Measurement and simulation of Optomechatronic system

Coordinator: An-Bang Wang, Dr.-Ing.

Institute of Applid Mechanics

National Taiwan University

E-mail: abwang@spring.iam.ntu.edu.tw

Contributors

- ***Gary Chen***
  Flotrend Corporation
- ***Tzong-Sheng Lee***
  Microsystems Application Technology Division
  Industrial Technilogy Research Institute
- *An-Bang Wang*
  Institute of Applid Mechanics
  National Taiwan University
- ***RueyHor Yen***
  Department of Mechanical Engineering
  National Taiwan University

Course contents

- Introduction to flow measurement in the optomechatronic system (by A.-B. Wang)
- Flow visualization (by A.-B. Wang)
- Temperature measurement (by T.-S. Lee)
- Pressure measurement (by A.-B. Wang)
- Velocity measurement (by A.-B. Wang)
- Introduction to simulations in the optomechatronic system (by R.-H. Yuen)
- Numerical simulations methods (by R.-H. Yuen)
- Simulation application & practice (by G.Chen)

Chapter 1
Introduction to Measurement and simulation of optomechatronic system

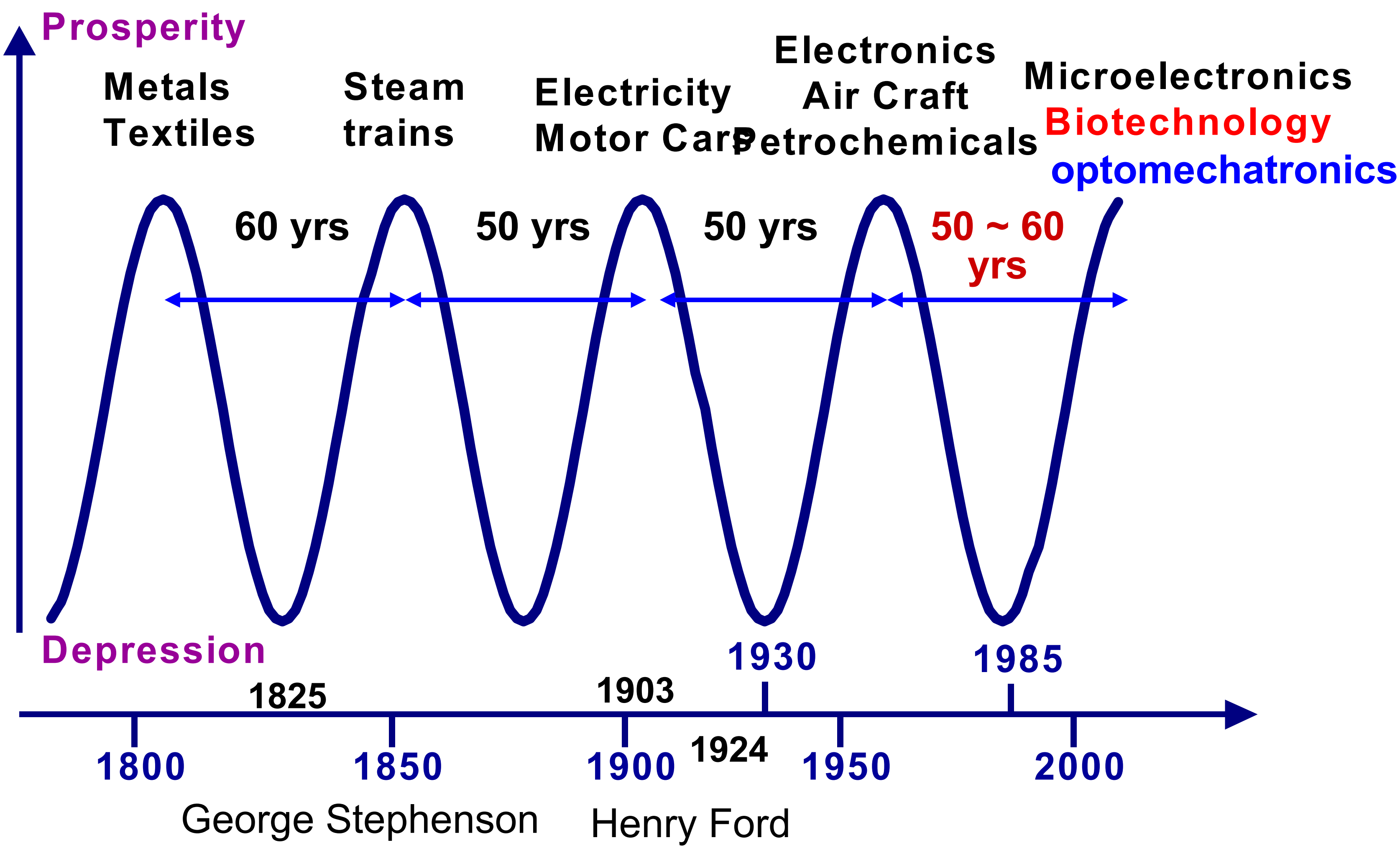
Contents

- What is the optomechatronic system ?
- Trend of the world
- Examples of optomechatronic system
- Why Measurements ?
- Why simulations ?

Introduction to the optomechatronic system

- What is the optomechatronic system ?
  Optoelectronic + ***Mechatronic*** system
- Products of optomechatronic system:
  optical storage, optical input/output devices (scanner, digital camera, PC-camera, fax machine, printer, …) , optoelectric displayer, optical communcations, optoelectric elements (LED, laser dial, CCD, …)

Trend of the world



IA-products

E-mail terminals

Air Communication / Smart Phone
Nokia/ 9000Communicator
Motorola / MAPS

Net TVs

Worldgate / Worldgate
Sony, Philips / WebTV

Gaming console devices

Sega / Dreamcast
Sony / PlayStation 2
Ninterdo / Dolphin

Smart handheld devices

Compaq / Aero series
3Com,Palm / Palm VII
Hewlett-Packard / Jornada series

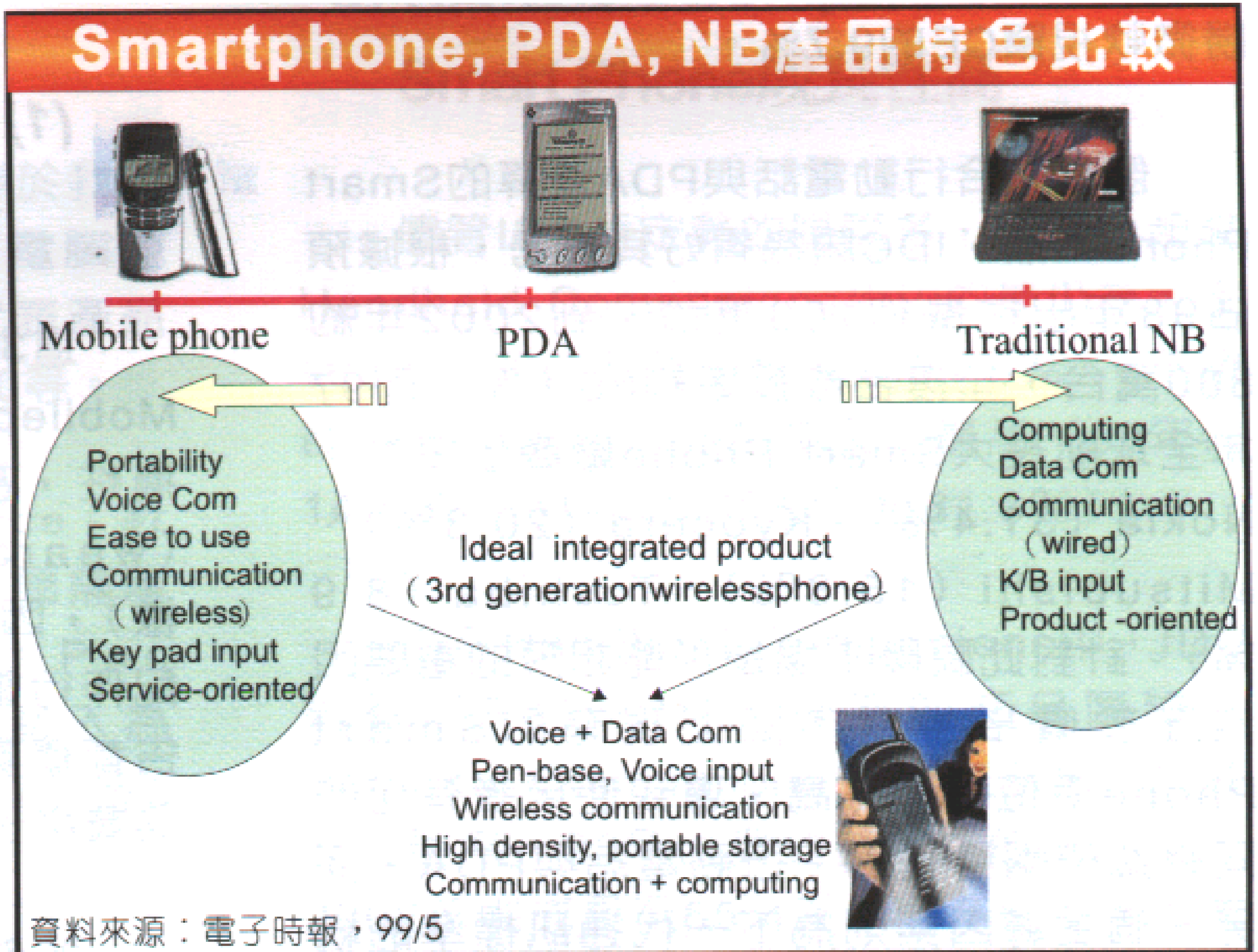
Screen Phones

InfoGear / iPhone
Alcatel / WebTouch
Nortel / Power Touch

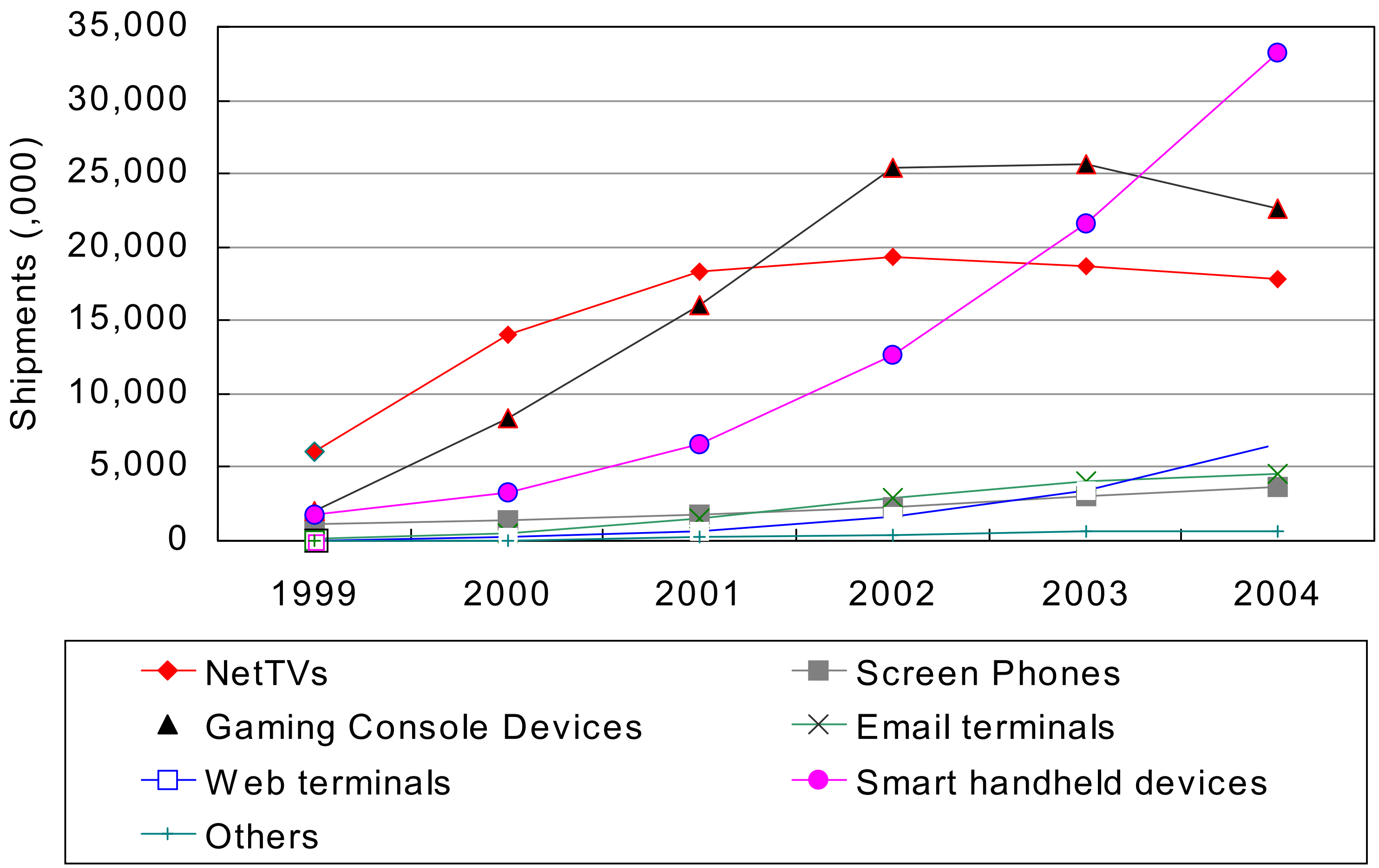
Web terminal

Wyes, Hewlett-Packard,
NCD/Tektronix, Sun,
Boundless, Neoware

3C products

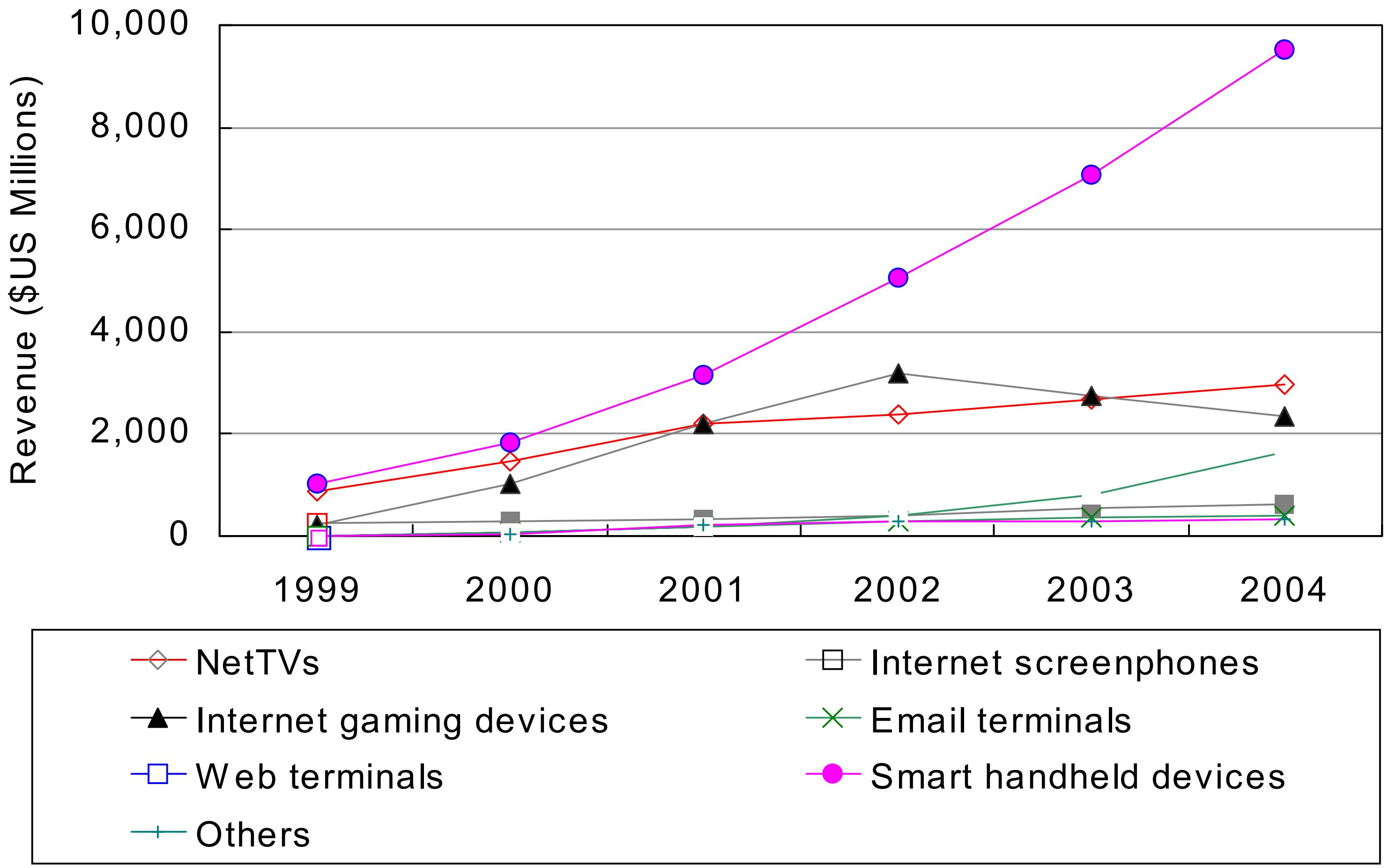

Smartphone, PDA, NB產品特色比較
Mobile phone
PDA
Traditional NB
Portability
Voice Com
Ease to use
Communication
(wireless)
Key pad input
Service-oriented
Ideal integrated product
(3rd generationwirelessphone)
Computing
Data Com
Communication
(wired)
K/B input
Product -oriented
Voice + Data Com
Pen-base, Voice input
Wireless communication
High density, portable storage
Communication + computing
資料來源：電子時報，99/5

IA market prediction (I)

