Slide 1

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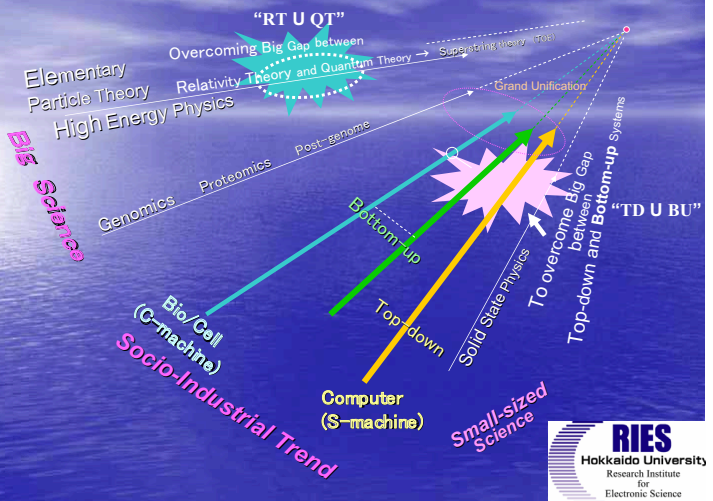Research Institute for Electronic Science

Uniting Top-down and Bottom-up Systems on Clean Unit System Platform (CUSP)
Based upon P-140PCT

Akira Ishibashi

Research Institute for Electronic Science
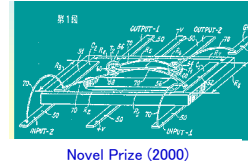Hokkaido University, Hokkaido 060-0812, Japan

Slide 2

Where do we find the most striking "confrontation"?

"RT U QT"
Overcoming Big Gap between
Relativity Theory and Quantum Theory → Superstring Theory (ToE)

Elementary Particle Theory
High Energy Physics
Big Science
Grand Unification
Genomics   Proteomics   Post-genome
Bottom-up
Top-down and Bottom-up Systems
To overcome Big Gap between Top-down and Bottom-up Systems
"TD U BU"
Bio/Cell (C-machine)
Socio-Industrial Trend
Solid State Physics
Computer (S-machine)
Small-sized Science

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Slide 3

1. P-140PCT Background

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Invention of Transistor (1947)
Bardeen, Schockley, Brattain

Novel Prize (1956)

Kilby's Patent (1958)
Had become Platform for IC, LSI, & VLSI

第1図   OUTPUT-1   OUTPUT-2
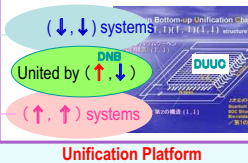INPUT-2   INPUT-L

Novel Prize (2000)

ENIAC
Pentium 4 Athlon XP
IT revolution
C. Shannon

Blooming Nano-Science & Technologies (2000~)

P-140PCT (2004)
for uniting Top-down & Bottom-up Systems, Eg-MRS, and CUSP

Top-down Systems
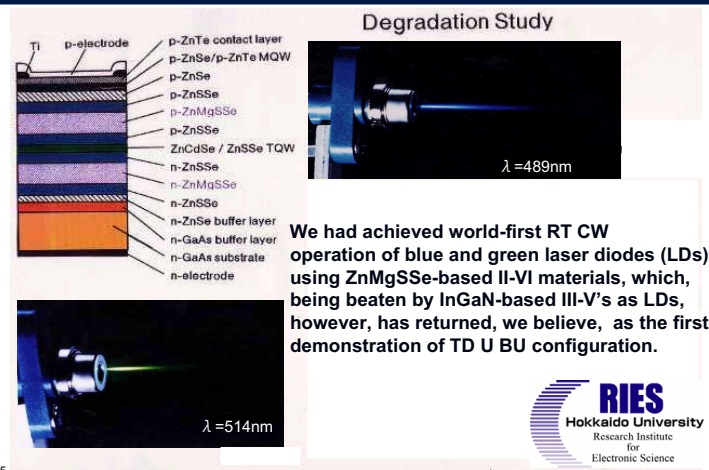($\downarrow,\downarrow$) systems
DNB
United by ($\uparrow,\downarrow$)
DUUO
Bottom-up Systems
($\uparrow,\uparrow$) systems

