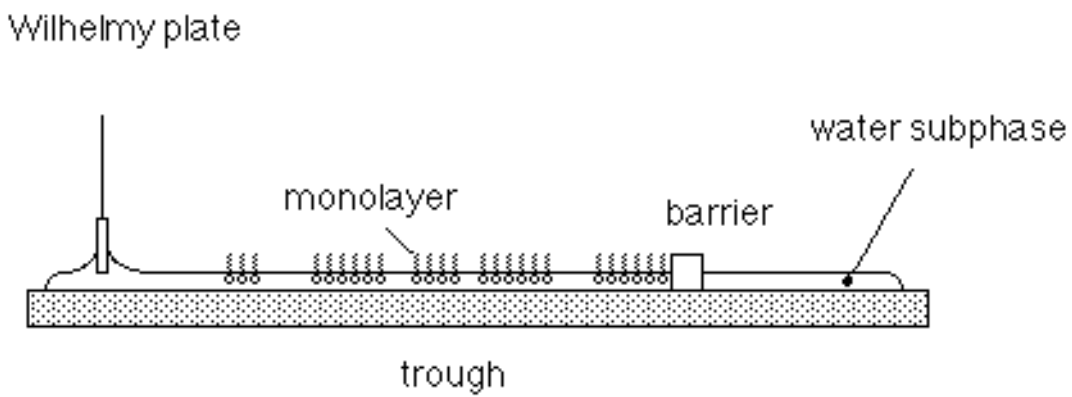
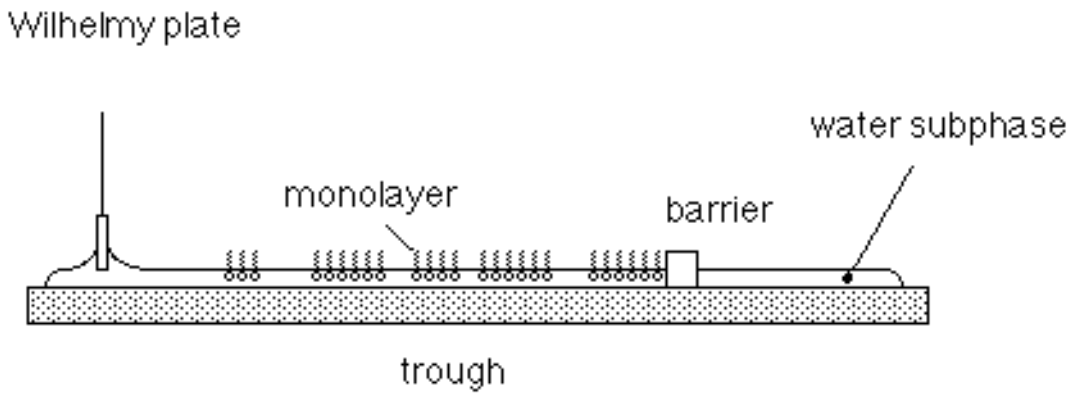


LANGMUIR TROUGHS



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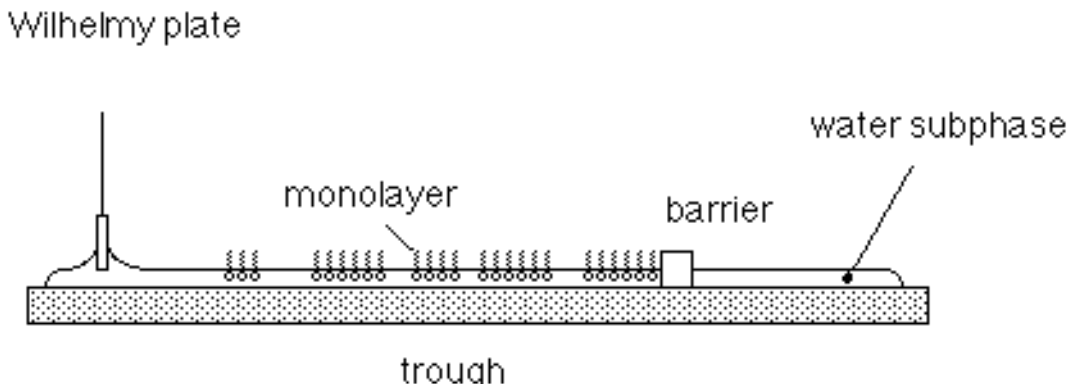

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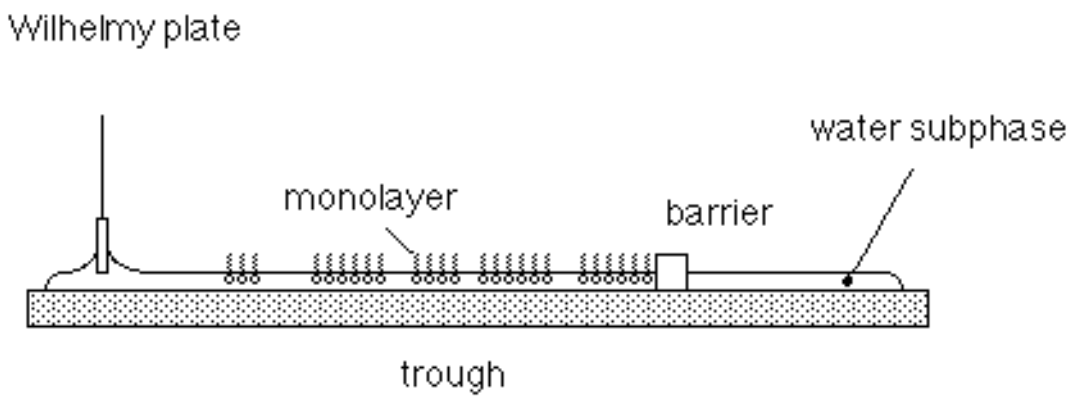