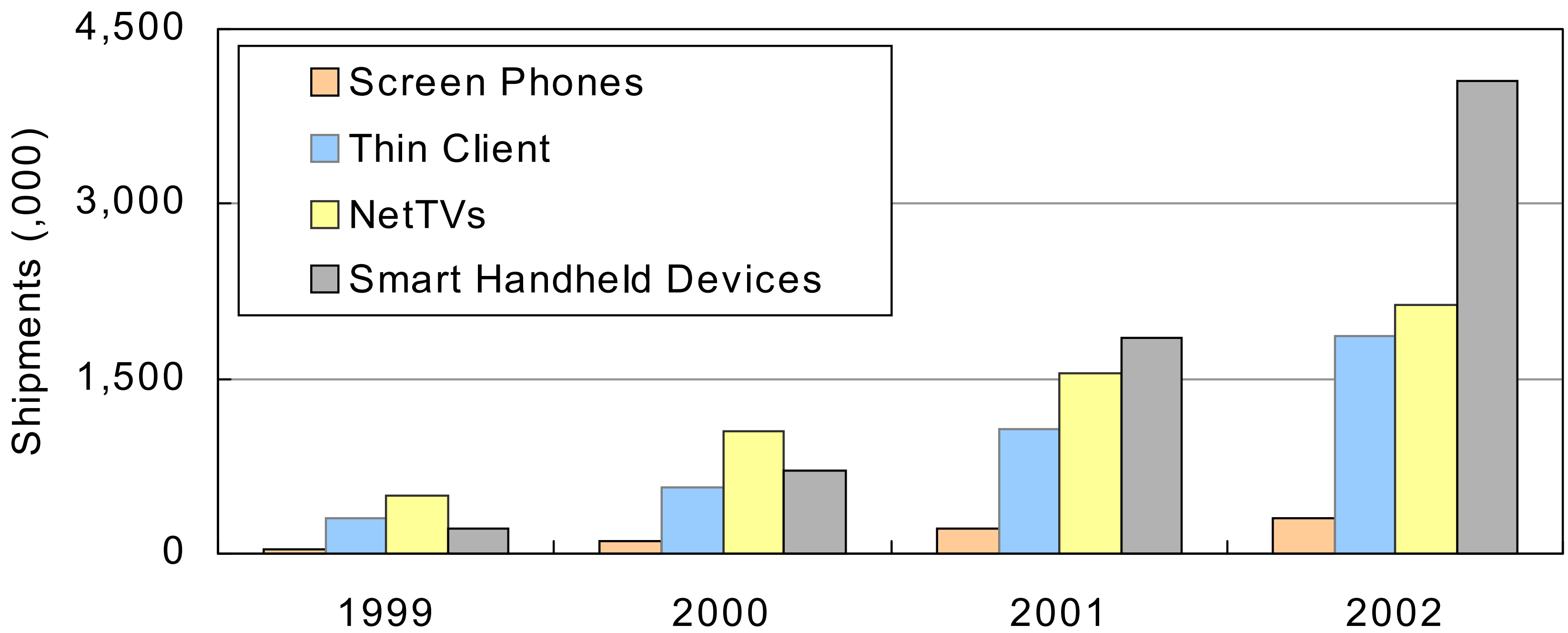


(Source: IDC, MIC ITIS 2000/3)

IA market prediction (II)

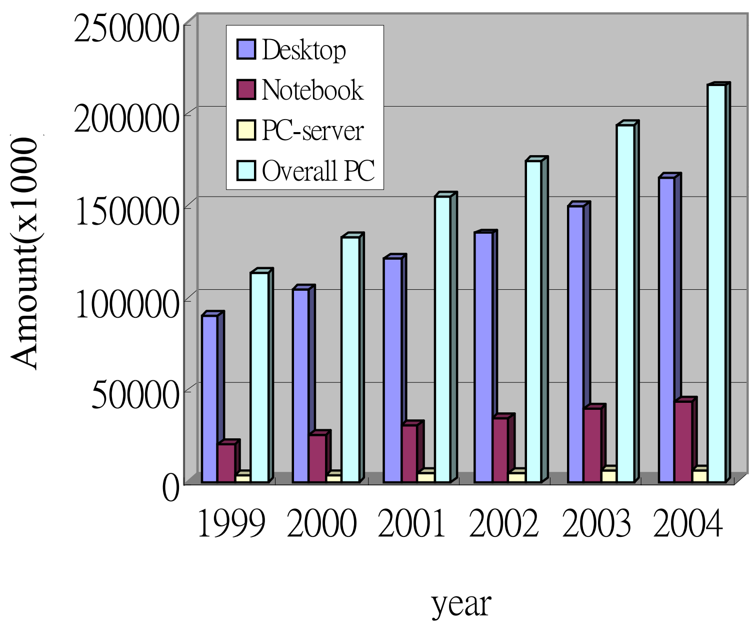


Prediction of IA from Taiwan

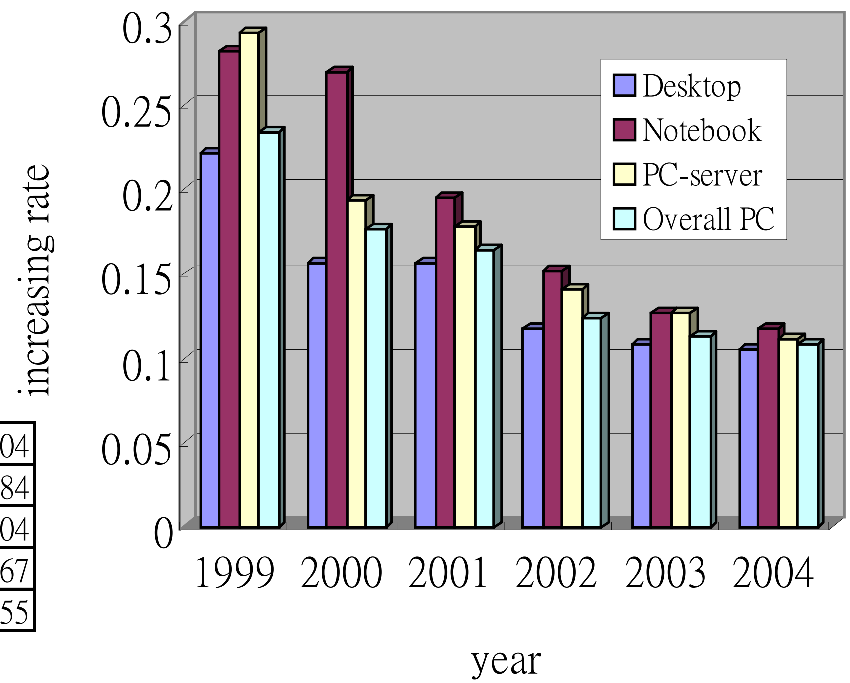


(Source: MIC ITIS 1999/12)

PC market analysis (1999-2004)



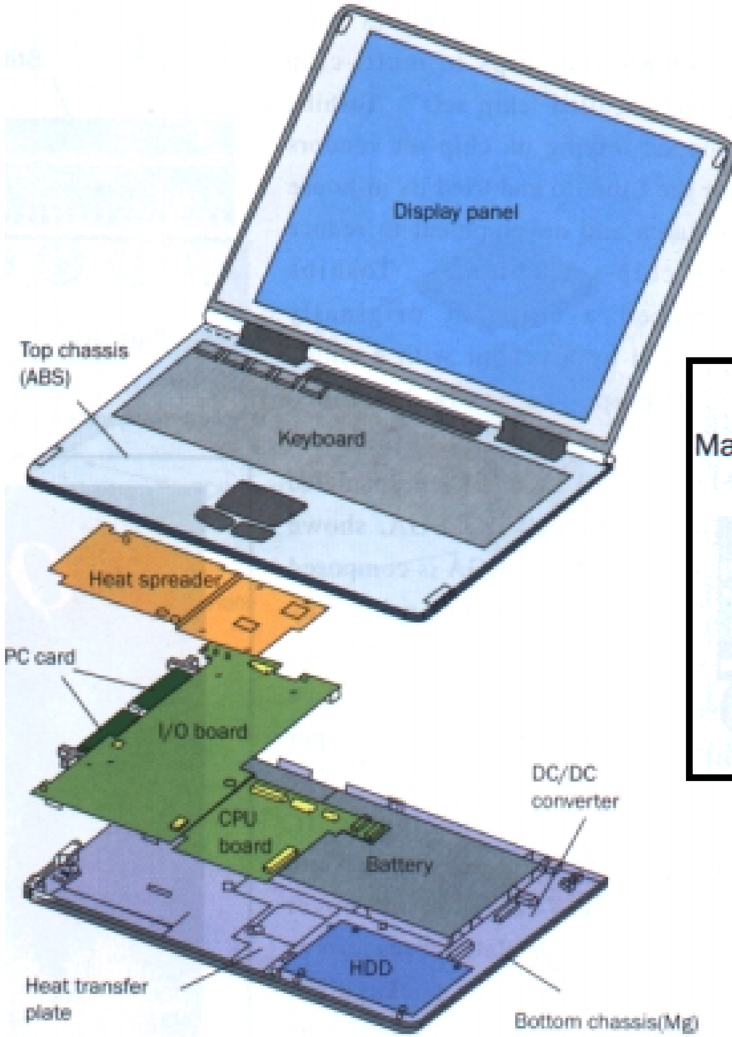
	1999	2000	2001	2002	2003	2004
Desktop	0.222	0.156	0.156	0.117	0.108	0.105
Notebook	0.282	0.269	0.195	0.151	0.127	0.117
PC-server	0.293	0.194	0.178	0.141	0.126	0.111
Overall PC	0.234	0.177	0.164	0.124	0.112	0.108

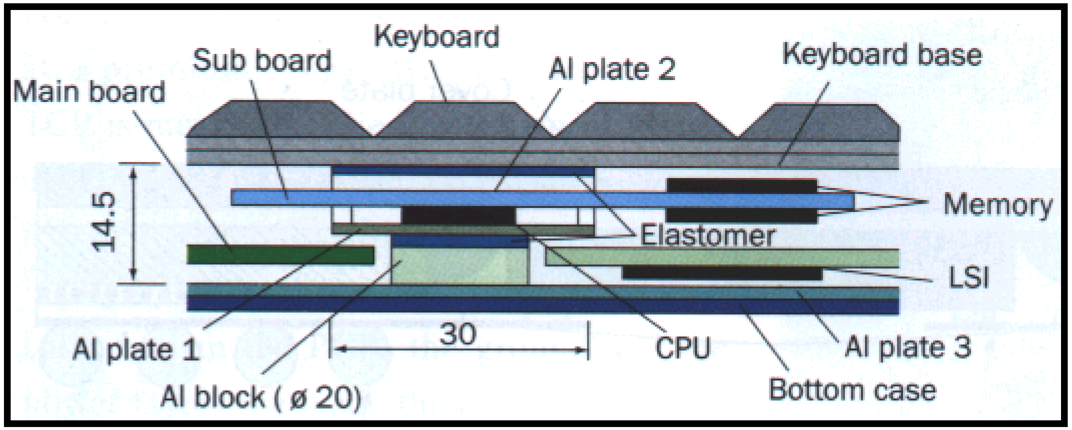


	1999	2000	2001	2002	2003	2004
Desktop	90260	104310	120551	134676	149205	164884
Notebook	19935	25295	30240	34798	39222	43804
PC-server	3125	3731	4394	5013	5643	6267
Overall PC	113320	133336	155185	174487	194070	214955

(unit: x1000, Source: IDC)

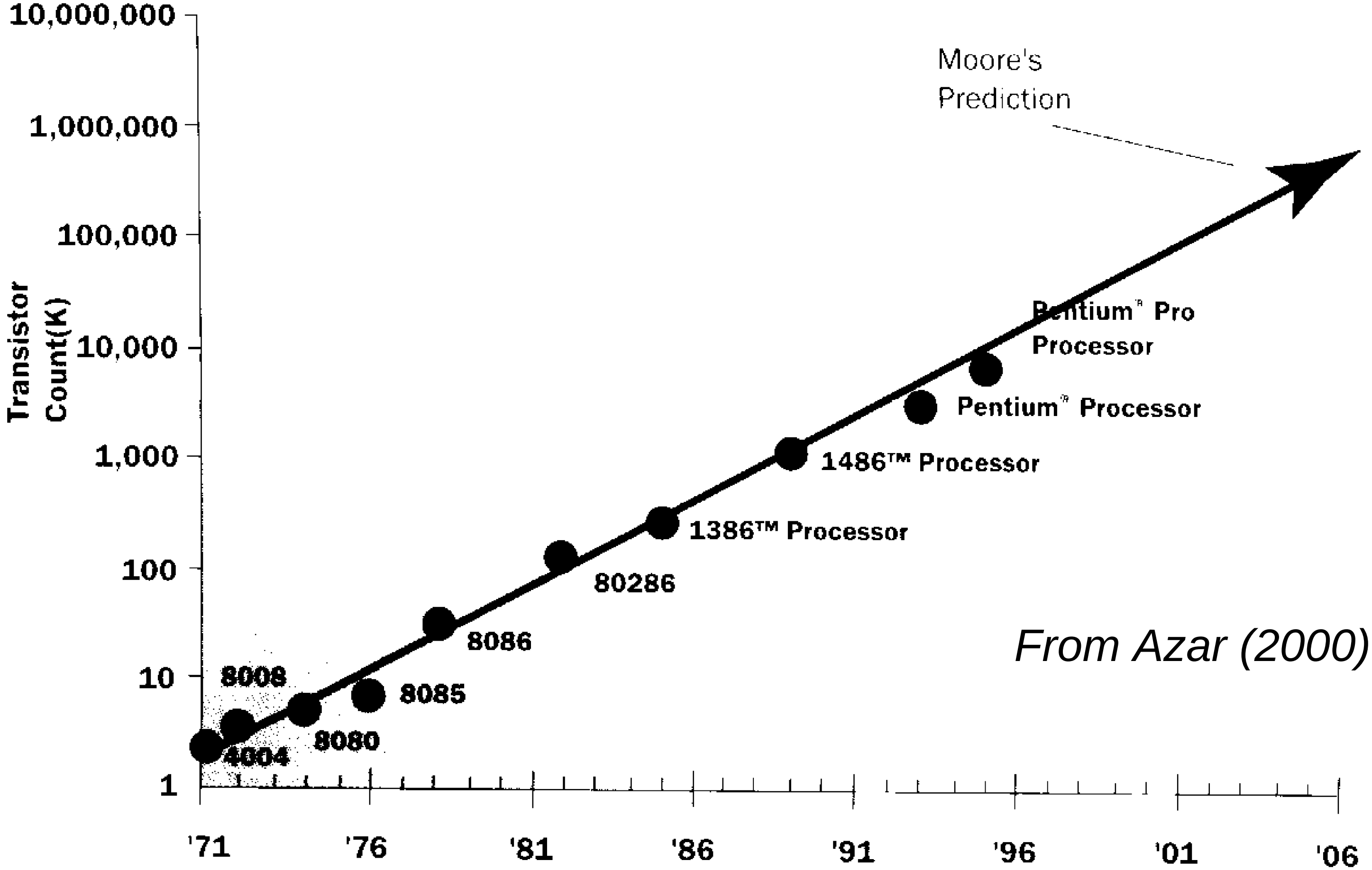
NB design & analysis





(W. Nakayama (1998))

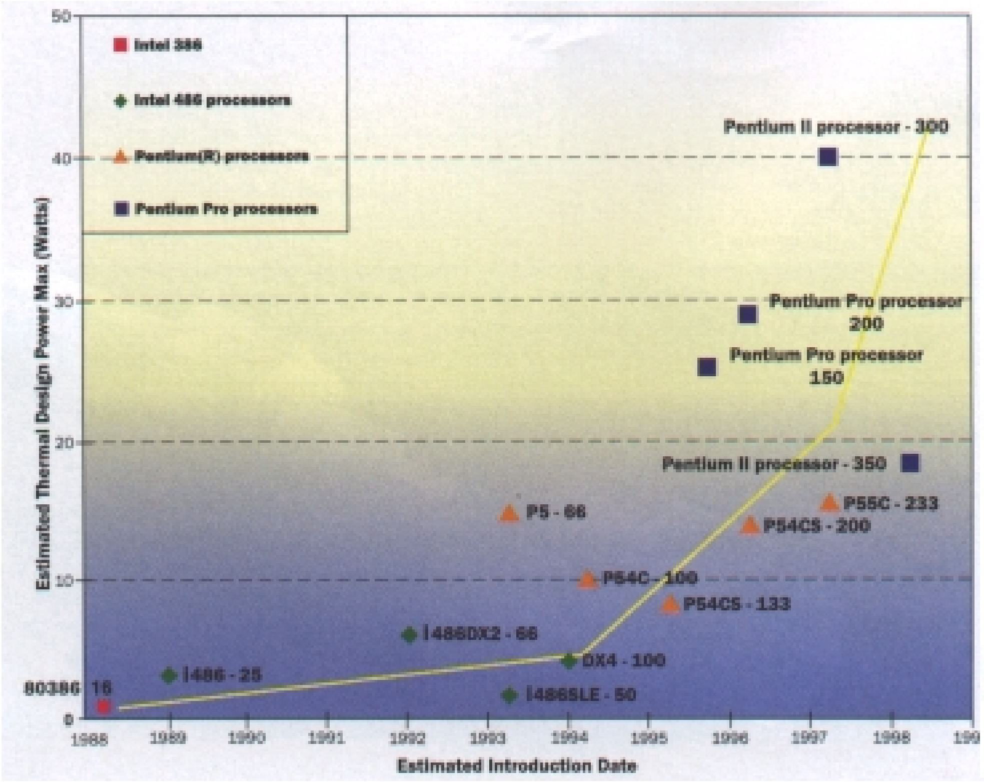
The Need of Thermal Management

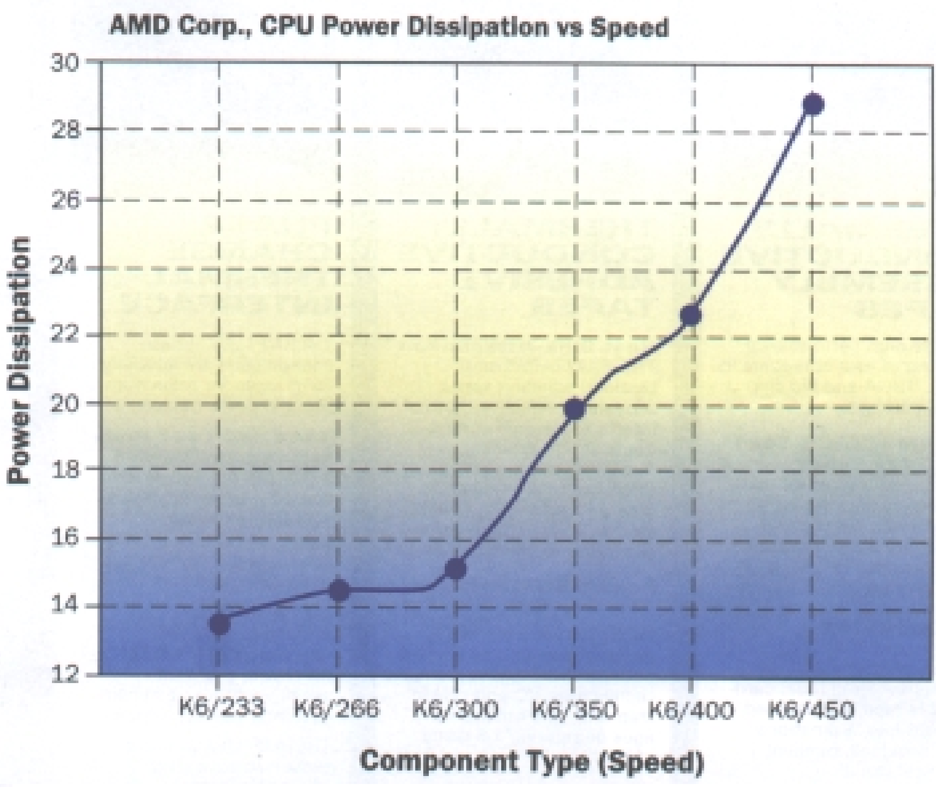


From Azar (2000)