Off-springs of Top-down devices
Brave New World
Off-springs of Bottom-up device

Phase-separated, so far.   Unification Platform

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Top-down and Bottom-up Systems

Chromosome
Cell
DNA
Gene-work
$\in$ Bottom-up Sys
$\Leftrightarrow$ Distributed Autonomous Sys.
Urine Bladder Epithelium
Brain-work
$\Leftrightarrow$ Top-down Sys.

Slide 5
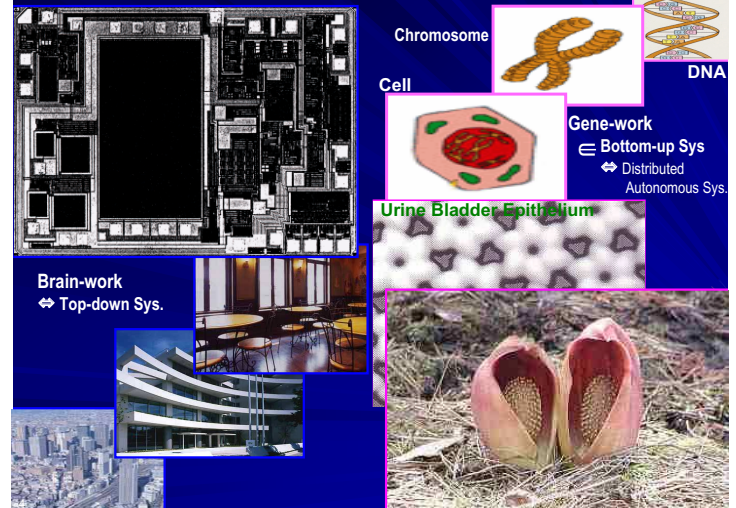
Degradation analysis of II-VI LD
inspiring uniting bottom-up structures and top-down systems

Degradation Study

Ti p-electrode
p-ZnTe contact layer
p-ZnSe/p-ZnTe MQW
p-ZnSe
p-ZnSSe
p-ZnMgSSe
p-ZnSSe
ZnCdSe / ZnSSe TQW
n-ZnSSe
n-ZnMgSSe
n-ZnSSe
n-ZnSe buffer layer
n-GaAs buffer layer
n-GaAs substrate
n-electrode

λ =489nm

We had achieved world-first RT CW operation of blue and green laser diodes (LDs) using ZnMgSSe-based II-VI materials, which, being beaten by InGaN-based III-V's as LDs, however, has returned, we believe, as the first demonstration of TD U BU configuration.

λ =514nm

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Slide 6

Number and Size of V-shaped Dislocation Structures

Dislocation Network

Fractal Dimension~1.55
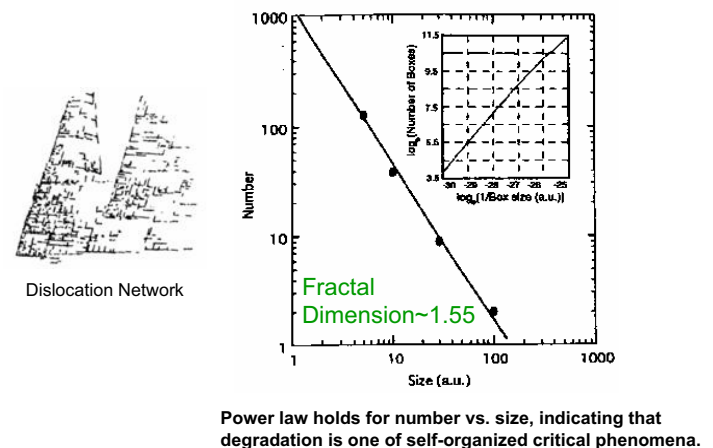
Power law holds for number vs. size, indicating that degradation is one of self-organized critical phenomena.