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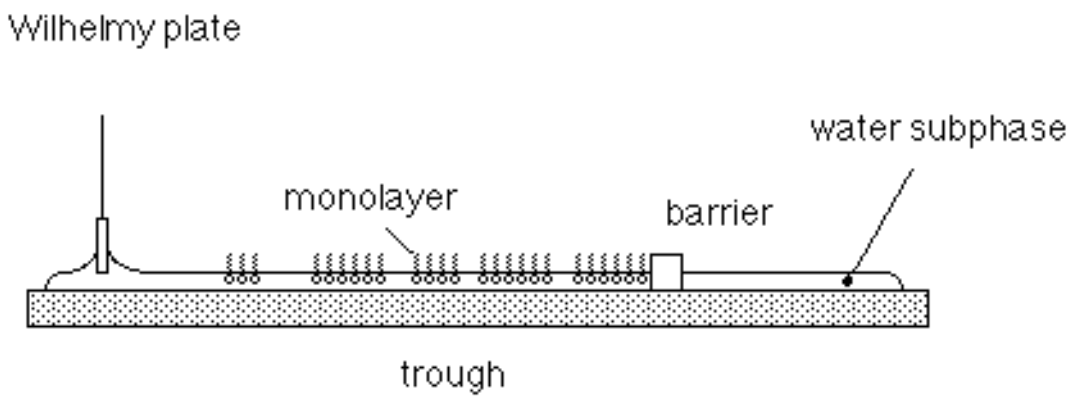

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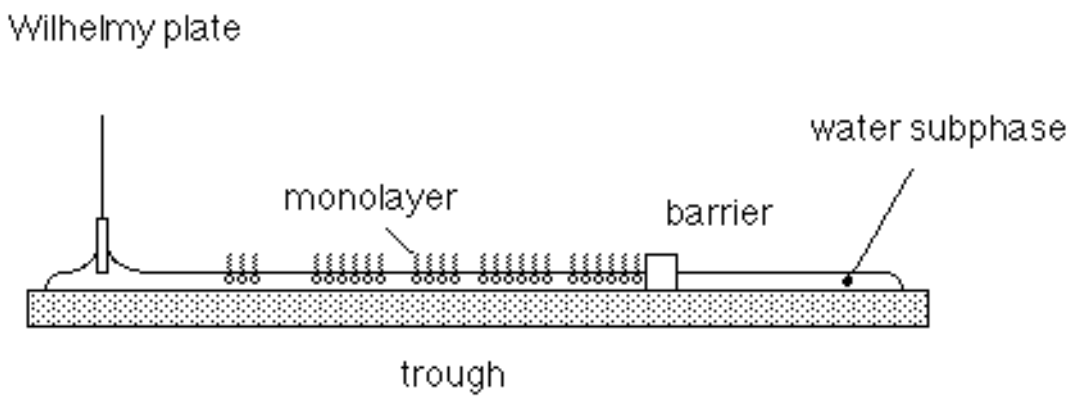

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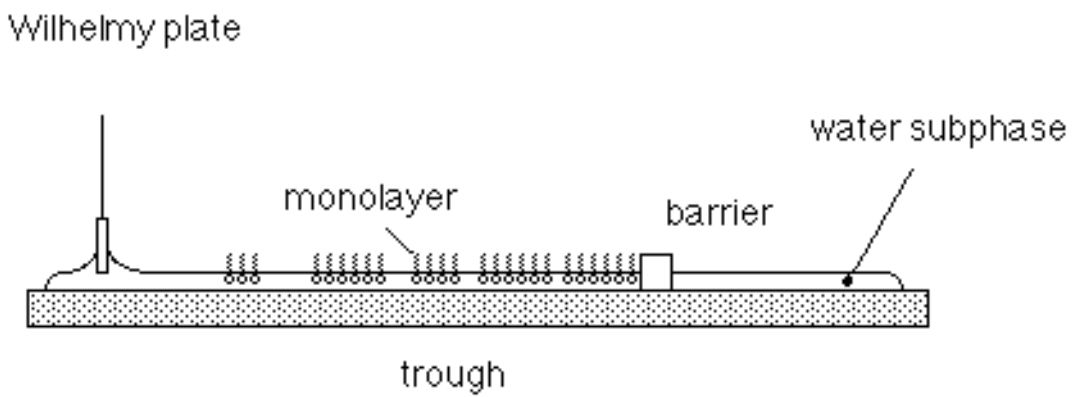

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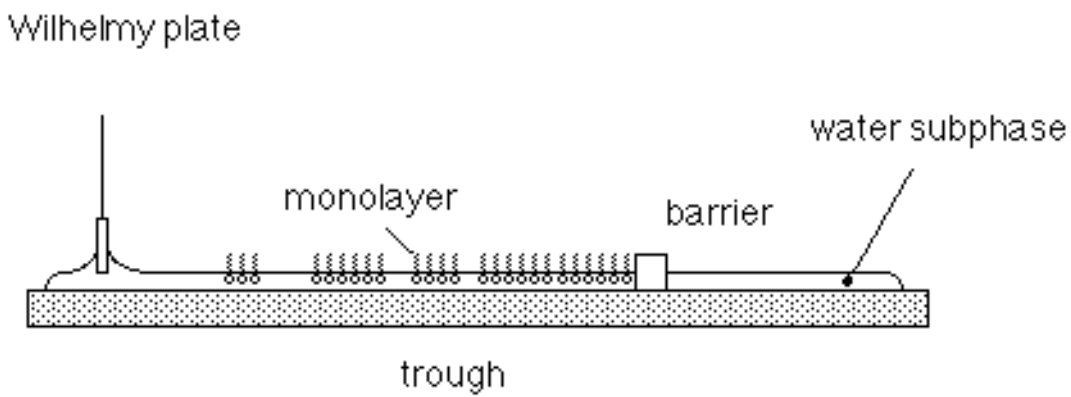