Thermal design of CPU

Design constrain: $T_{j,max} \leq 125°C$

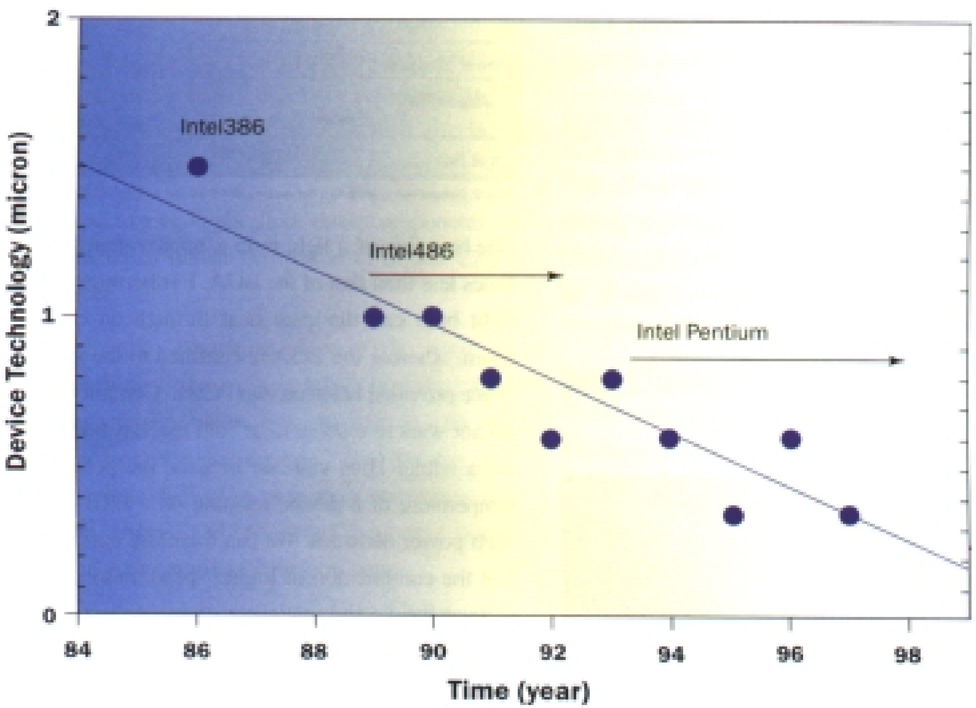




From Azar (2000)

Thermal requirement & design

Year	No. Gates/Device	Feature Size (μm)	Voltage	Power ($\mu W/Gate/MHz$)
1995	300k	0.35	3.3V	0.64
1997	1m	0.25	3.0V	0.27
1999	3m	0.25	2.5V	0.15



	Light Bulb	BGA Package
Power dissipation	100W	25W
Surface area	106 cm^2 (bulb surface area)	1.96 cm^2 (die area)
Heat flux	0.9 W/cm^2	12.75 W/cm^2

- High speed
- No. gates on device
- Spatial constrain

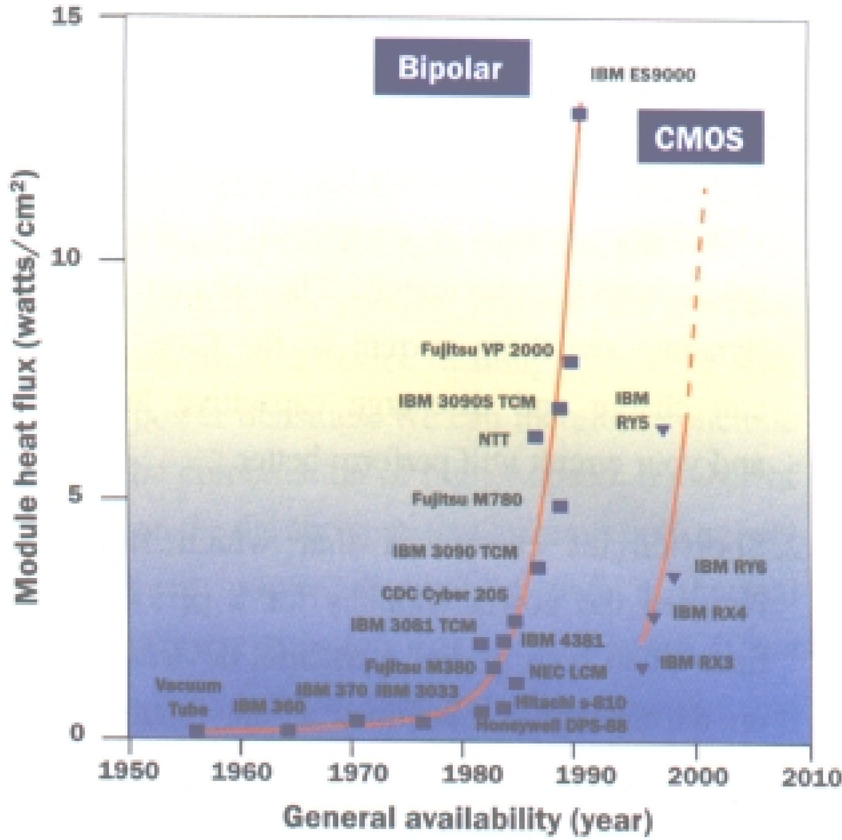
From Azar (2000)

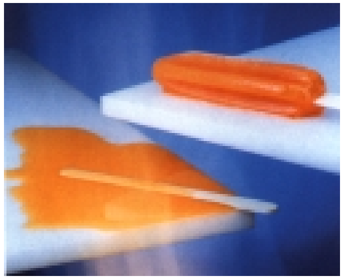
Solutions in the future

New electronic technology

- Silicon germanium (SiGe)
- Amorphous computing
- DNA, optical and quantum machine New cooling technology
- More precise CFD-designs,
- New material ..

From Azar (2000)





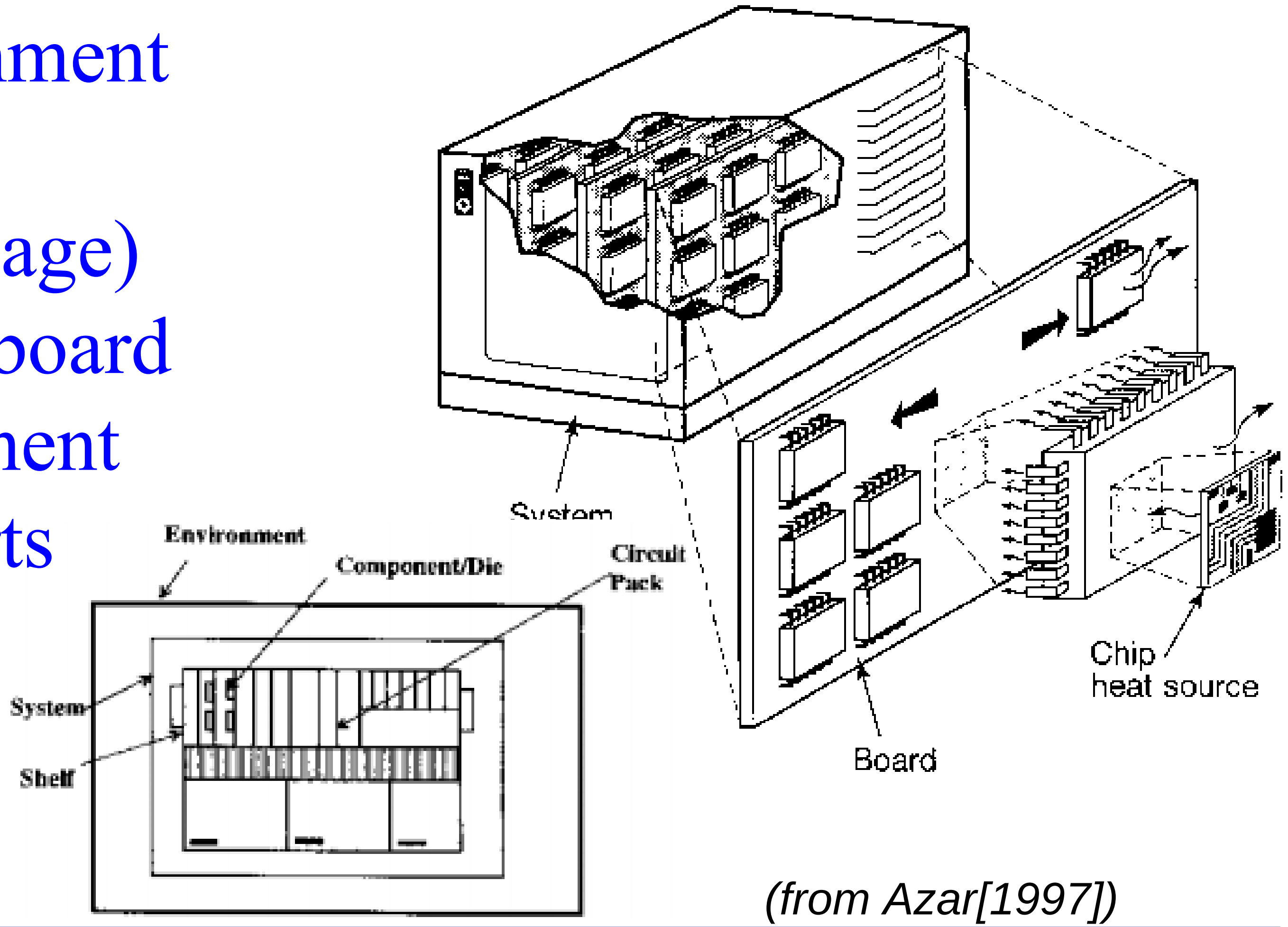
(photo: thermally conductive plastic compound from Mack Plastics, k > 20W/mK up to 600°F)

The need of thermal management

- The objective of thermal management is to ensure reliable mechanical and operational performance for adverse environmental condition of system.
- Reduction of temperature
  ⇨ reduce thermal stress ⇨ remain operation reliability
- component junction temperature within 80 ~ 180°C.

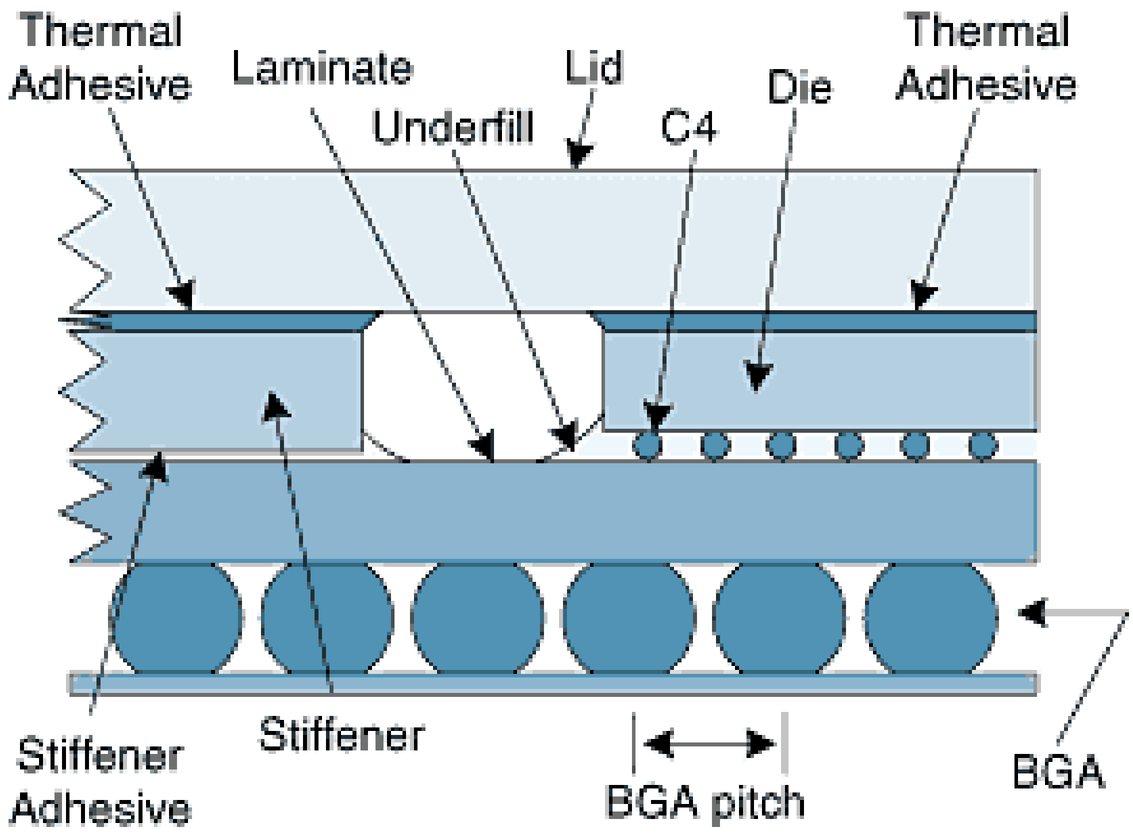
Electronic cooling

- An electronic enclosure includes:
  - environment
  - system
  - shelf (cage)
  - circuit board
  - component
  - Die parts

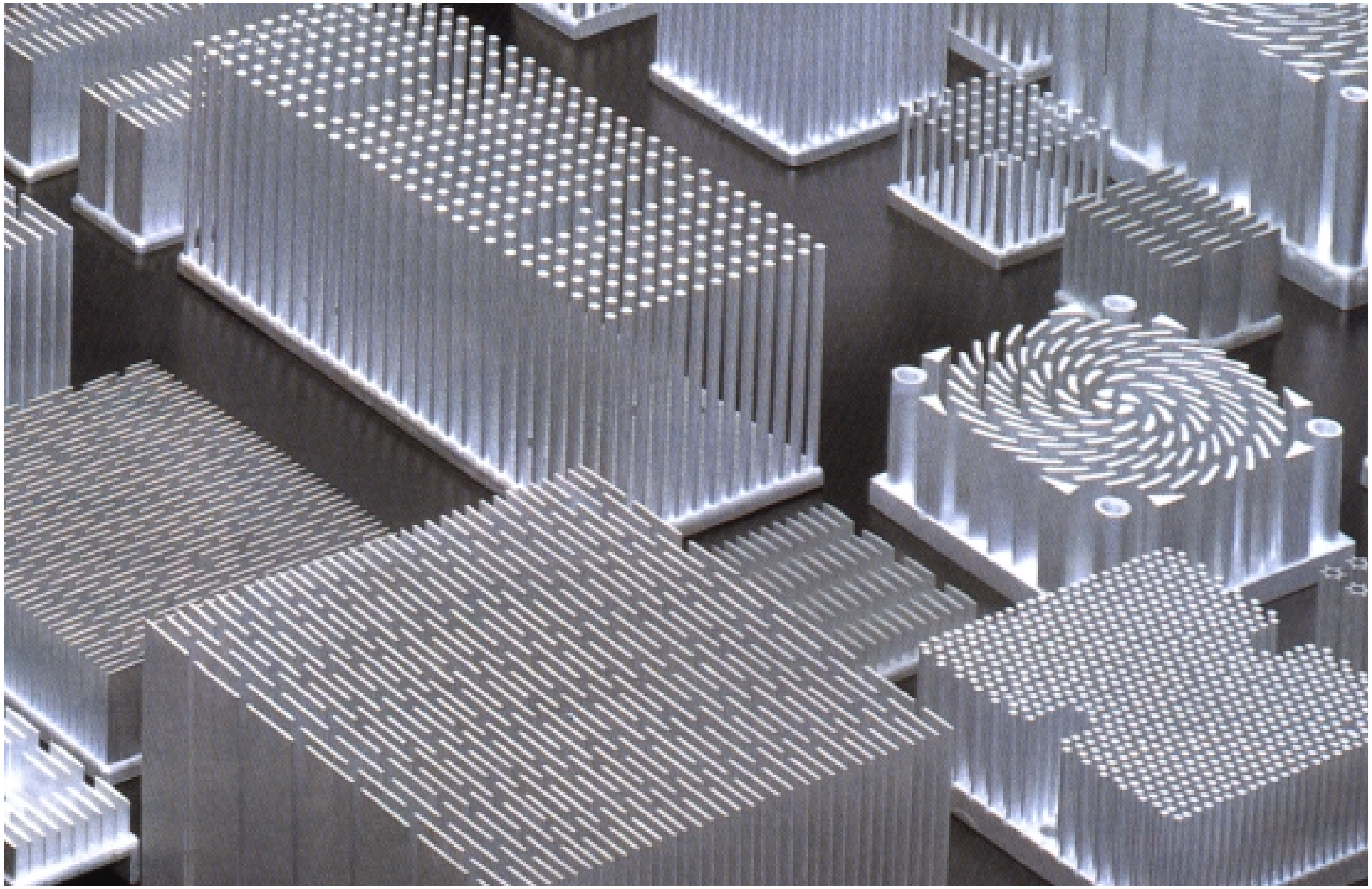


(from Azar[1997])