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Primitive Achievement of TD ∪ BU in fully solid state manner.

A. Ishibashi and K. Kondo, *Electron. Lett., 40 1268 (2004)*

We had achieved RT CW operation of Blue Laser Diodes for the first time in the world.
→ We have found the dislocation network seen in degraded II–VI Blue LD is caused by the self-organized criticality.
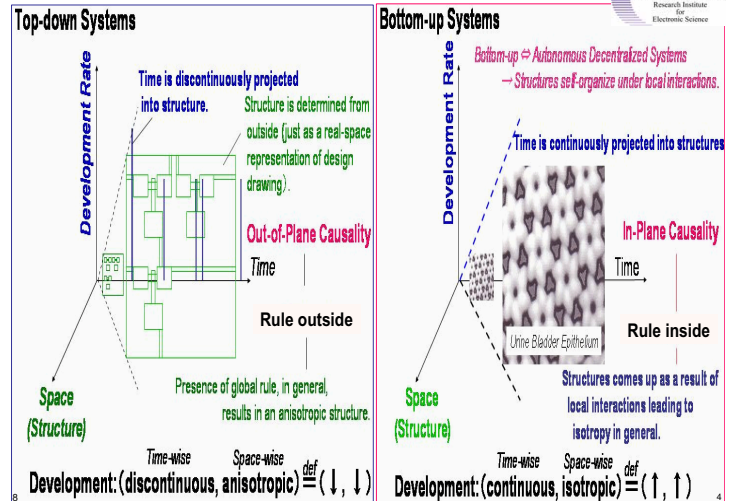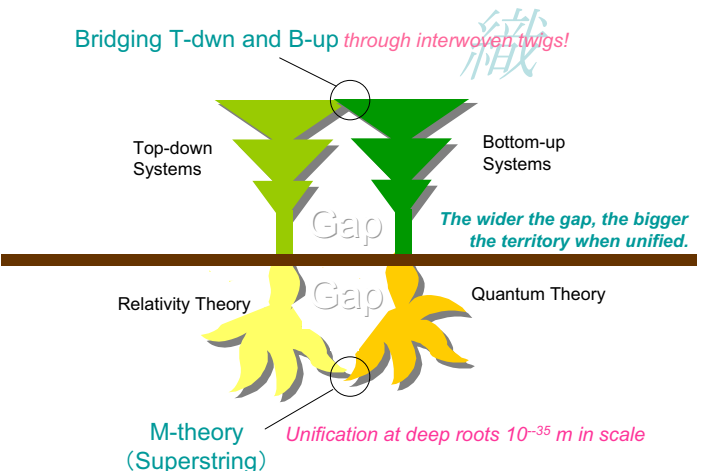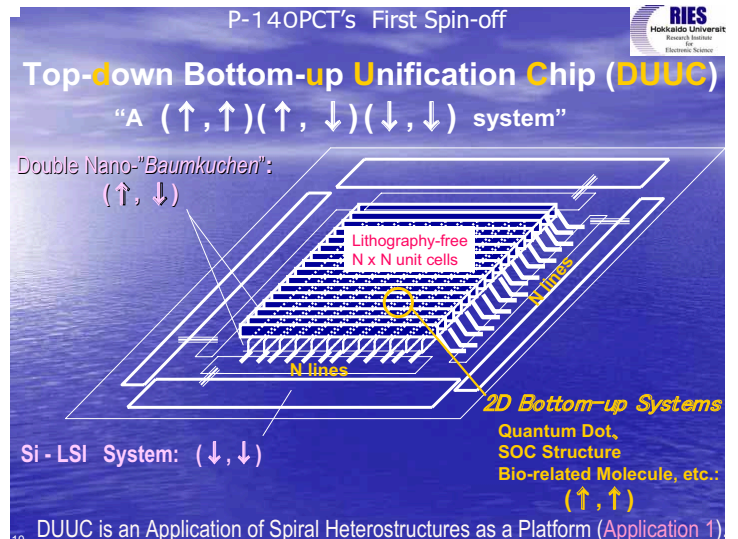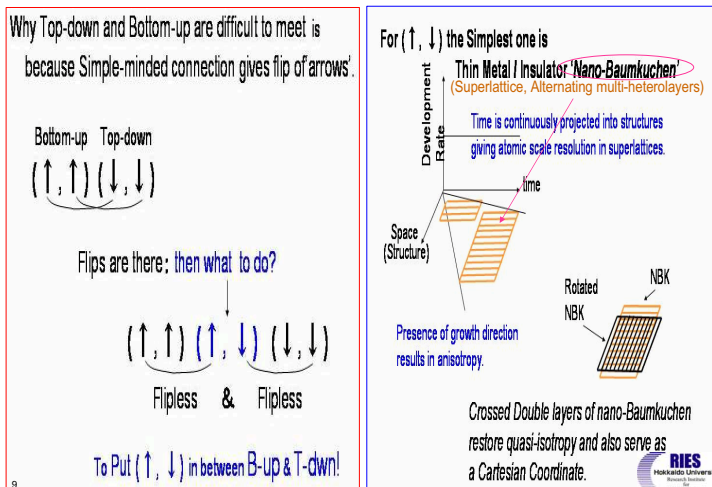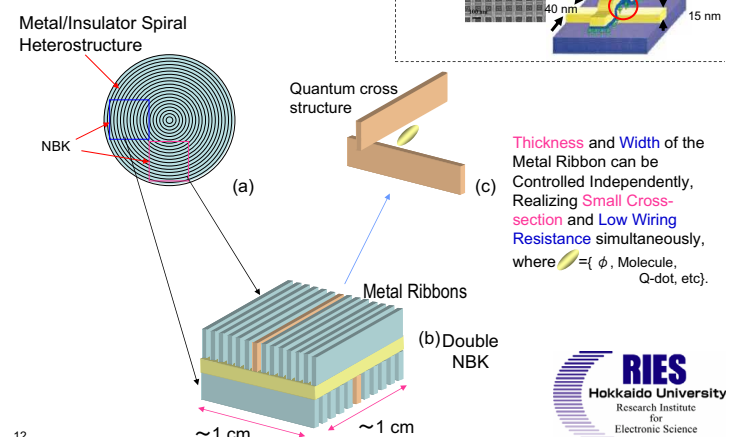
Electrodes
Stacking Fault
Active region
Self-organized Disloc. Network (Bottom-up)
Stacking Fault's seed (Top-down)
[001]
[110]
Substrate