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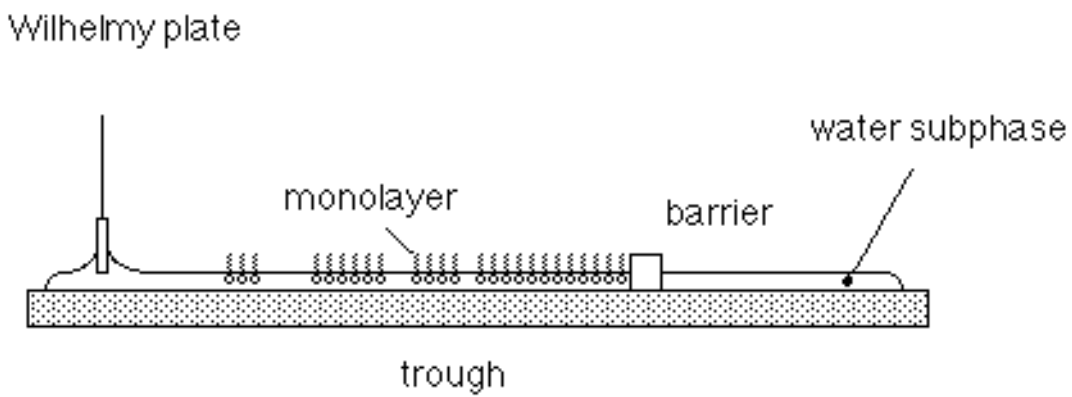

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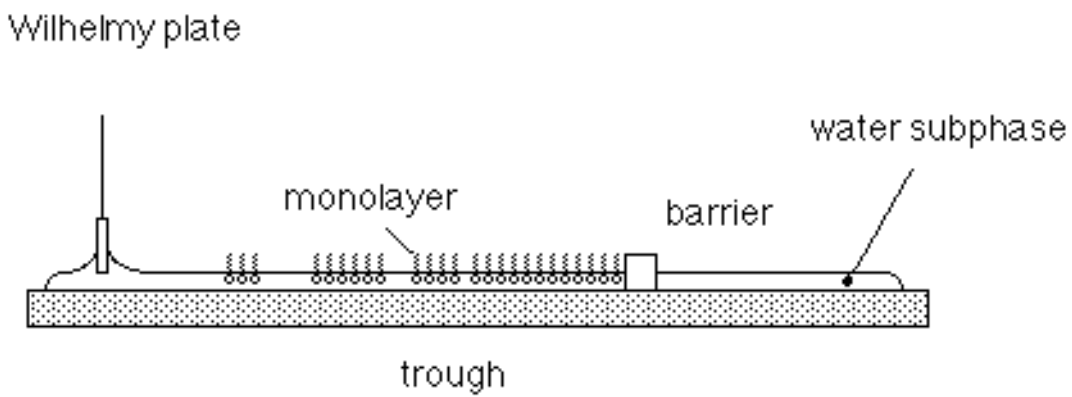

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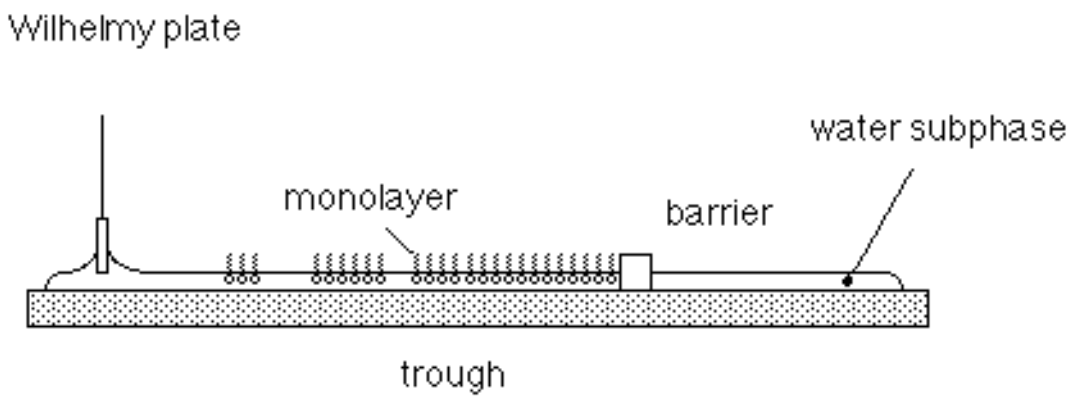

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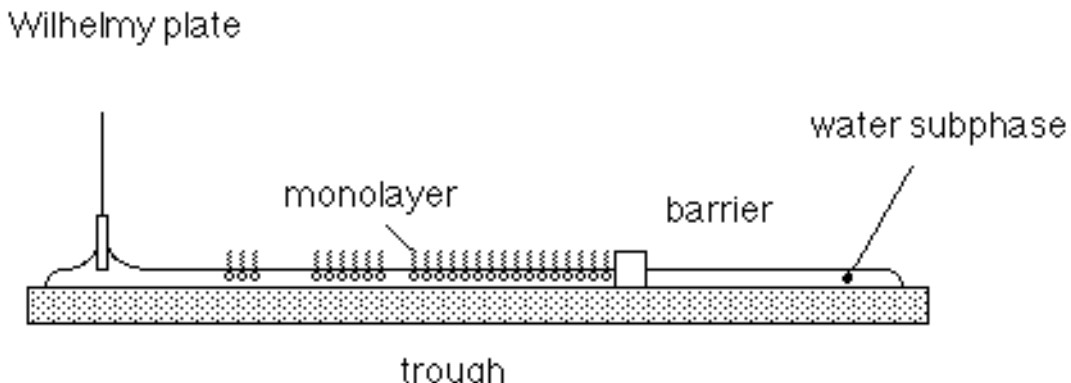