Example of thermal management



Electronic sink design

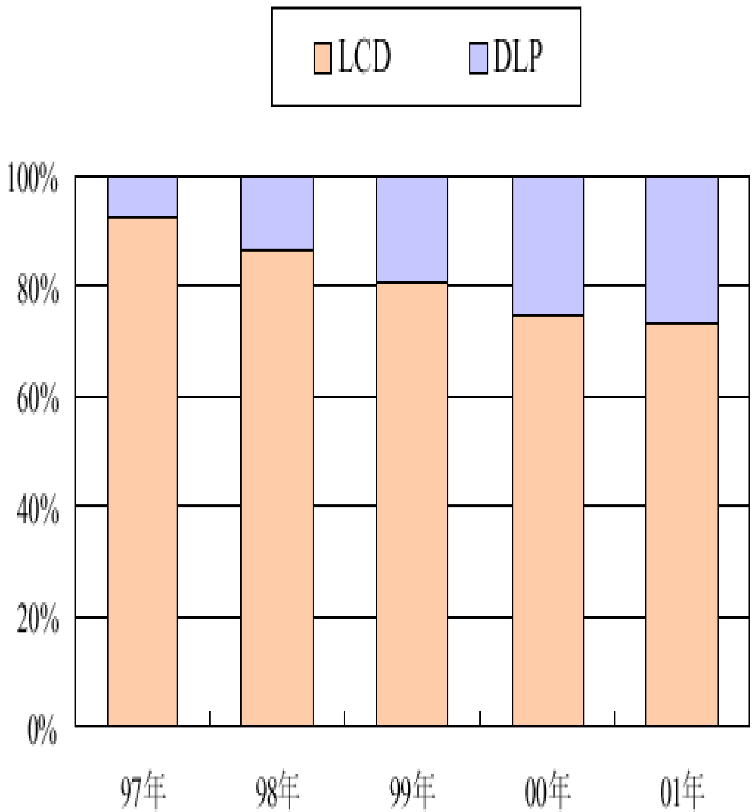


Data projector

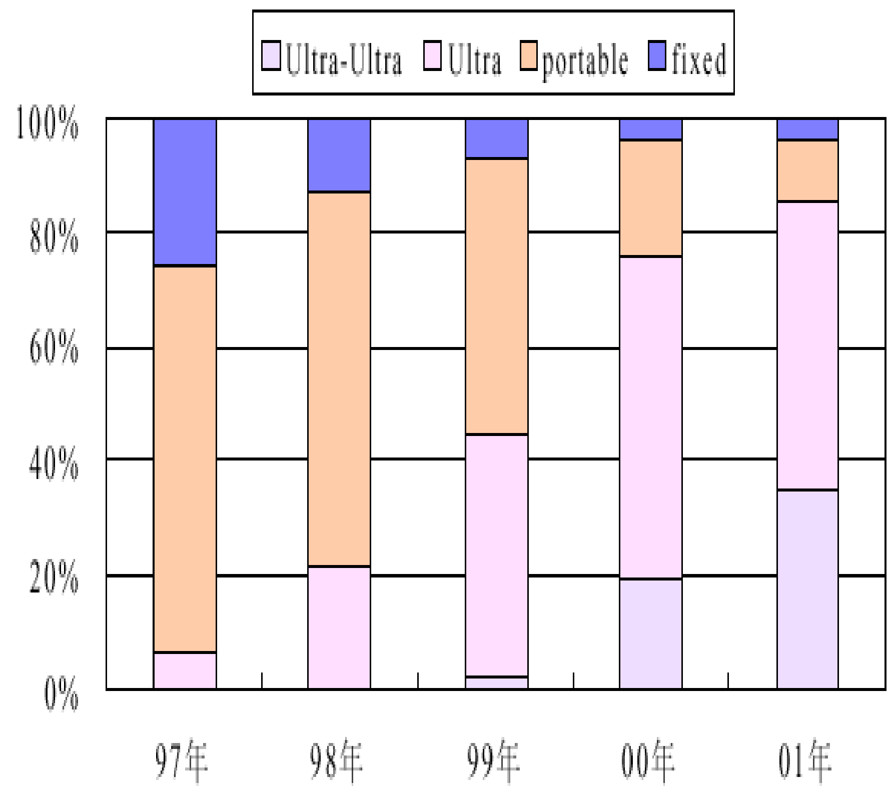
- The size-limit of the CRT-TV ~ 40”, (> 100kg)
- Projection type is suitable for the large size display, e.g., 40“ ~ 60” (or more)
- Advantages of the data projector (in comparison with the RGB-CRT projector):
  - small size, light
  - high lumination (ANSI > 800Lumens)
  - high resolution (800x 600SVGA, 1024 x 768XGA)
  - lower price
  - user-friendly

Development of Data projector

Type:



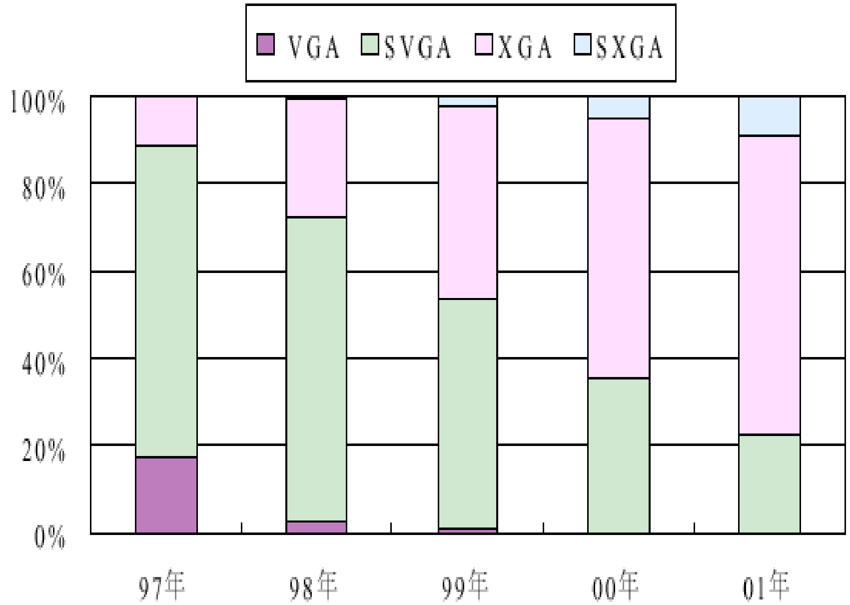
Weight:



(Source: PIDA)

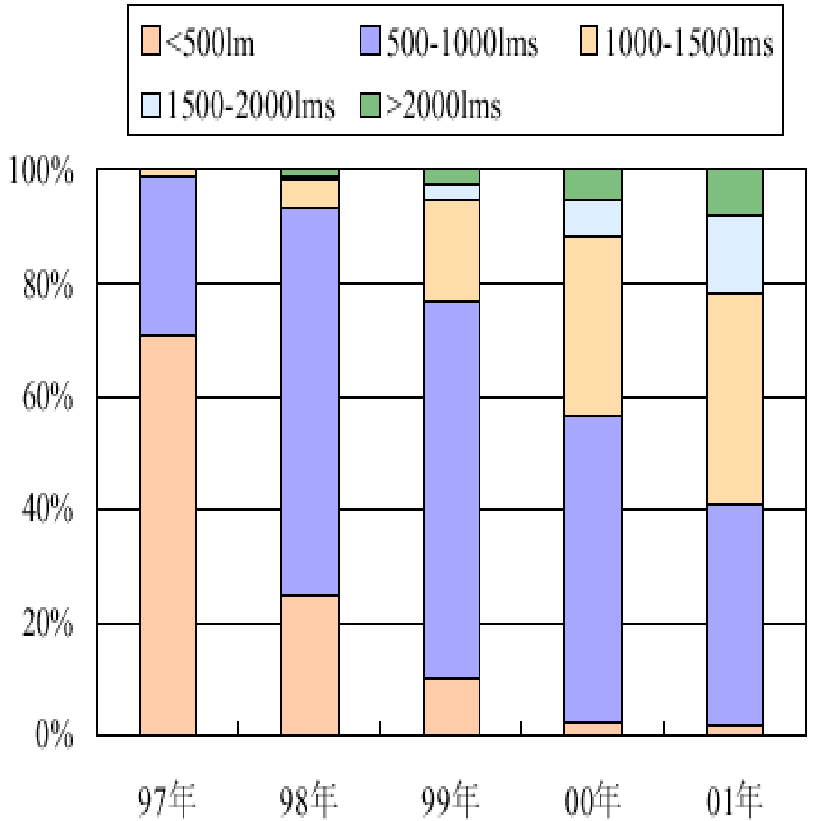
Development of Data projector

Resolution:



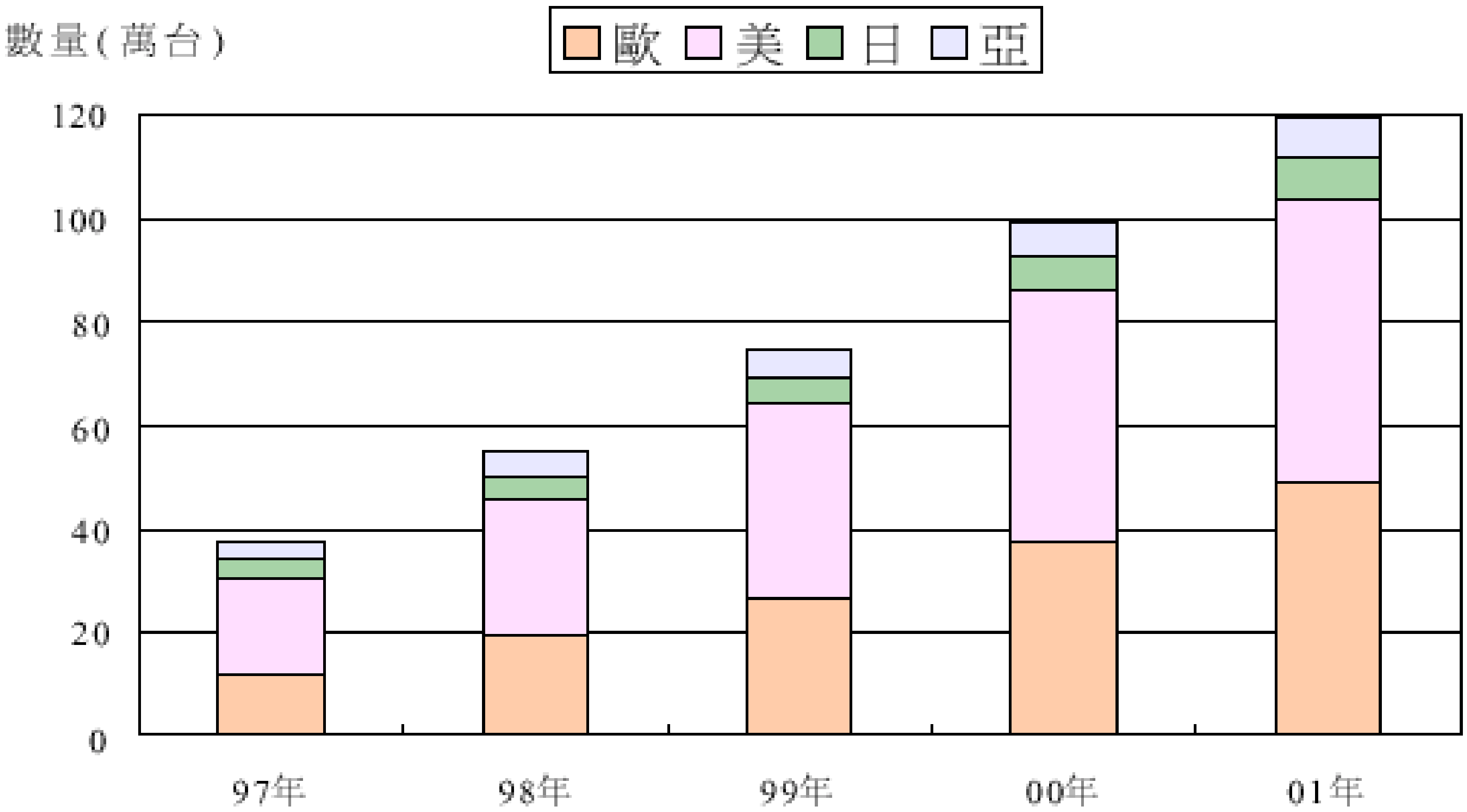
VGA:640x480
SVGA:800x640
XGA:1024x768
SXGA:1280x1024
UXGA:1600x1200

Brightness:



(Source: PIDA)

Market of Data projector

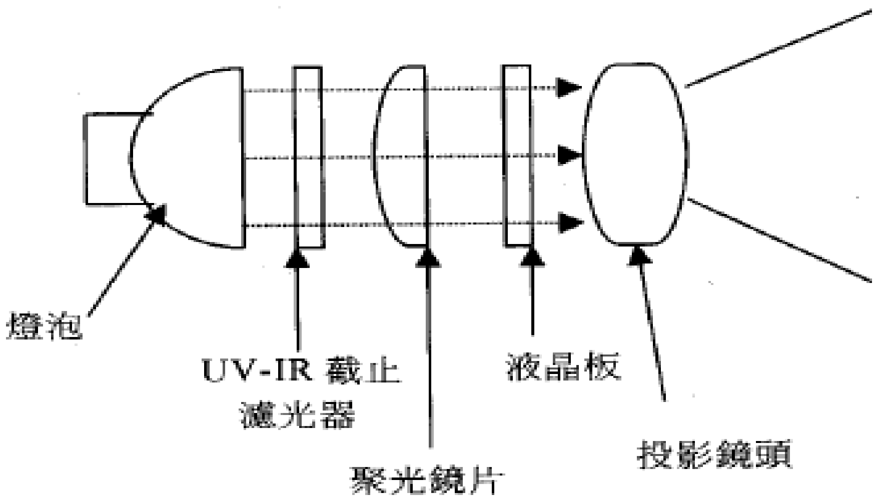


(Source: PIDA)

Schematic diagram of Data projector

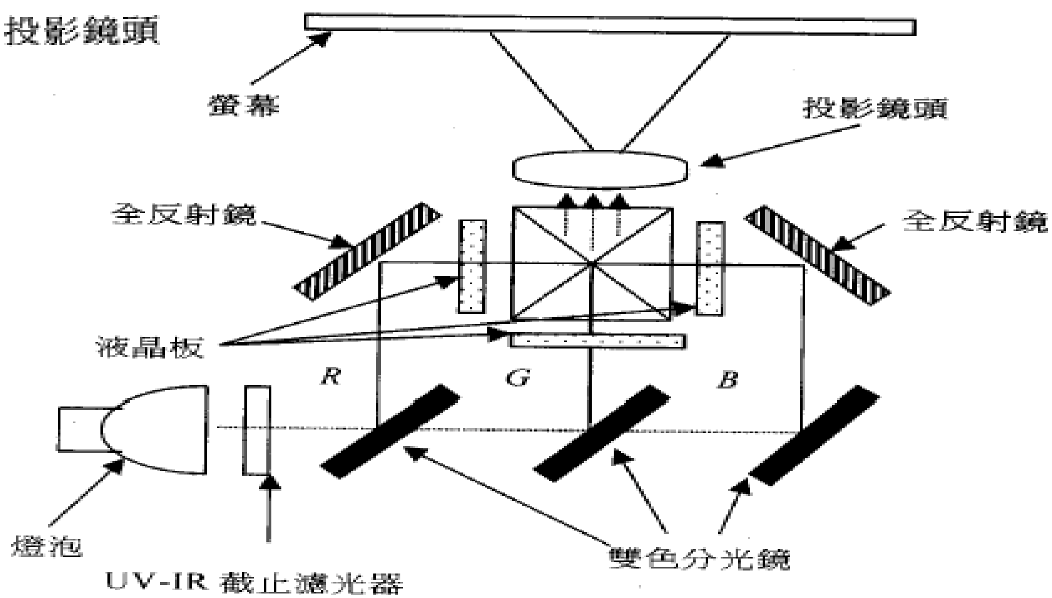
- A data projector includes (a) illumination, (b) color separation & combination, and (c) projection subsystems