Dislocation Network （Fractal structure）

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Primitive bridging between TD- and BU-Structures in a fully solid state system.

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Slide 8

P-140PCT is based upon the insight…

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Top-down Systems

Development Rate

Time is discontinuously projected into structure.
Structure is determined from outside (just as a real-space representation of design drawing).

Out-of-Plane Causality
Time

Rule outside

Space (Structure)

Presence of global rule, in general, results in an anisotropic structure.

Time-wise   Space-wise
Development: (discontinuous, anisotropic) $\overset{def}{=}$ (↓, ↓)

Bottom-up Systems

Development Rate

Bottom-up ⇔ Autonomous Decentralized Systems
→ Structures self-organize under local interactions.

Time is continuously projected into structures

In-Plane Causality
Time

Urine Bladder Epithelium

Rule inside

Space (Structure)

Structures comes up as a result of local interactions leading to isotropy in general.

Time-wise   Space-wise
Development: (continuous, isotropic) $\overset{def}{=}$ (↑, ↑)

8   4

Slide 9

Use of the third structure （↑, ↓）to unite TD- with BU-systems

Why Top-down and Bottom-up are difficult to meet is because Simple-minded connection gives flip of arrows'.

Bottom-up   Top-down
(↑, ↑) (↓, ↓)

Flips are there: then what to do?

(↑, ↑) (↑, ↓) (↓, ↓)
Flipless   &   Flipless

To Put (↑, ↓) in between B-up & T-dwn!

For (↑, ↓) the Simplest one is

Development Rate

Thin Metal / Insulator '*Nano-Baumkuchen*'
(Superlattice, Alternating multi-heterolayers)

Time is continuously projected into structures giving atomic scale resolution in superlattices.

time

Space (Structure)

Presence of growth direction results in anisotropy.

Rotated NBK
NBK

Crossed Double layers of nano-Baumkuchen restore quasi-isotropy and also serve as a Cartesian Coordinate.

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P-140PCT's First Spin-off

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Top-down Bottom-up Unification Chip (DUUC)
"A (↑,↑)(↑,↓)(↓,↓) system"

Double Nano-"*Baumkuchen*": (↑, ↓)

Lithography-free N x N unit cells

N lines

N lines

Si - LSI System: (↓,↓)

2D Bottom-up Systems
Quantum Dot, SOC Structure
Bio-related Molecule, etc.: (↑,↑)

DUUC is an Application of Spiral Heterostructures as a Platform (Application 1)

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Bridging T-dwn and B-up *through interwoven twigs!*

織

Top-down Systems

Bottom-up Systems

Gap

The wider the gap, the bigger the territory when unified.

Gap

Relativity Theory

Quantum Theory

M-theory （Superstring）

Unification at deep roots 10^{-35} m in scale

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P-140PCT's 2nd Spin-off

Quantum Cross (Q-Cross)
for Electronic Devices

Metal/Insulator Spiral Heterostructure

NBK

(a)

Quantum cross structure

(c)

(b) Double NBK

Metal Ribbons

~1 cm   ~1 cm

cf. Hewlett-Packard
Appl. Phys. Lett. **82** 1610 (2003)
40 nm   40 nm   40 nm   15 nm

Thickness and Width of the Metal Ribbon can be Controlled Independently, Realizing Small Cross-section and Low Wiring Resistance simultaneously, where ={ φ, Molecule, Q-dot, etc}.

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Slide 13

P-140PCT's 3rd Spin-off

Spiral Heterostructures
for Optical Devices , especially the photovoltaic devices

Incident light

n-metal
n-type
Photocarriers (electrons)
p-type
Photocarriers (holes)
p-metal

Conventional Solar Cell (Cross section)

p-metal
n-metal
pn junction

holes
electrons
Incident light

Carrier Diffusion (radial direction)

New Structure based on Spiral Heterostructure (Top View)

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Slide 14

Further, to utilize the whole spectrum of the Sun,
proposed is a new structure …

Incident light

p-n junction plane

Width W_1 W_2

Wide-gap semiconductor

Medium-gap semiconductor

Counter electrode

Narrow-gap semiconductor

W_k

n-metal
p-type
n-type
Insulator Film

Carrier drift direction

Photon propagation direction

Z

n-metal

…Eg-Maximally Reconfigured Solar-cell (**Eg-MRS**) !

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Slide 15

Eg-MRS can provide us with a high energy conversion efficiency

Theoretical 10-striped Eg-MRS's Efficiency~**70%**

Photon Density $n_{ph}(h\nu)$ $(10^{20}/cm^2 s)$

Curve(1)

Eg_n Eg_k Eg_1

Energy (eV)

$$J_L(E_g)=q\int_{h\nu=E_g}^{\infty}\left(dn_{ph}/dh\nu\right)d(h\nu)$$

$$\eta = \frac{\text{Rectangles of } E_m n_{ph}}{\text{Area under Curve}(1)}$$

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For TD U BU Processing , Cleanroom (CR) is needed, but …..

Non-one-directional air-flow clean room

FED Class1,000~100,000

Tunnel system clean room

FED Class10~10,000

Uni-directional down-air-flow clean room

FED Class1~100

CR typically cost up to tens of million dollars!