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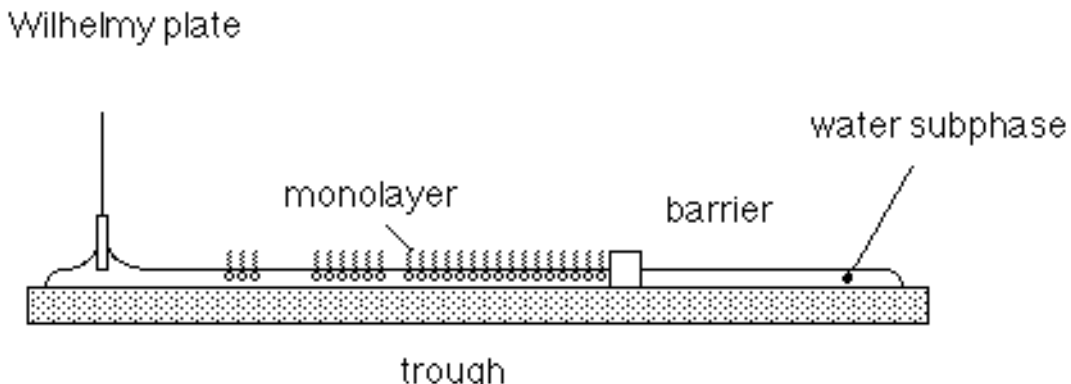

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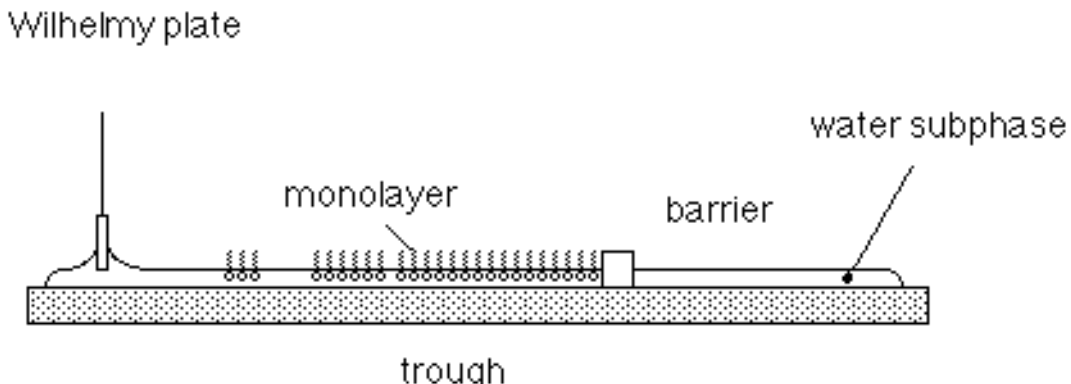

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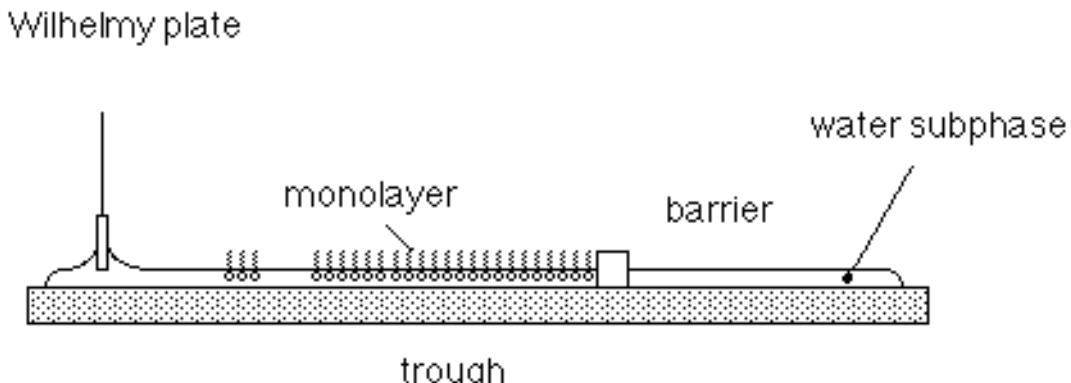
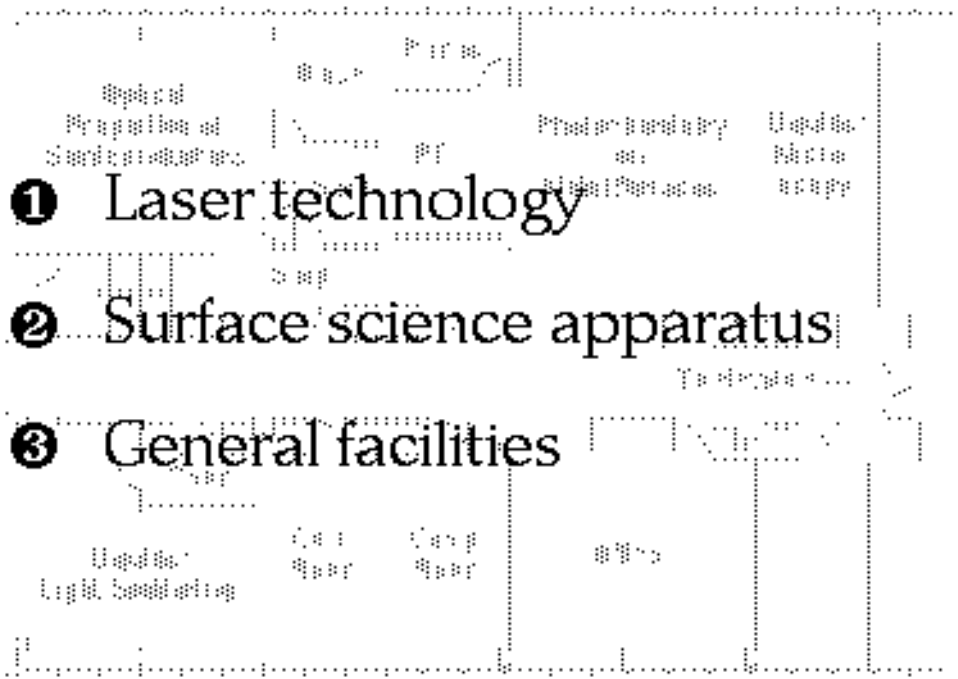