LCD Data projector

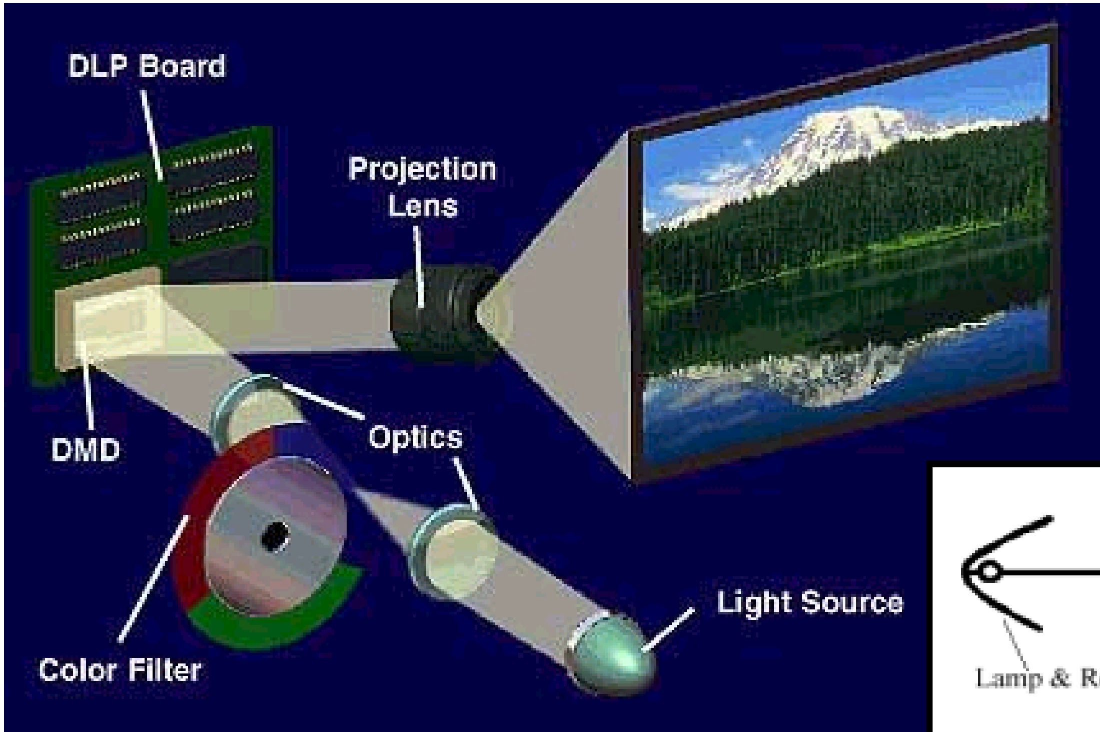


LCD: liquid crystal display

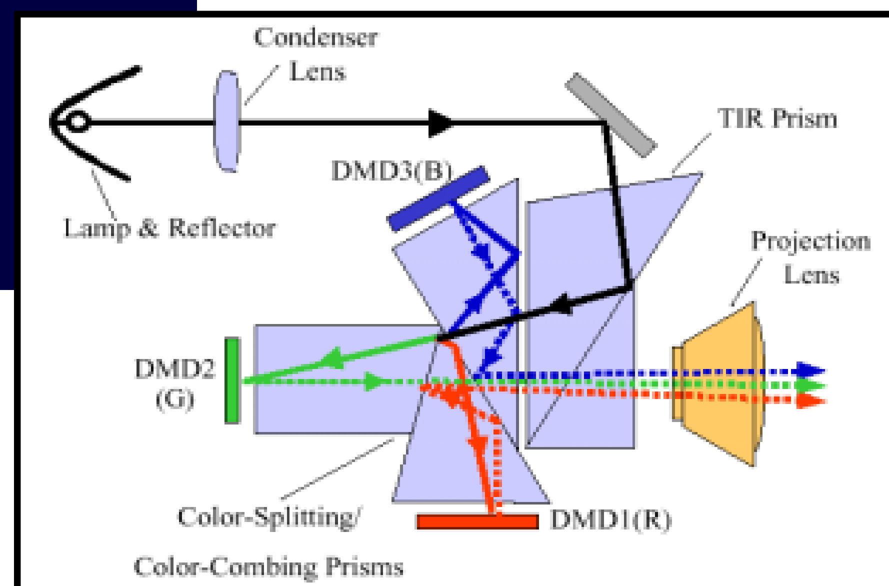
Single panel type & 3-panel type



DLP Data projector

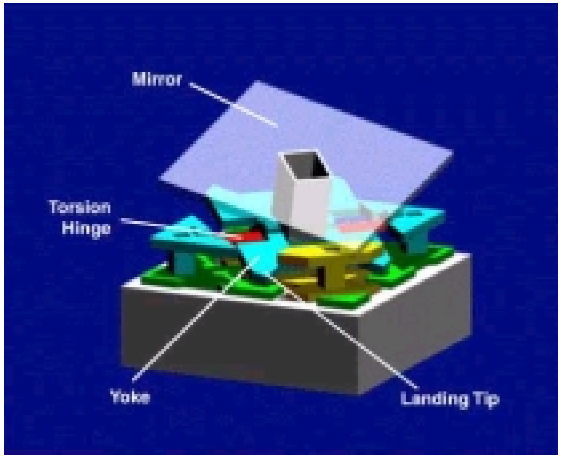


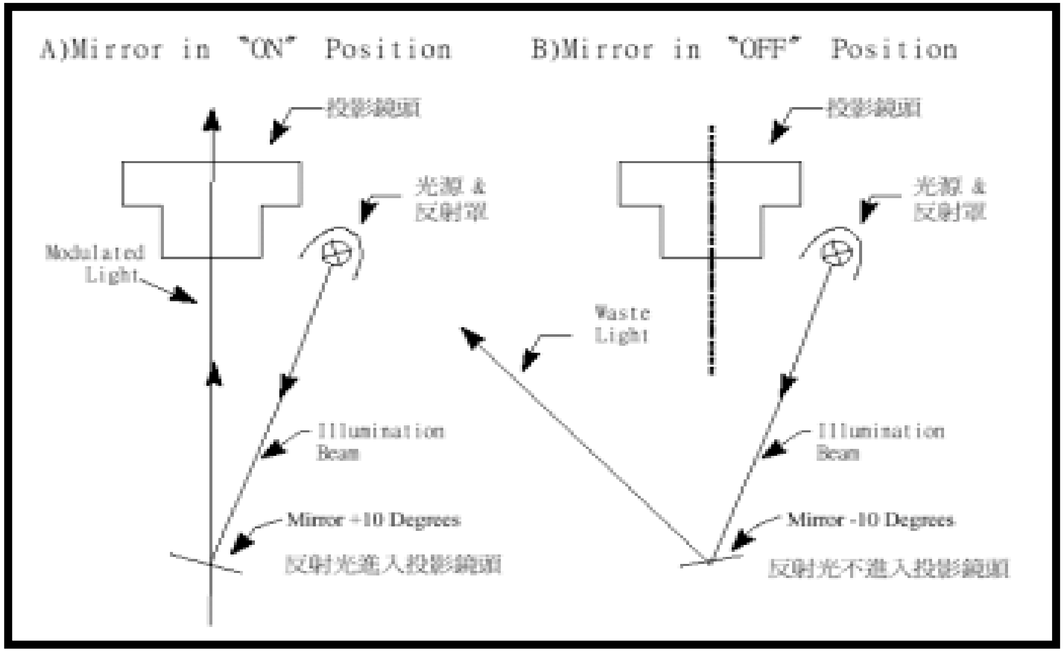
DLP: digital light processing



DLP Projector Optical System

DMD





(source: WWW.TI.COM)

LCD & DLP

LCD: liquid crystal display

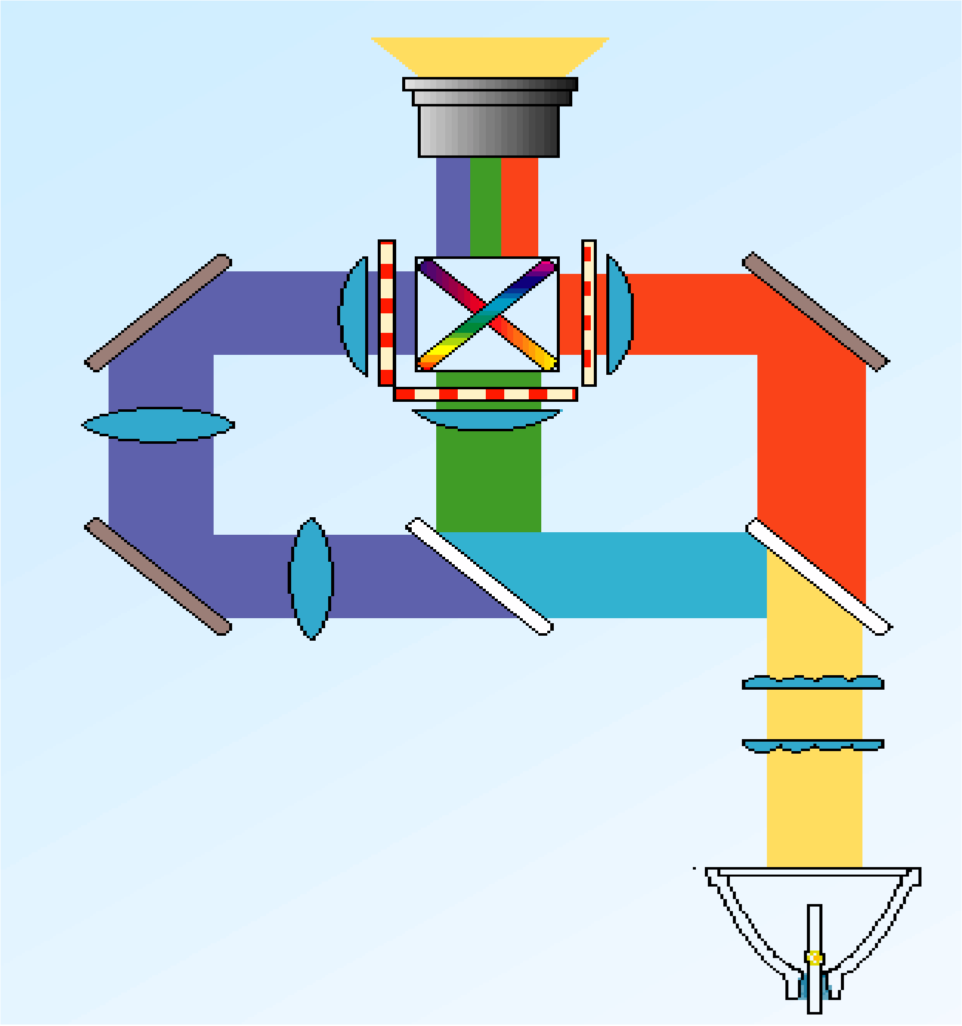
DLP: digital Light processing

	LCD	DLP
resolution	VGA, XGA	XGA
brightness	High	Low
contrast	High	Low
weight	Heavy	Light
complexity	High	Low
cost	Low	High

Development of Data projector

- Future development:
  - lower cost
  - lower weight
  - lower noise
  - satisfactory resolution
  - satisfactory light intensity
  - better light uniformity
  - high efficiency (Lumen/watt)

Development of Data projector



× 0.9 (optics)

× 0.6 (display)

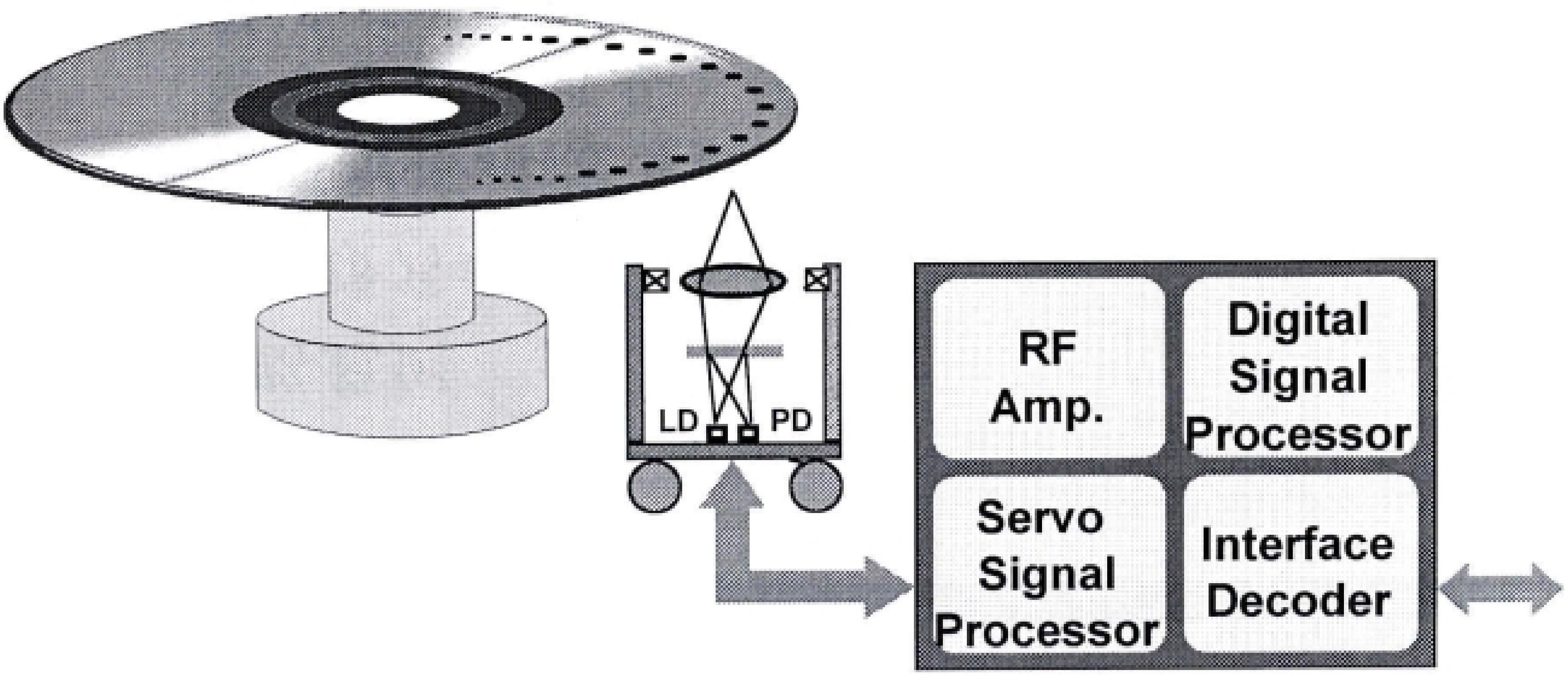
× 0.66 (color)

× 0.8 (polarisation)

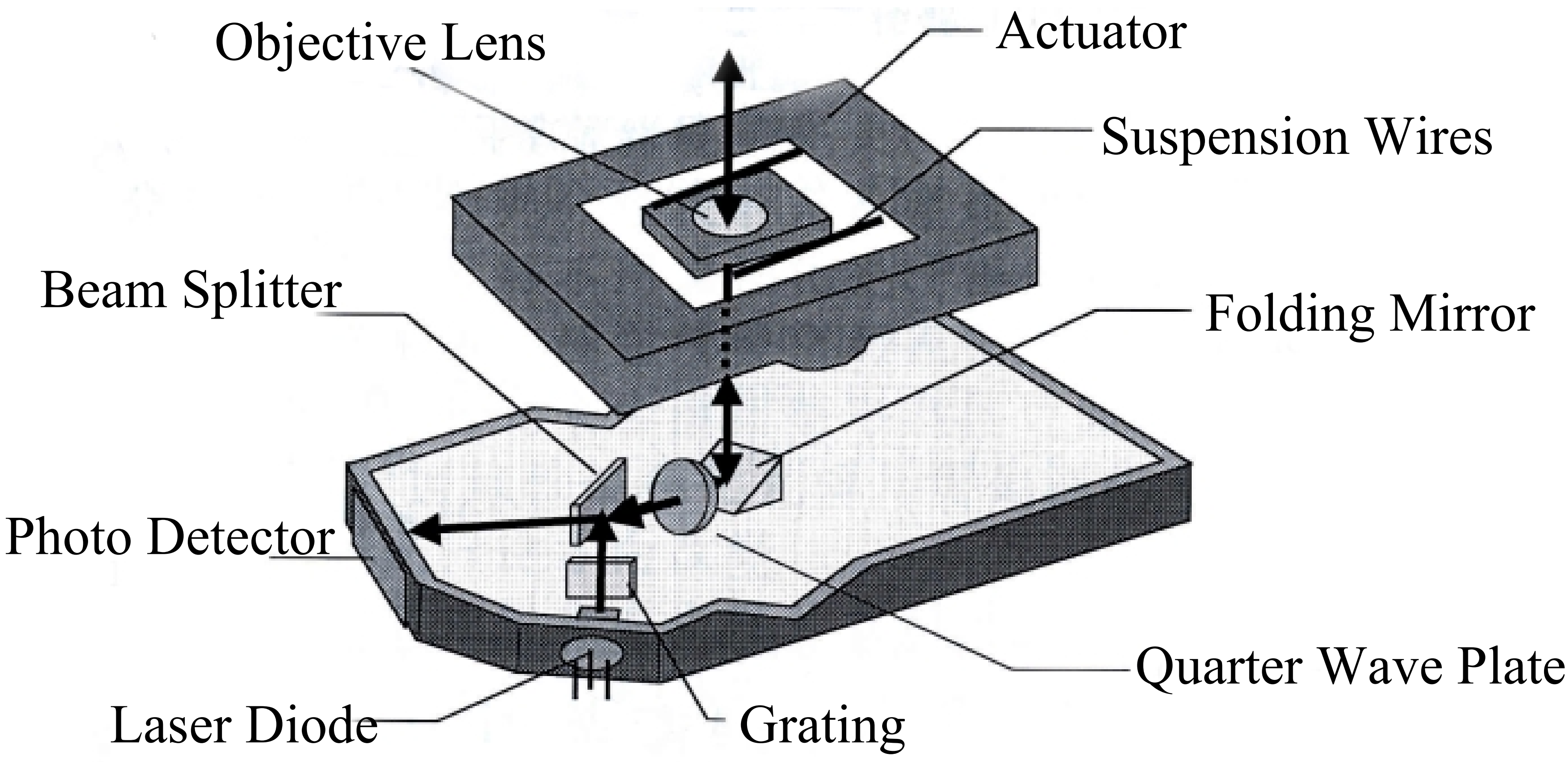
~0.3 total optical efficiency

more than 25% today in comparison with 5% in 1993.