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P-140PCT's 4th Spin-off: Clean Unit System Platform (CUSP)

Thrust to unite TD- w/ BU-systems urges us to topologically transform Cleanroom.
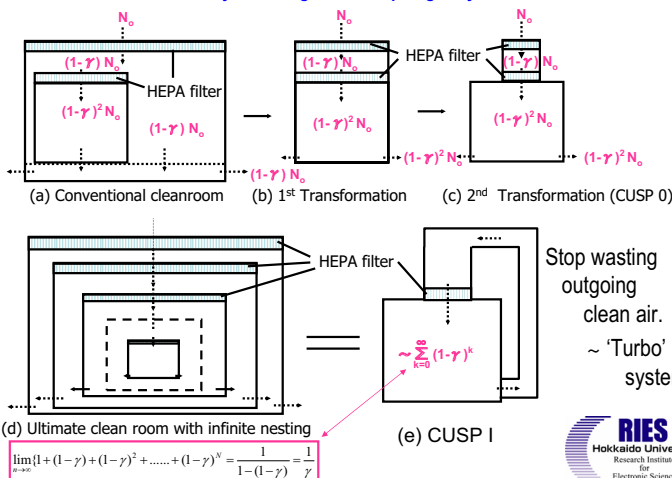
N_o
$(1-\gamma) N_o$
$(1-\gamma)^2 N_o$
$(1-\gamma) N_o$
HEPA filter

(a) Conventional cleanroom

N_o
$(1-\gamma) N_o$
$(1-\gamma)^2 N_o$
HEPA filter
$(1-\gamma) N_o$

(b) 1st Transformation

N_o
$(1-\gamma) N_o$
$(1-\gamma)^2 N_o$
HEPA filter
$(1-\gamma)^2 N_o$
$(1-\gamma)^2 N_o$

(c) 2nd Transformation (CUSP 0)

HEPA filter

(d) Ultimate clean room with infinite nesting

Stop wasting outgoing clean air.
~ 'Turbo' system

$$\sim \sum_{k=0}^{\infty} (1-\gamma)^k$$

(e) CUSP I

$$\lim_{n\to\infty}\{1+(1-\gamma)+(1-\gamma)^2+\ldots+(1-\gamma)^N\}=\frac{1}{1-(1-\gamma)}=\frac{1}{\gamma}$$

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CUSP provides us with ultimate cleanliness of ISO class -1,
which is four orders of magnitude better than that in super cleanroom.

CUSP II

ISO class

Airborne particle concentration (m^{-3})

Clean Room (CR)

Super CR

CUSP I

CUSP II

Latest data

Dust size (μm)

7

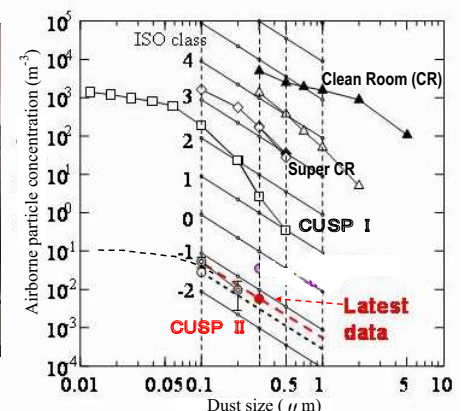18 CUSP to enable us to make DUUC, Q-Cross, and Eg-MRS with high yield.