FACILITIES



❶ Laser technology

❷ Surface science apparatus

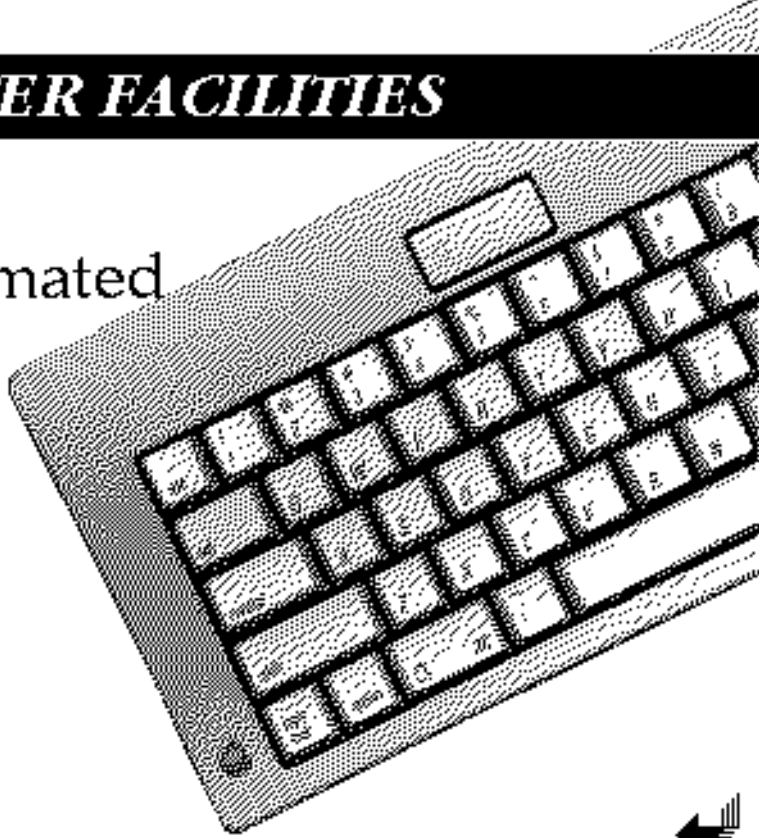
❸ General facilities

GENERAL FACILITIES

- SEM, TEM & STM facilities
- Clean room microfabrication facility
- Accelerator facility (RBS, FRS, PIXE)
- Thin film deposition & lithography
- Molecular Beam Epitaxy

COMPUTER FACILITIES

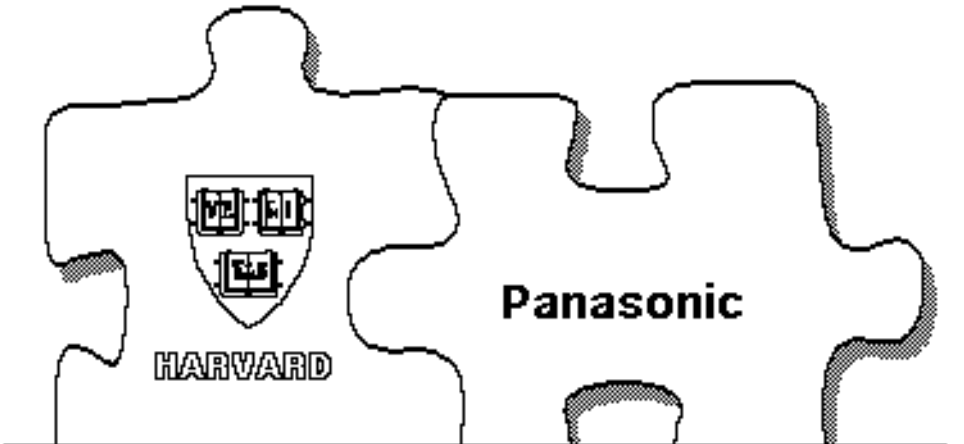
- All setups automated
- LabView
- Ethernet LAN



❶ Research

❷ Facilities

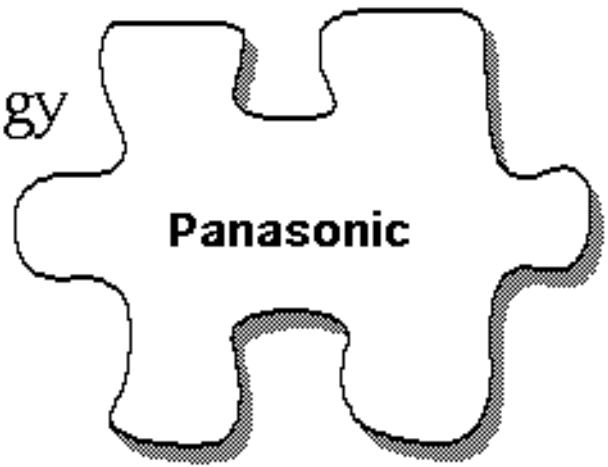
❸ Plans



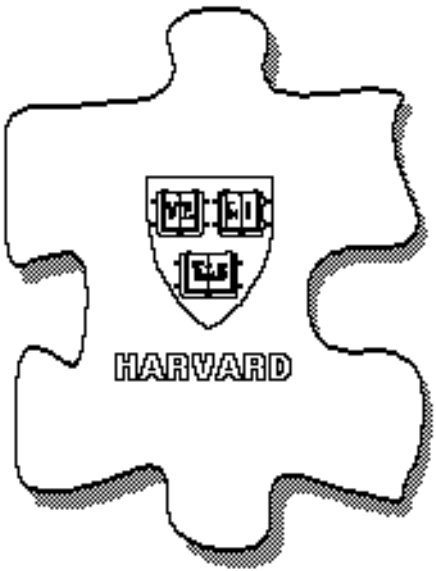
- Joint expertise
- Femtosecond Machining