DVD/CD constructure

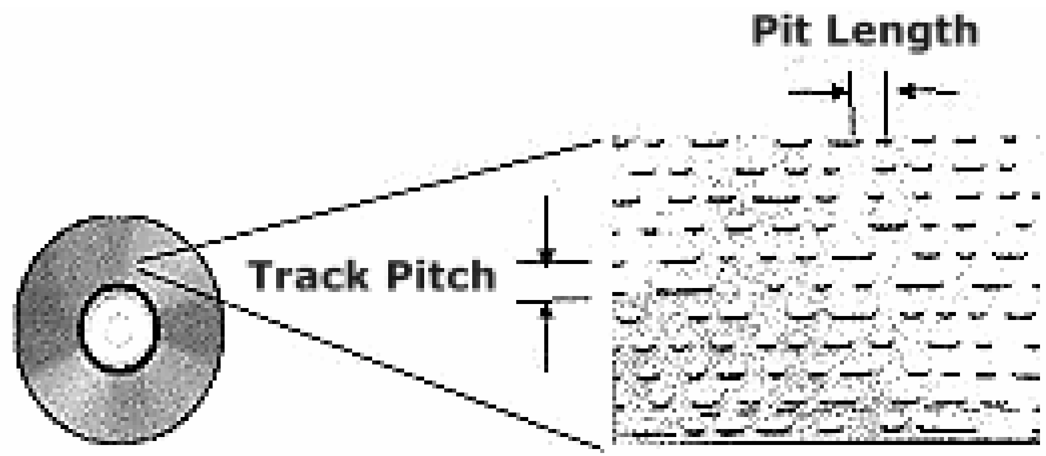


Pickup head of DVD/CD



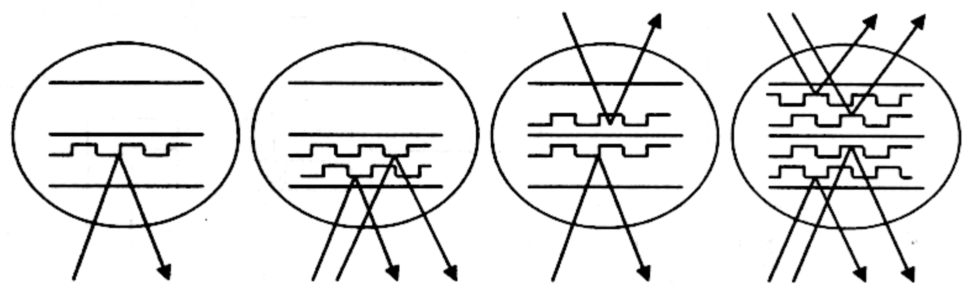
DVD & CD

	DVD	CD
Track pitch (um)	0.74	1.6
Minimum pit length (um)	0.4/0.43	0.83
Substrate thickness (mm)	0.6	1.2
Wavelength (nm)	650	780
Reference velocity (m/s)	3.49/3.84	1.2~1.4
Numerical aperature	0.6	0.45



DVD & CD

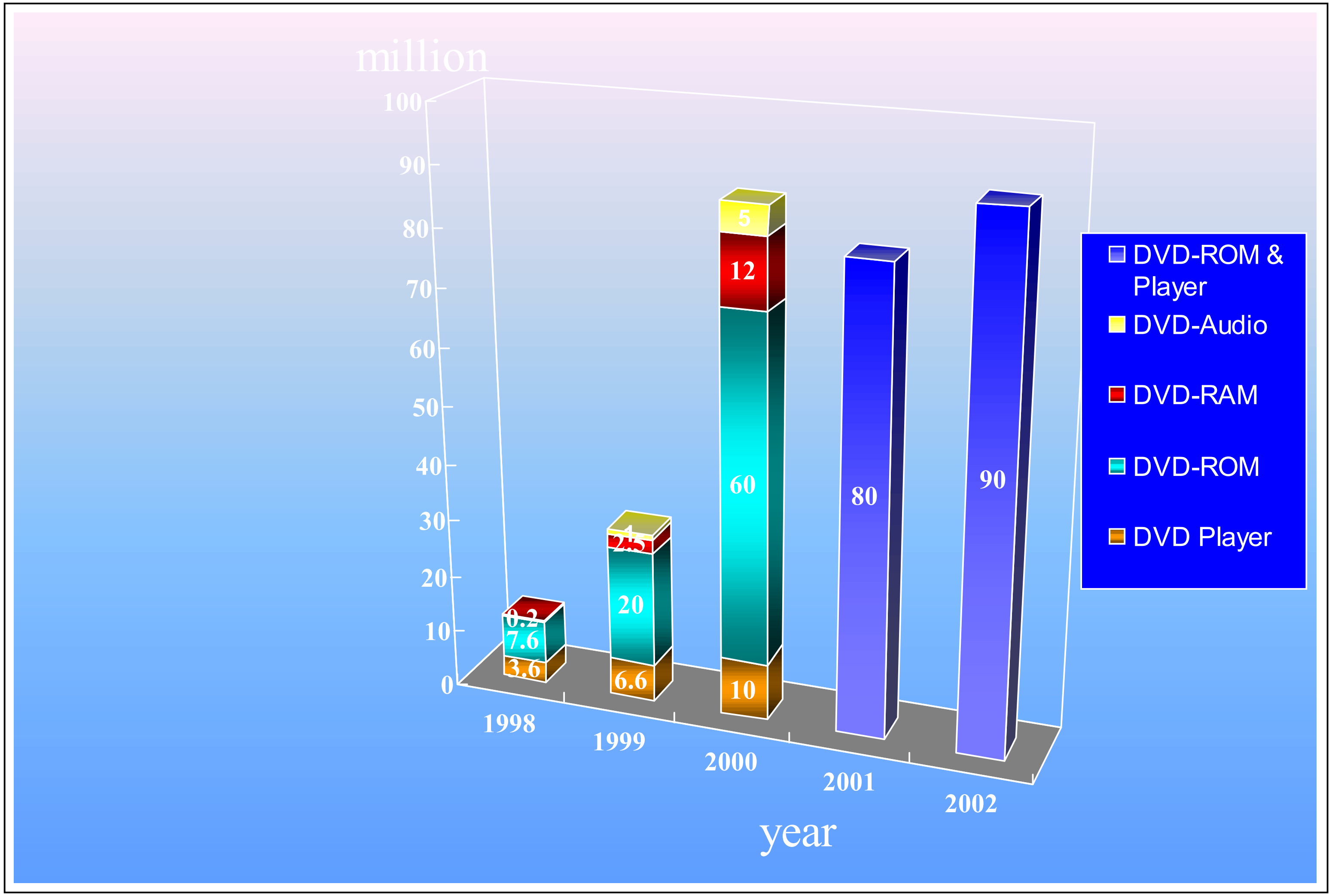
Discs		Single sided single layer	Single sided dual layer	double-sided single layer	Double-sided dual layer
Max. capacity	12cm	4.7GB	8.5GB	9.4GB	17GB
	8cm	1.4GB	2.6GB	2.8GB	5.2GB



Reflectivity：SL 45~85%，DL 18~30%

Distance between two layer：55± 15 μm

DVD-driver market



Specification of pickup head

- Spot size on track — λ/NA
- Spot size on substrate — $d\,NA$
- Defocus margin — $\lambda/(NA)^2$
- Tilt margin — $\lambda/d(NA)^3$
- Spherical aberration — $\lambda/\delta(NA)^4$

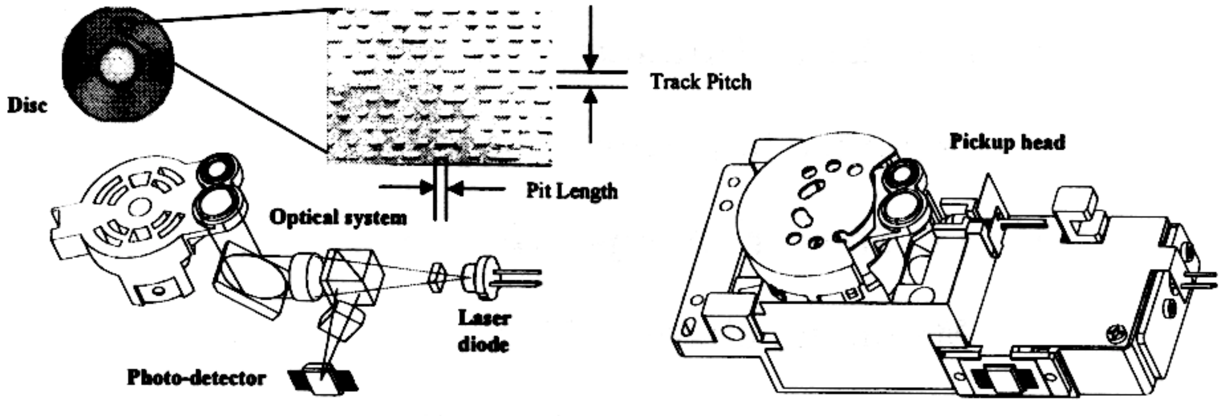
NA ： Objective lens numerical aperture

λ ： Wavelength of light source

d ： Substrate thickness

δ ： Thickness variation

Difficulties of DVD



- DVD pickup heads read high density disc(4.7G)：Track 0.74 μm，min. pit length 0.4 μm
- Objective lens NA=0.6 and spot size (FWHM) must be smaller than 0.6 μm .
- DVD optical heads have complicated optical system, high speed response actuator, and high bandwidth photo detector, and generate the signals to focusing , tracking, and reading.
- DVD optical heads have high precision demand：focusing error＜± 0.23 μm，tracking ＜± 0.022 μm，optical head axis tilt error＜± 10 arc min.

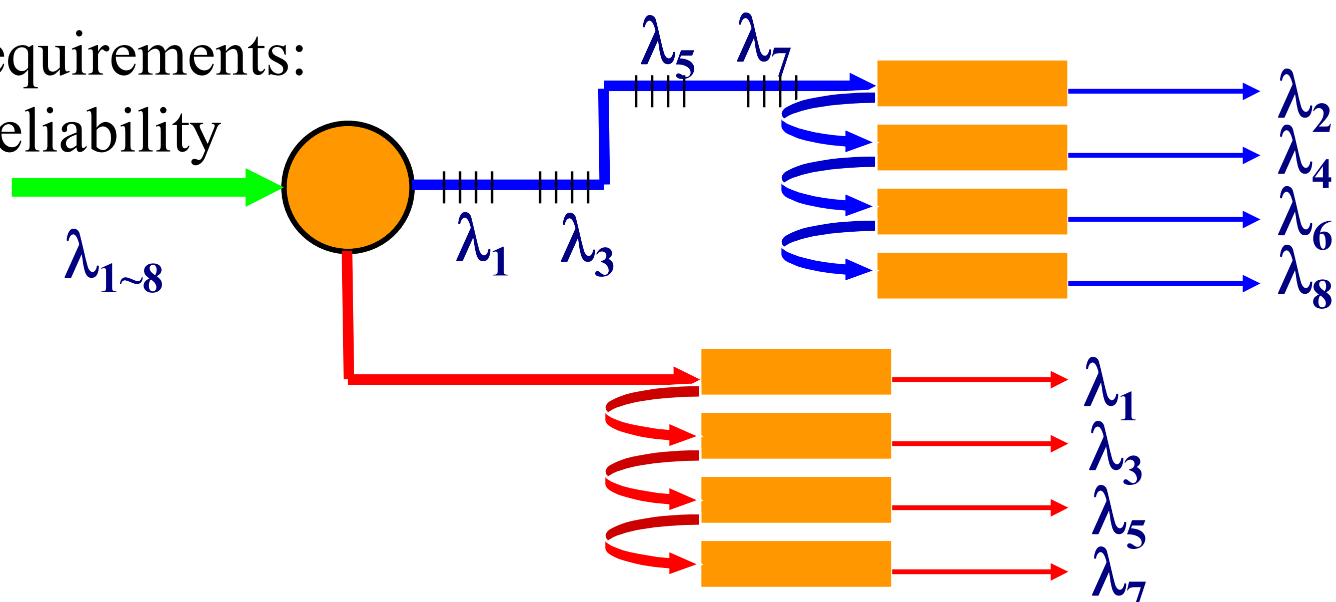
Bragg fiber grating (I)

Application: wave selector for optical communication

$\lambda = 2\ m\ n\ \Lambda$

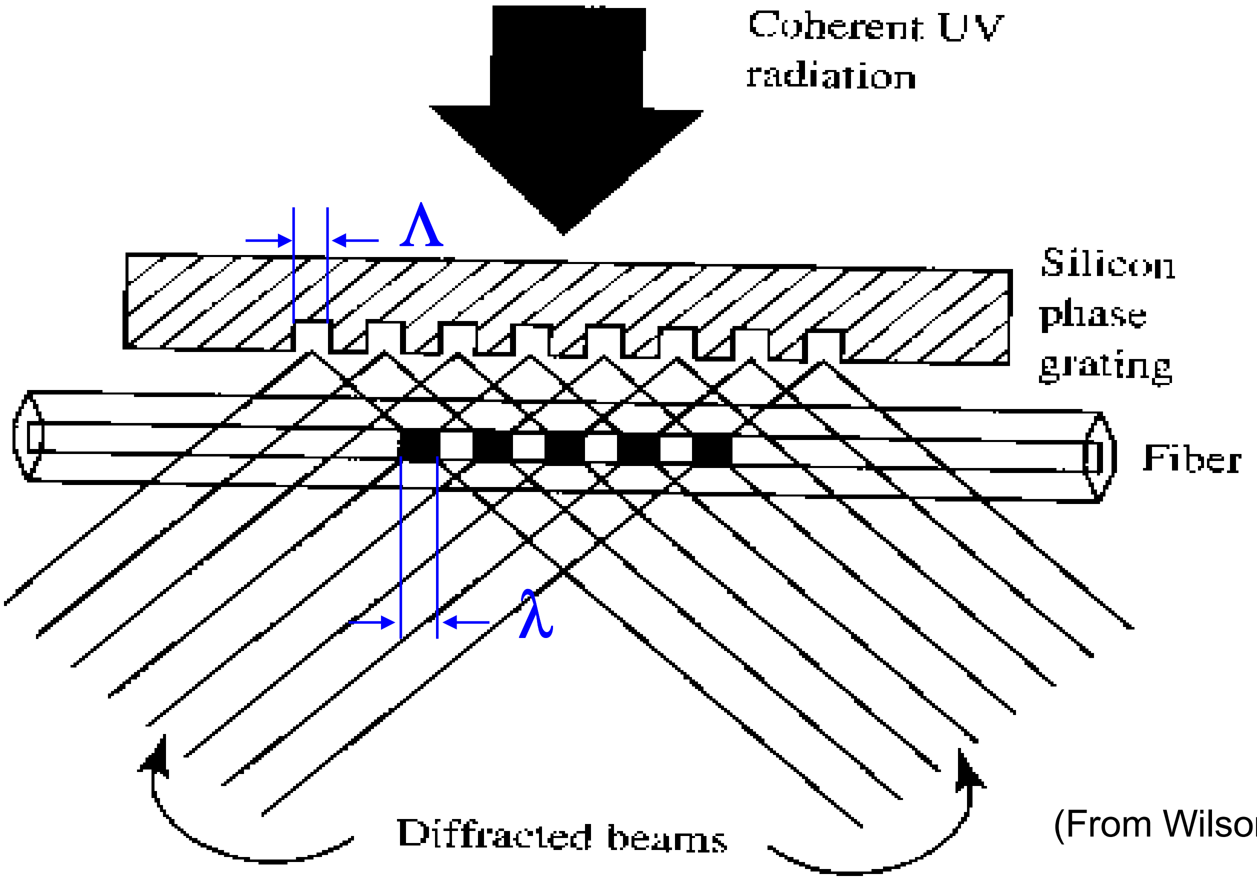
Requirements:

- reliability



Bragg fiber grating fabrication

Ga-doped fiber $\xrightarrow{\text{UV}(\sim 240\text{nm})}$ $\Delta n\ (\sim 10^{-4})$