Slide 19

CUSP provides us with ultimate cleanliness of ISO class -1,
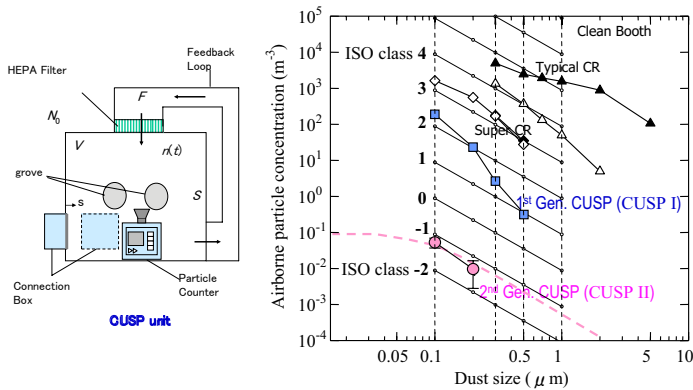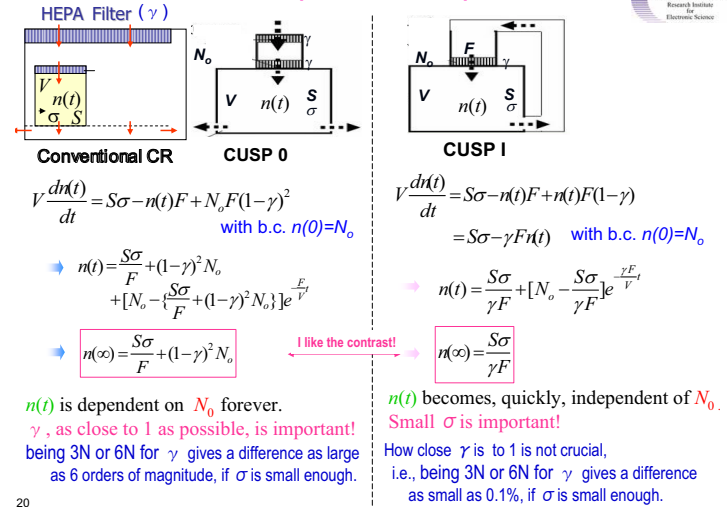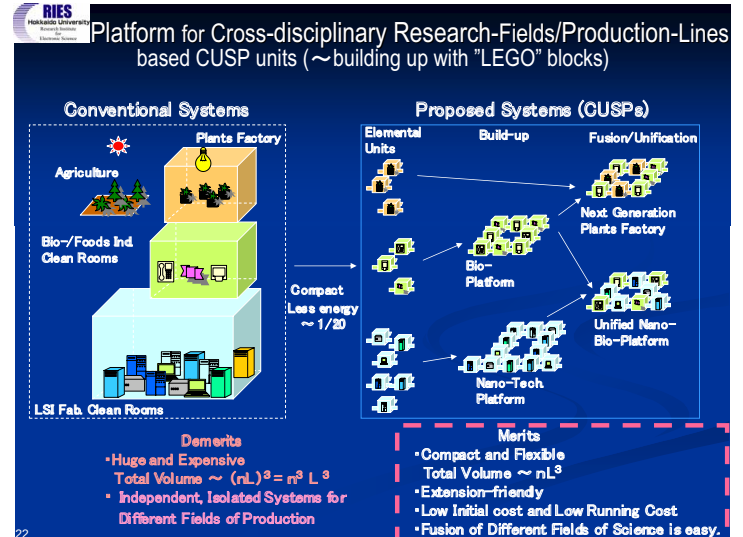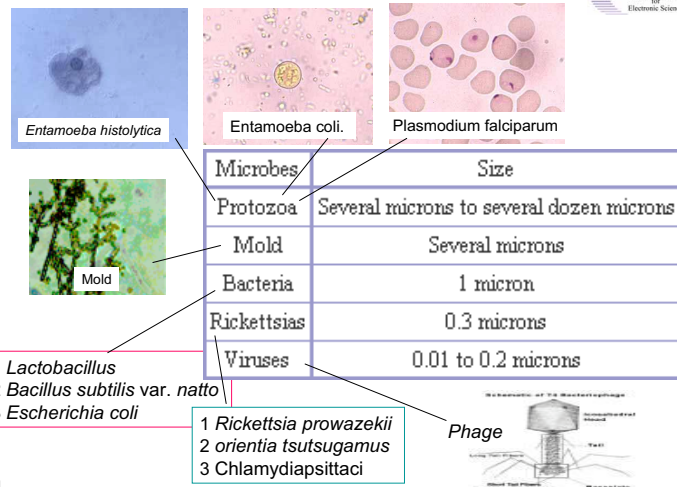which is four orders of magnitude better than that in super cleanroom.