CURRENT EXPERTISE

- device technology
- applications
- manufacturing

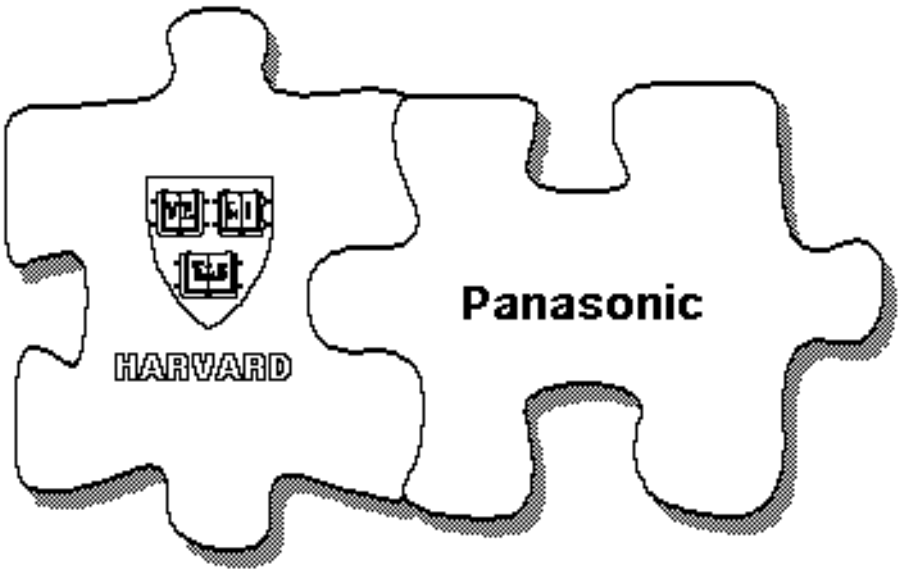


CURRENT EXPERTISE

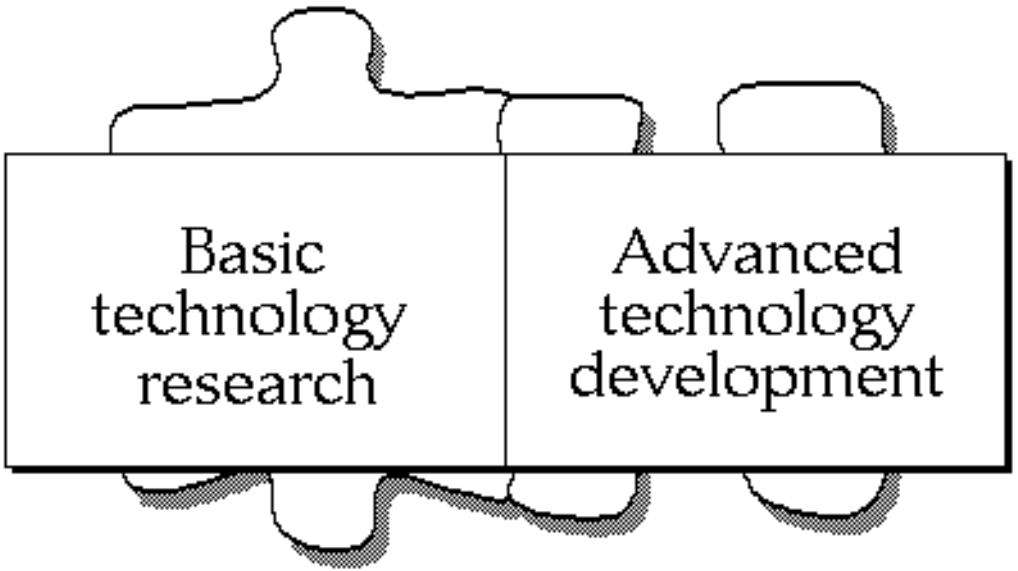


- laser technology
- surface facilities
- materials

CURRENT EXPERTISE



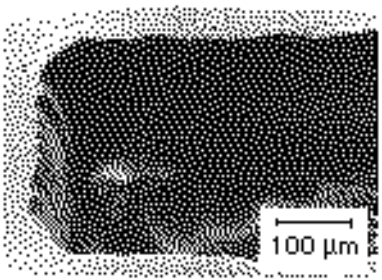
FEMTOSECOND LASER MACHINING



FEMTOSECOND LASER MACHINING

- ablation without heat transfer
- more precise cuts
- machining of transparent materials
- 3D machining