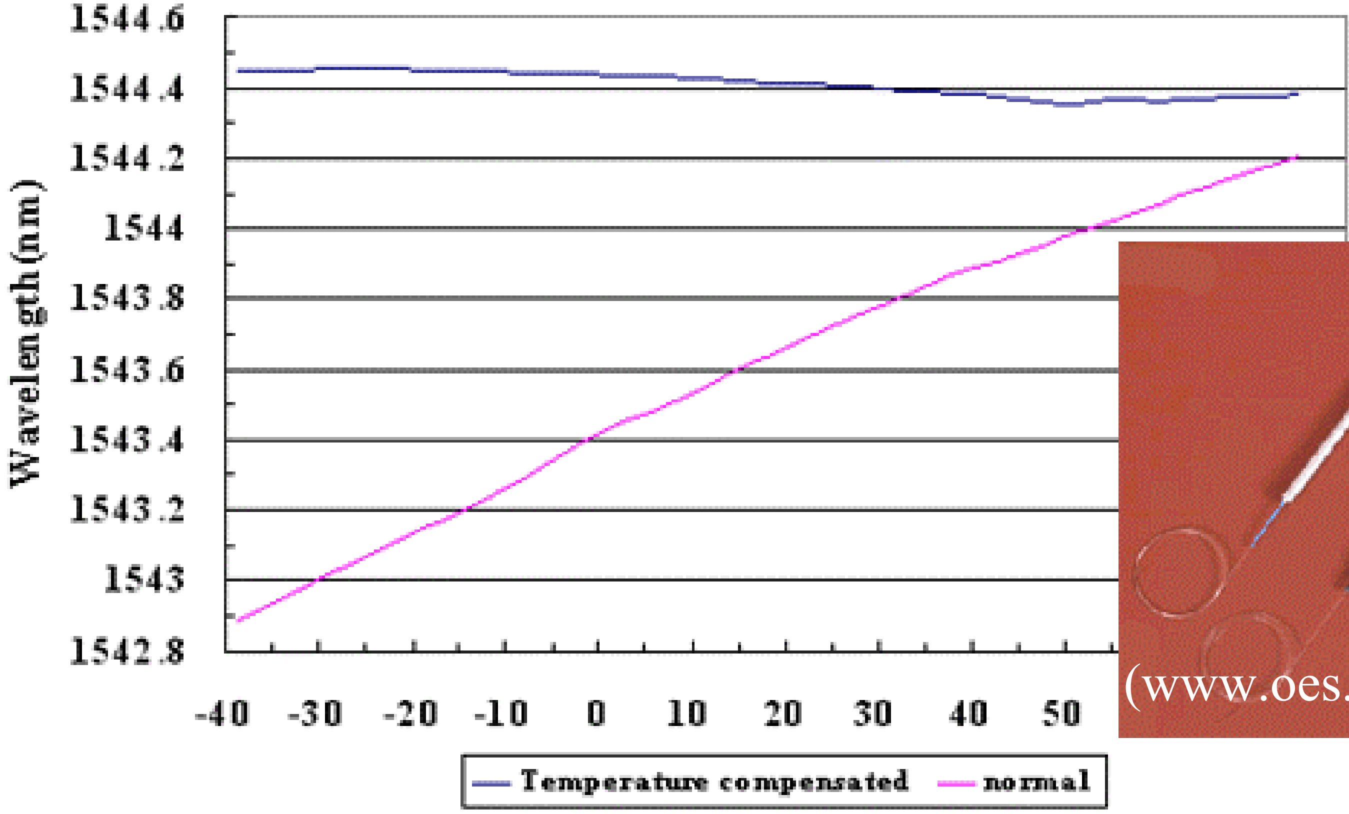
(From Wilson & Hawkes)

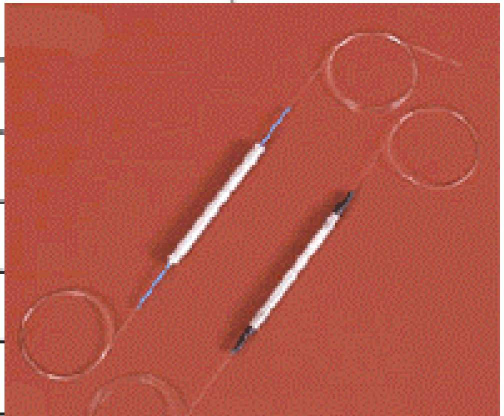
Bragg fiber grating example

Application: wave selector, circulator

Thermal sensitivity: 0.01nm/°C

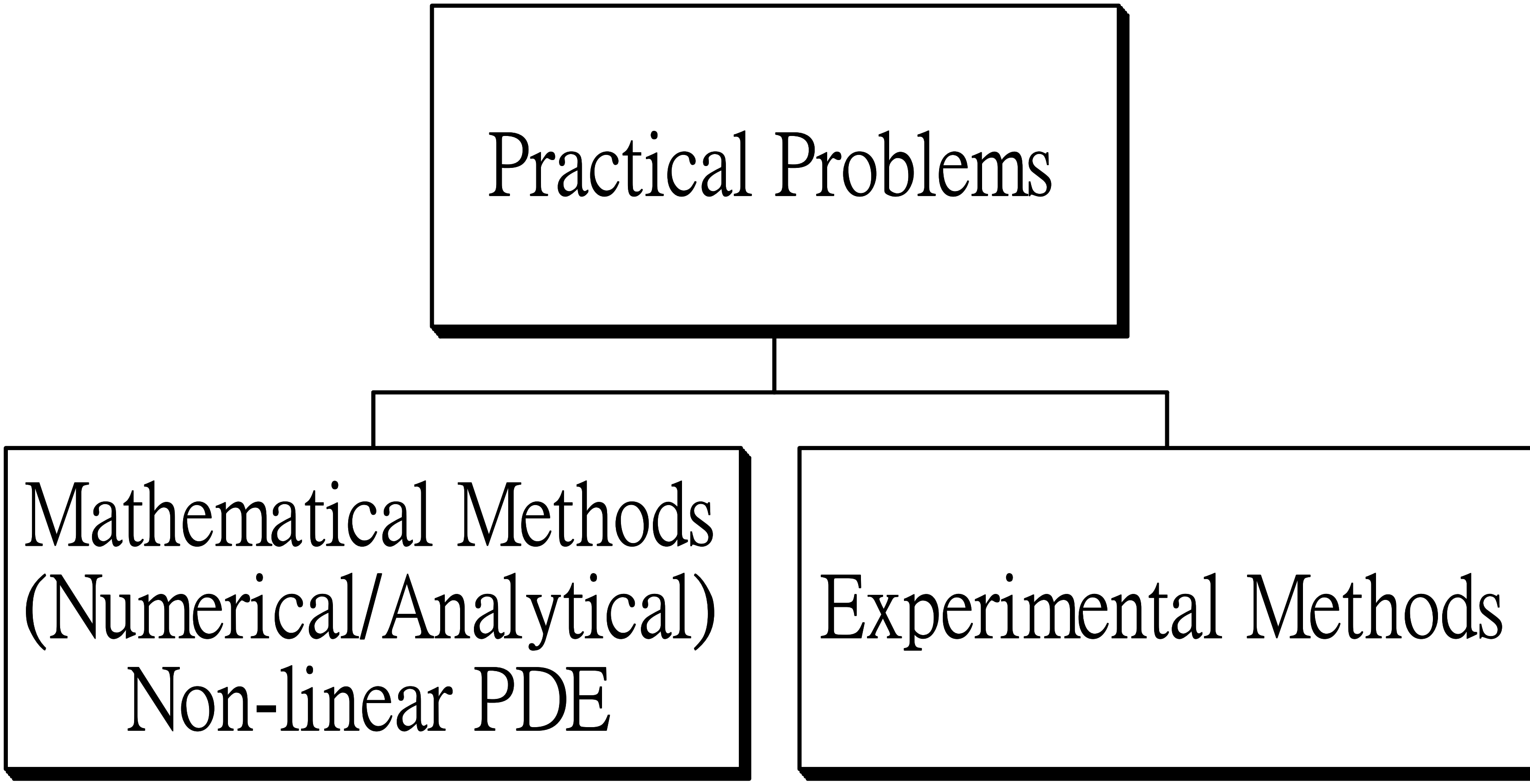
(thermal expansion coef. 2.3×10^{-6} for Si)



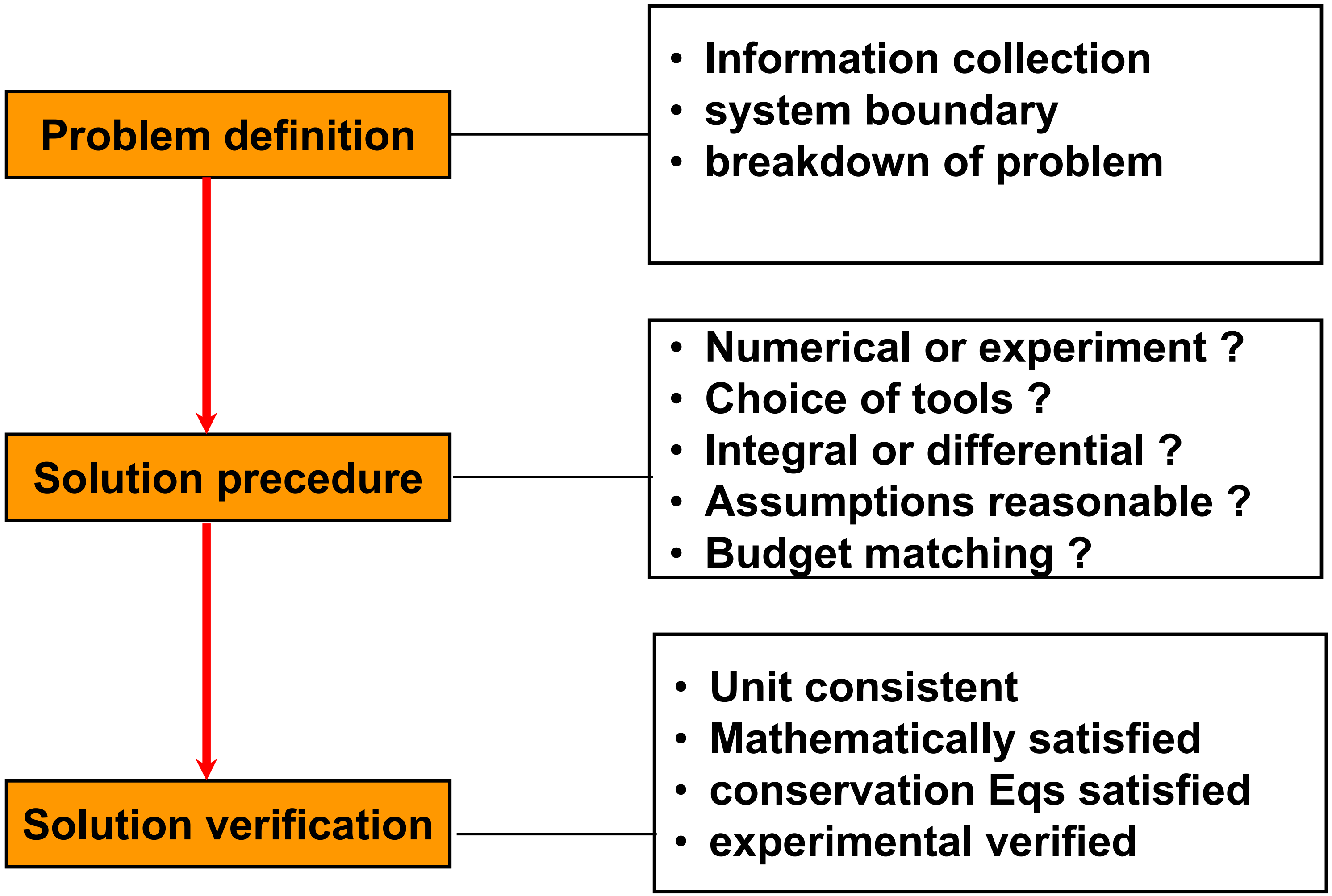


(www.oes.itri.org.tw)