CUSP to enable us to make DUUC, Q-Cross, and Eg-MRS with high yield.

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CUSP outperforms even super cleanrooms !

HEPA Filter (γ)

Conventional CR CUSP 0 CUSP I

$$V\frac{dn(t)}{dt} = S\sigma - n(t)F + N_o F(1-\gamma)^2$$

with b.c. $n(0)=N_o$

$$n(t) = \frac{S\sigma}{F} + (1-\gamma)^2 N_o + [N_o - \{\frac{S\sigma}{F} + (1-\gamma)^2 N_o\}]e^{\frac{F}{V}t}$$

$$\boxed{n(\infty) = \frac{S\sigma}{F} + (1-\gamma)^2 N_o}$$

I like the contrast!

$$V\frac{dn(t)}{dt} = S\sigma - n(t)F + n(t)F(1-\gamma)$$
$$= S\sigma - \gamma Fn(t)$$

with b.c. $n(0)=N_o$

$$n(t) = \frac{S\sigma}{\gamma F} + [N_o - \frac{S\sigma}{\gamma F}]e^{-\frac{\gamma F}{V}t}$$

$$\boxed{n(\infty) = \frac{S\sigma}{\gamma F}}$$

$n(t)$ is dependent on N_0 forever.
γ, as close to 1 as possible, is important!
being 3N or 6N for γ gives a difference as large as 6 orders of magnitude, if σ is small enough.

$n(t)$ becomes, quickly, independent of N_0.
Small σ is important!
How close γ is to 1 is not crucial,
i.e., being 3N or 6N for γ gives a difference as small as 0.1%, if σ is small enough.

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Microbes and their sizes

Entamoeba histolytica

Entamoeba coli.

Plasmodium falciparum

Mold

Microbes	Size
Protozoa	Several microns to several dozen microns
Mold	Several microns
Bacteria	1 micron
Rickettsias	0.3 microns
Viruses	0.01 to 0.2 microns

1 *Lactobacillus*
2 *Bacillus subtilis* var. *natto*
3 *Escherichia coli*

1 *Rickettsia prowazekii*
2 *orientia tsutsugamus*
3 Chlamydiapsittaci

Phage

Slide 22

Platform for Cross-disciplinary Research-Fields/Production-Lines
based CUSP units (～building up with "LEGO" blocks)

Conventional Systems

Proposed Systems (CUSPs)

Agriculture

Bio-/Foods Ind. Clean Rooms

LSI Fab. Clean Rooms

Plants Factory

Elemental Units Build-up Fusion/Unification

Next Generation Plants Factory

Bio-Platform

Unified Nano-Bio-Platform

Nano-Tech Platform

Compact Less energy ～1/20

Demerits
- Huge and Expensive Total Volume ～ (nL.)³ = n³ L ³
- Independent, Isolated Systems for Different Fields of Production

Merits
- Compact and Flexible Total Volume ～ nL³
- Extension-friendly
- Low Initial cost and Low Running Cost
- Fusion of Different Fields of Science is easy.

Slide 23

Summary

"TD ∪ BU" as Generating function…

Device-based Approach

Spiral Heterostructures
(for DUUC, Memory, Solar Cells)

For Molecular Electronics, Spintronics
Metal
Meta Ribbon
Edge
Q-Cross Device
Insulator
Insulator
Metal
Metal
y
x

1 DUUC
2 Q-Cross Devices
3 Eg-MRS

Platform-based Approach

Segment 1
(Semiconductor-processing)
Inlet box
Inlet box

Segment 3
(others)

Outlet box
Transfer box
Segment 2
(Bio-processing)

4 Clean Unit System Platform (CUSP)

… *a P-140 PCT World* has emerged.