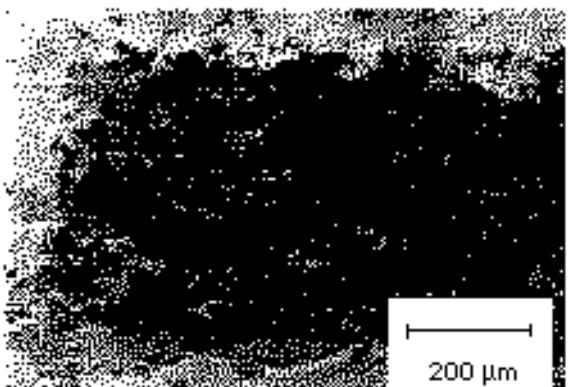
FS LASER MACHINING RESEARCH



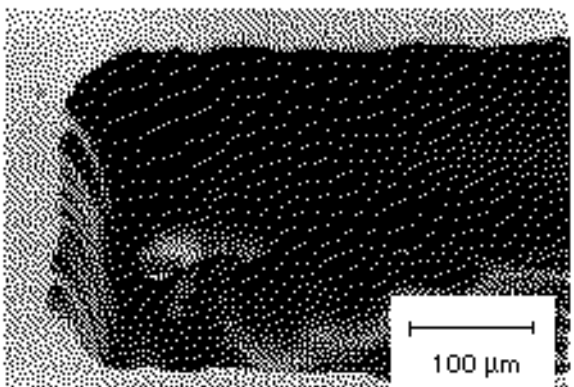
Teflon machined with
femtosecond pulses

1. physical processes
2. materials
3. experimental probes
4. laser development

physics of ablation



nanosecond pulse ablation

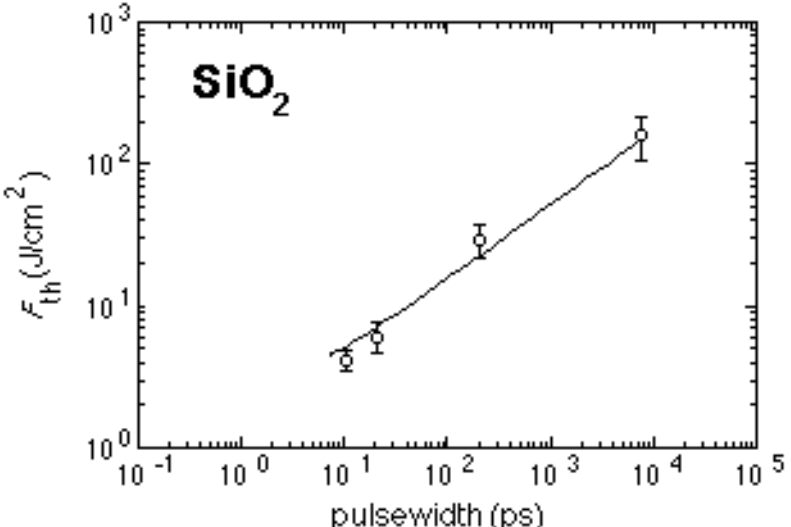


femtosecond pulse ablation

S. Küper and M. Stuke, Appl. Phys. Lett. **54**, 4 (1989)

PHYSICAL PROCESSES

optical damage mechanisms



D. Du, et al., Ultrafast Phenomena IX (Springer Verlag, 1994)

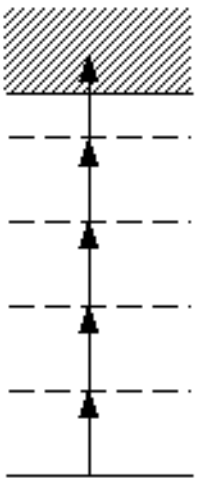
PHYSICAL PROCESSES

multiphoton absorption

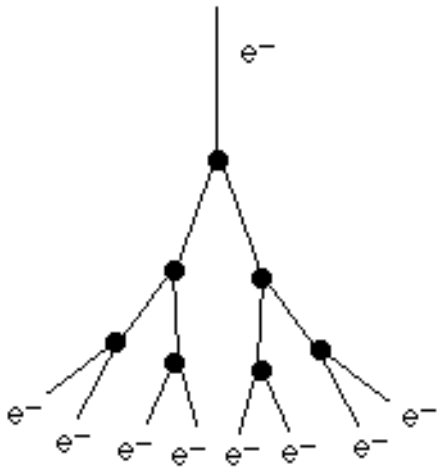
free electron absorption

avalanche ionization

optical breakdown

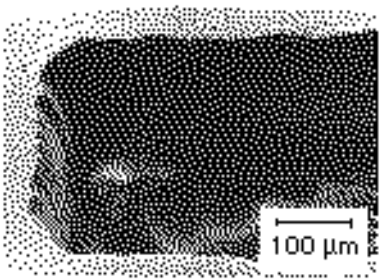


multiphoton absorption



avalanche ionization

FS LASER MACHINING RESEARCH



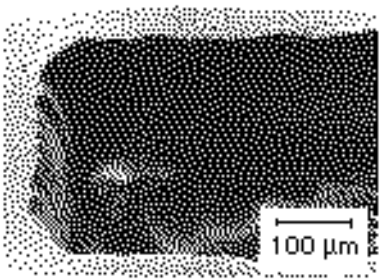
Teflon machined with
femtosecond pulses

1. physical processes
2. materials
3. experimental probes
4. laser development

MATERIALS

- polymers
- silica
- semiconductors
- metals

FS LASER MACHINING RESEARCH



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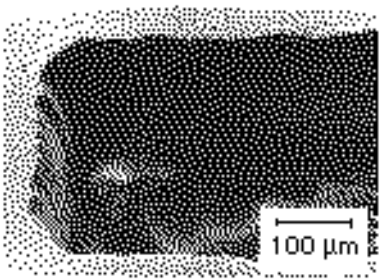

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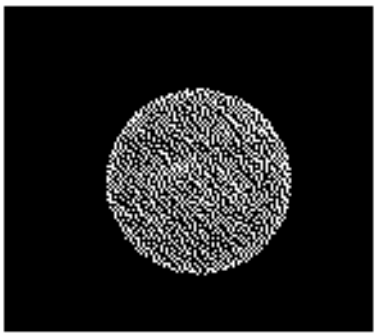
EXPERIMENTAL PROBES

–0.5 ps



M.C. Downer, et al.
JOSA B **2**, 595 (1985)

Ultrafast imaging

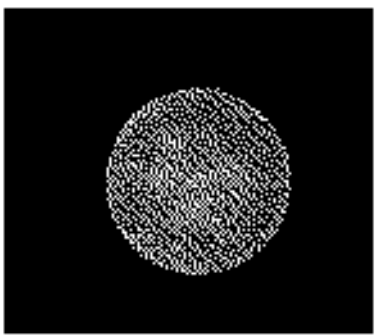
Time-resolved spectroscopy

Nonlinear optics

SEM, TEM

EXPERIMENTAL PROBES

0.1 ps



M.C. Downer, et al.
JOSA B **2**, 595 (1985)

Ultrafast imaging

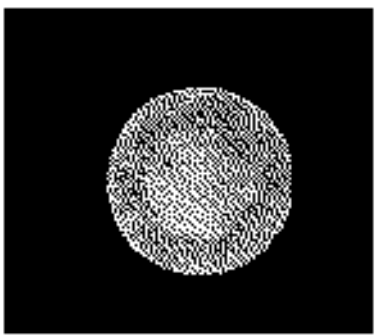
Time-resolved spectroscopy

Nonlinear optics

SEM, TEM

EXPERIMENTAL PROBES

0.5 ps



M.C. Downer, et al.
JOSA B **2**, 595 (1985)

Ultrafast imaging

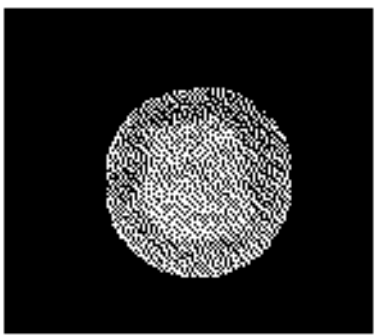
Time-resolved spectroscopy

Nonlinear optics

SEM, TEM

EXPERIMENTAL PROBES

1 ps



M.C. Downer, et al.
JOSA B **2**, 595 (1985)

Ultrafast imaging

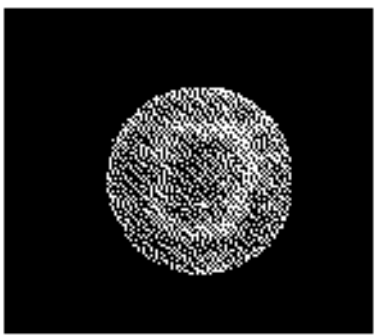
Time-resolved spectroscopy

Nonlinear optics

SEM, TEM

EXPERIMENTAL PROBES

10 ps



M.C. Downer, et al.
JOSA B **2**, 595 (1985)

Ultrafast imaging

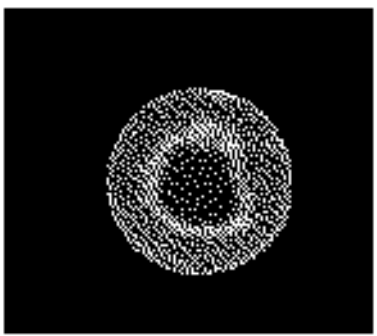
Time-resolved spectroscopy

Nonlinear optics

SEM, TEM

EXPERIMENTAL PROBES

50 ps



M.C. Downer, et al.
JOSA B **2**, 595 (1985)

Ultrafast imaging

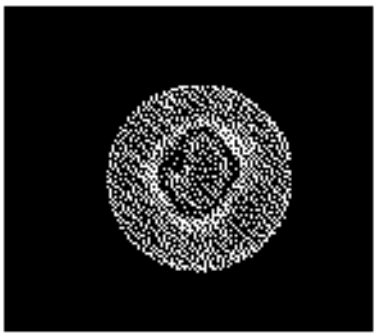
Time-resolved spectroscopy

Nonlinear optics

SEM, TEM

EXPERIMENTAL PROBES

300 ps



M.C. Downer, et al.
JOSA B **2**, 595 (1985)

Ultrafast imaging

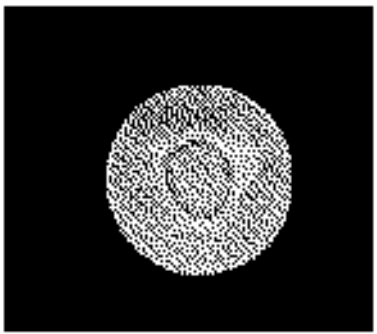
Time-resolved spectroscopy

Nonlinear optics

SEM, TEM

EXPERIMENTAL PROBES

550 ps



M.C. Downer, et al.
JOSA B **2**, 595 (1985)

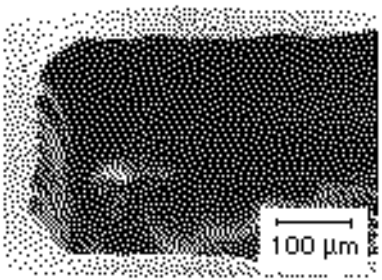
Ultrafast imaging

Time-resolved spectroscopy

Nonlinear optics

SEM, TEM

FS LASER MACHINING RESEARCH



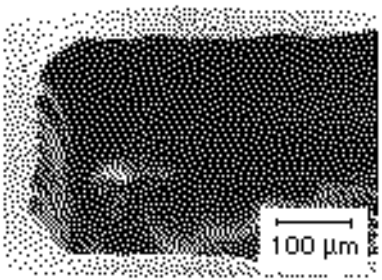
Teflon machined with
femtosecond pulses

1. physical processes
2. materials
3. experimental probes
4. laser development

LASER DEVELOPMENT

- high energy
- high beam quality
- high repetition rate
- variable pulse duration
- variable wavelength (visible, UV)
- delivery system

FS LASER MACHINING RESEARCH



Teflon machined with
femtosecond pulses

1. physical processes
2. materials
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4. laser development

COLLABORATIVE GOALS

- technology transfer
- applications development
- creation of new materials / devices
- micromachining
- exchange with FST Project Center staff

Panasonic

FUTURE APPLICATIONS

- 3D memory
- devices for optical logic
- integrated optical devices
- industrial and medical applications

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