Tools for Solving Problems

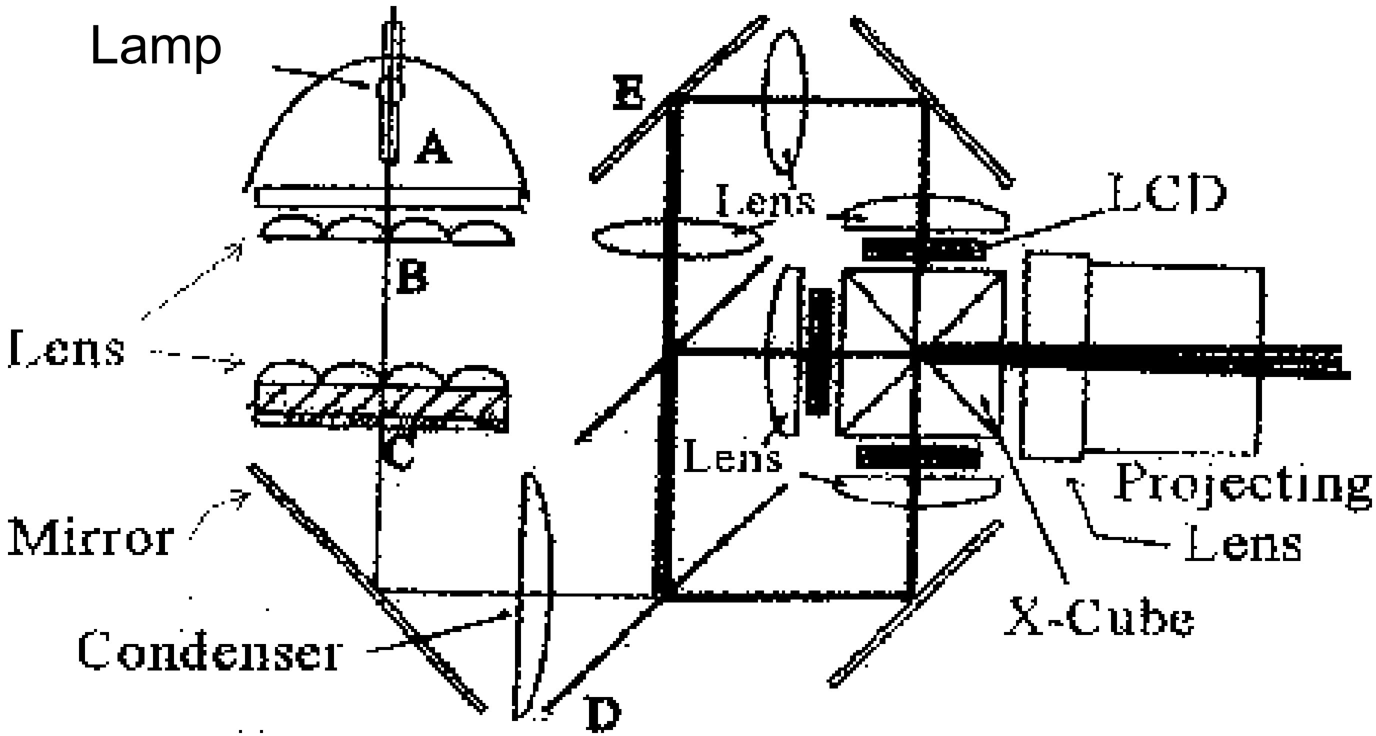


Flow chart for Solving Problems

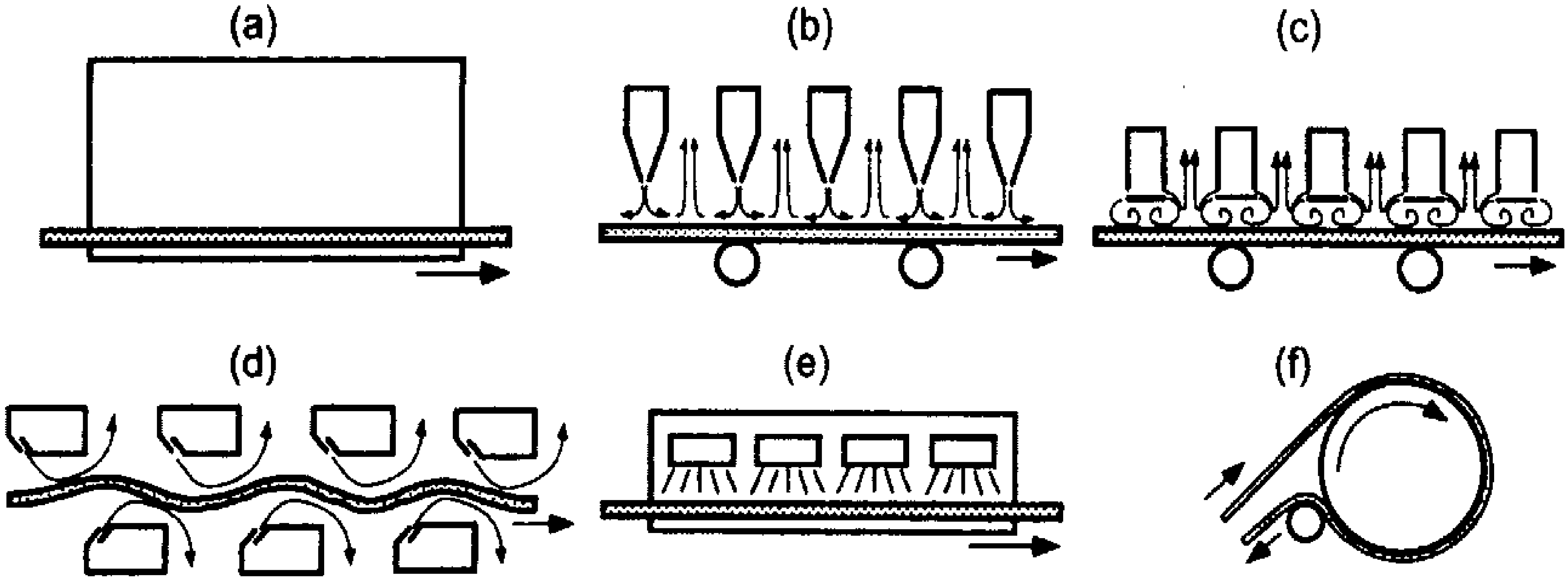


Thermal management

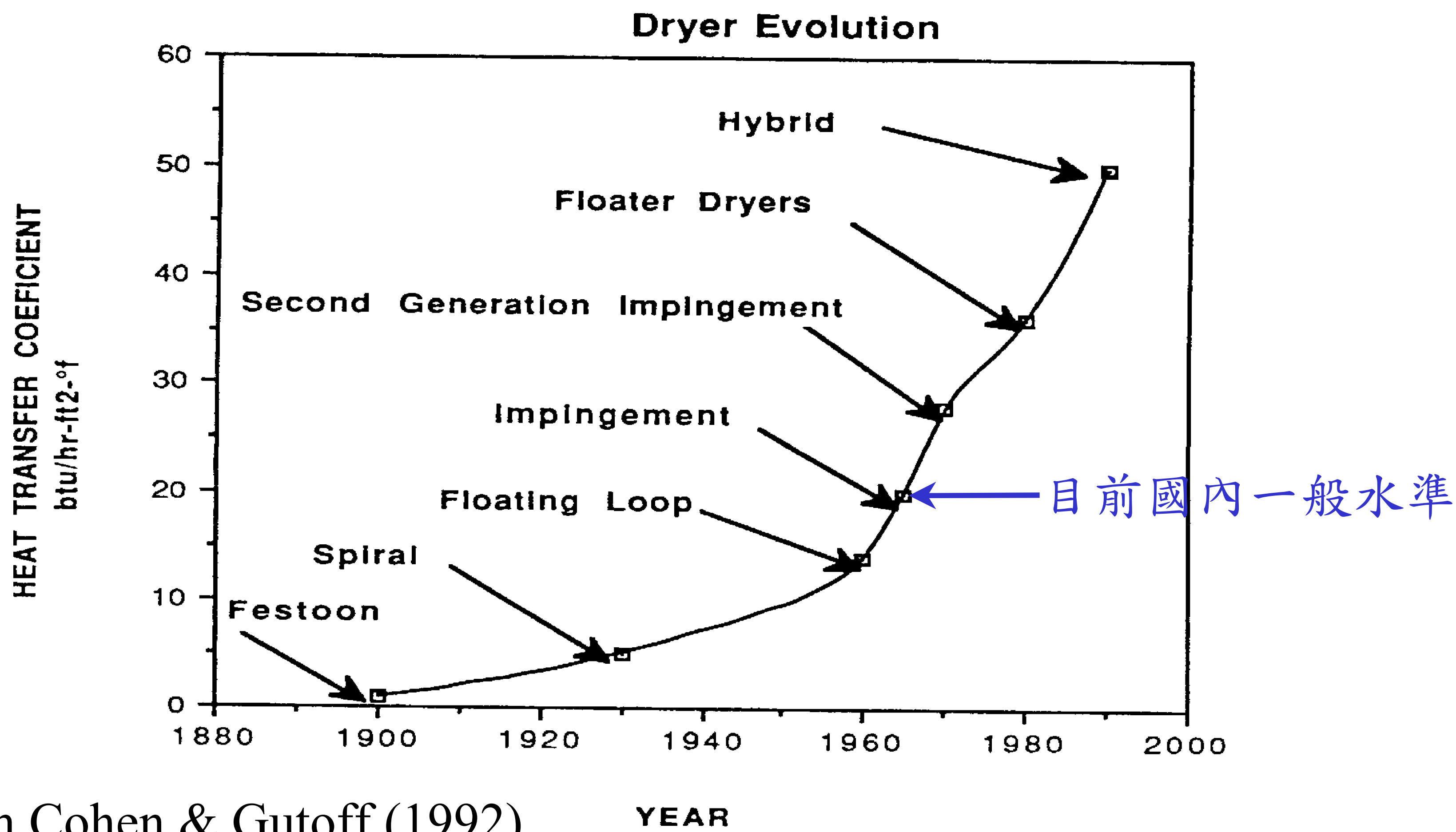
Light illumination ➚➚ ? Size ➘➘ ?



Drying technology (I)

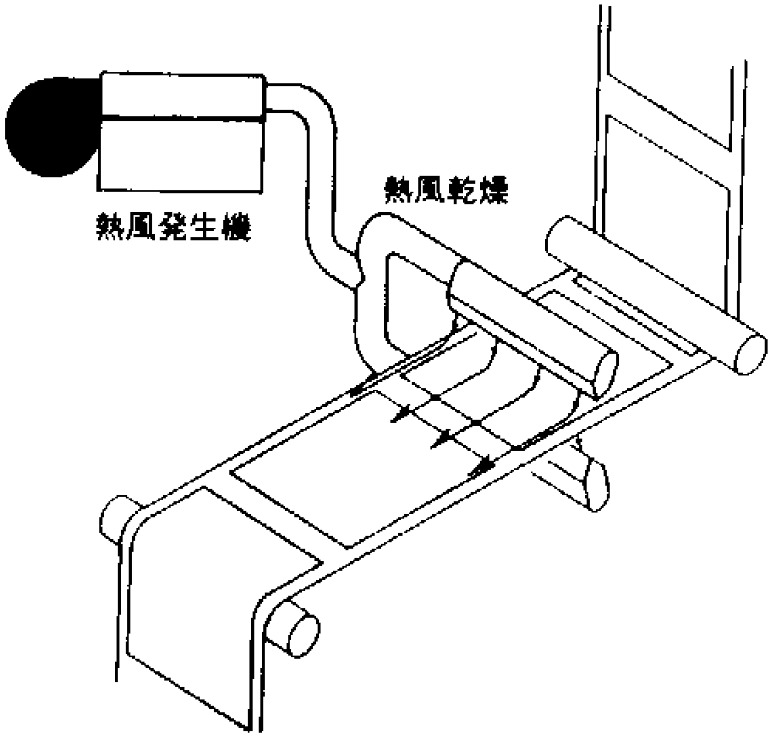


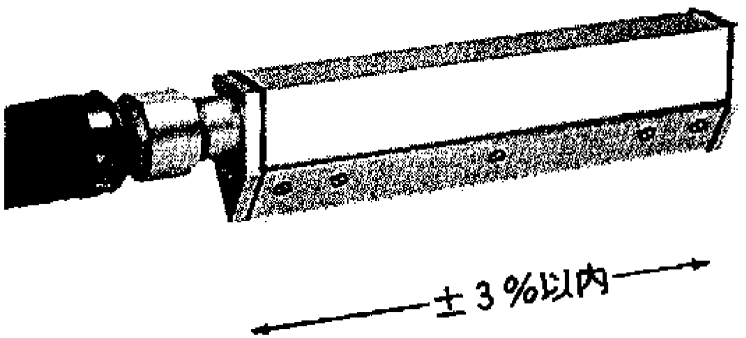
Drying technology (II)

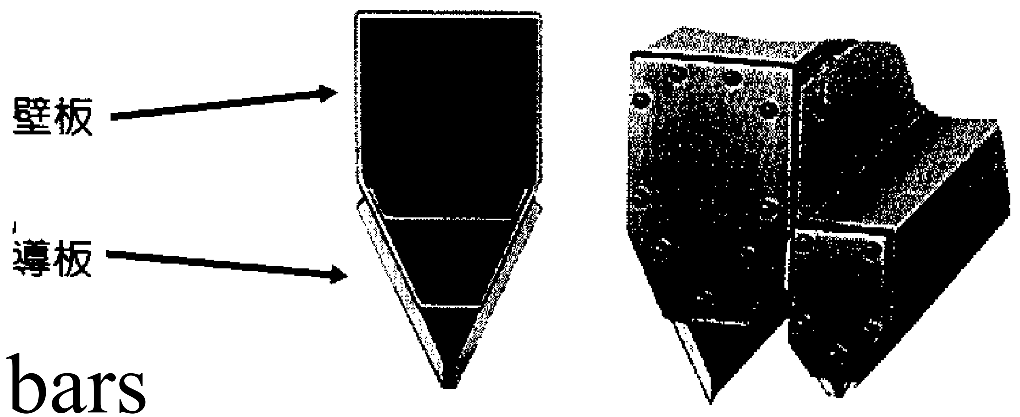


From Cohen & Gutoff (1992)

Drying technology (III)

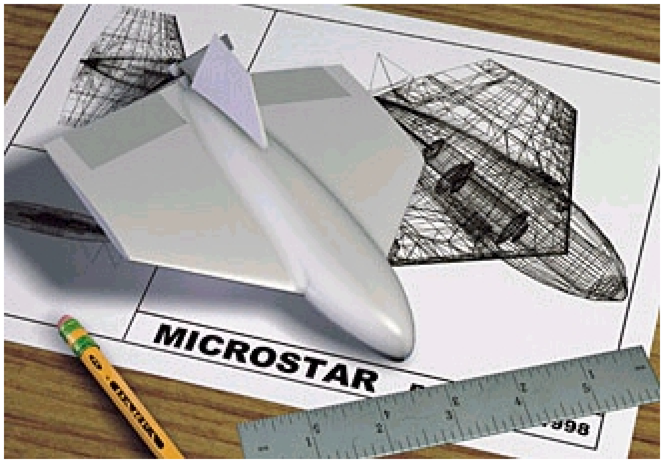


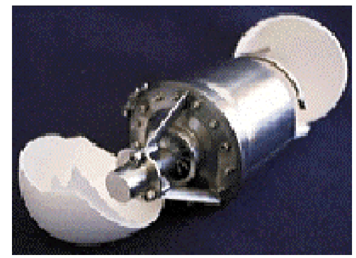


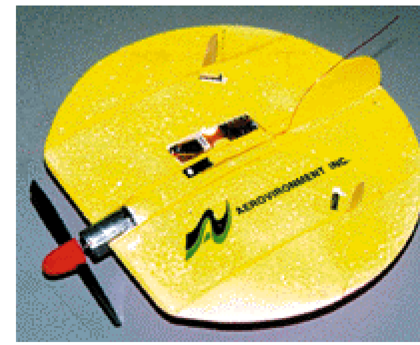


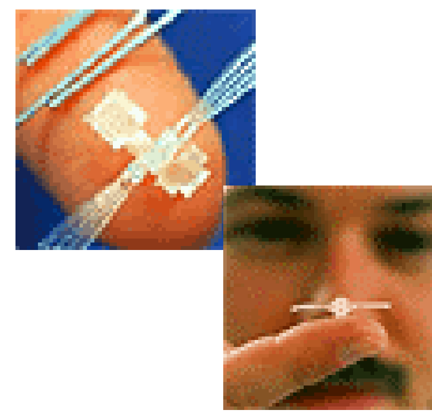
$T_{max} < 250°C, P_{max} < 2$ bars

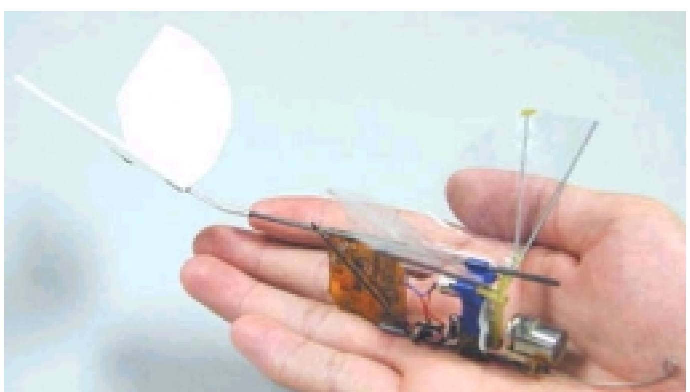
Current designs of MAVs

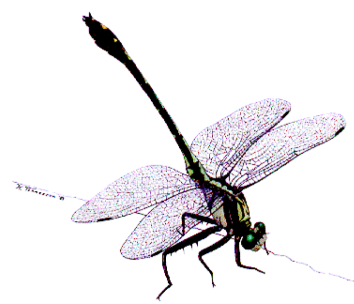












Measuring technology

Why experiment ?

- Extend physical understanding of a particular flow phenomenon, especially when the problem is not phenomenologically understood
- Test new theoretical results
- Verify mathematical models of CFD
- Establish scaling laws
- Measure for control purpose

Thermal Flow Measurements

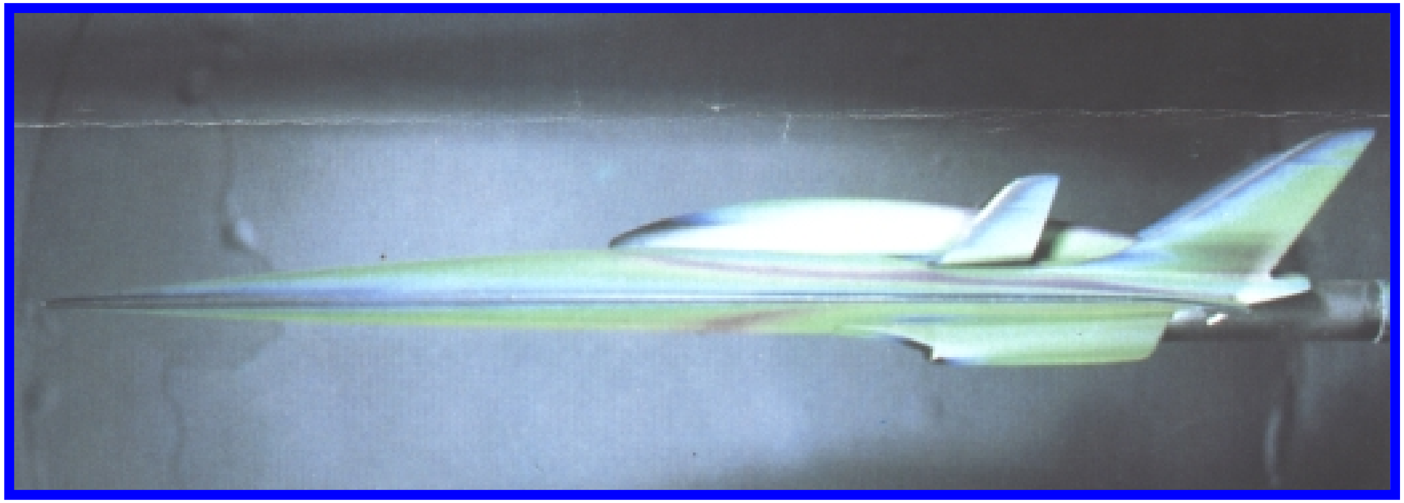
- Fluid + solid : *liquid, gas, mixed-phase, …*
- Measurement of fluid properties:
  viscosity, density, surface tension, …
- Measurements of flow properties:
  Pressure, velocity, particle size distributions, temperature distributions, shear force, …
- General requirements:
  accuracy, repeatability, cost, …

Temperature Measurement

Contacting measuring
Non-contacting method

Hg-thermal meter
Thermal couple
Thermister
IR-measuring device
….

<29° black
30° red
32° yellow
35° green
40° blue
>47° black



(Sänger, Hypersonic space-shuttle test in the DLR)

Pressure Measurements

- Pressure is derived from force per unit area.
- Pressure transducers convert an applied pressure into a sensible signal (electric signal or others) through the change of displacement, strain, piezoelectric response…
- The choice of transducer varies greatly depending on many factor like pressure range, dynamic response, pressure media, dimensional restrictions,… etc

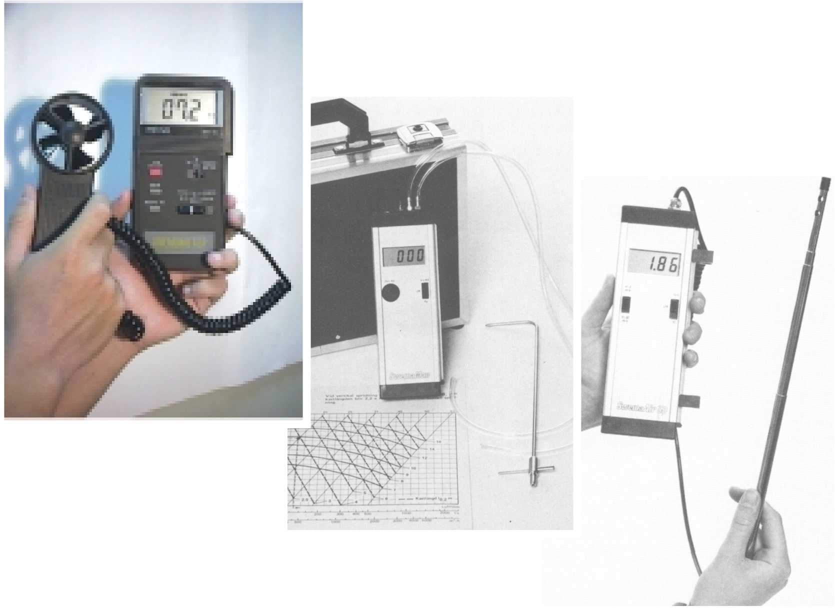
Velocity Measurements (I)

Bernoulli's Equation

$$\frac{p_0}{\rho_0} = \frac{p}{\rho} + \frac{V^2}{2}$$

- **Average velocity: flow meter**
- **Local velocity:**

  - Mechanical rotator
  - Pitot-static tube
  - Hot-wire/-film

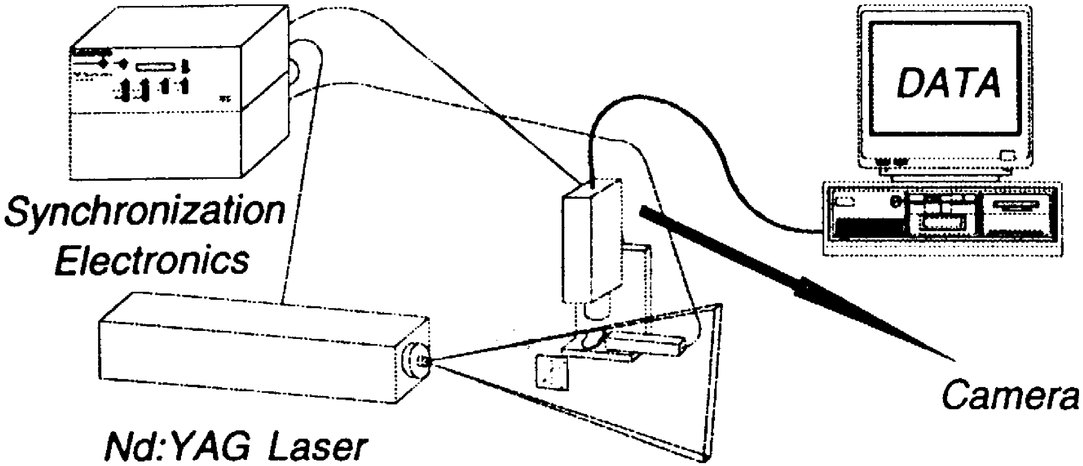


Velocity Measurements (II)

- *LDA or LDV: Laser Doppler Anemometer (or Velocimetry)*
- *PIV: particle image velocimetry*

$$V(x,t)=\Delta x(x,t)/\Delta t$$

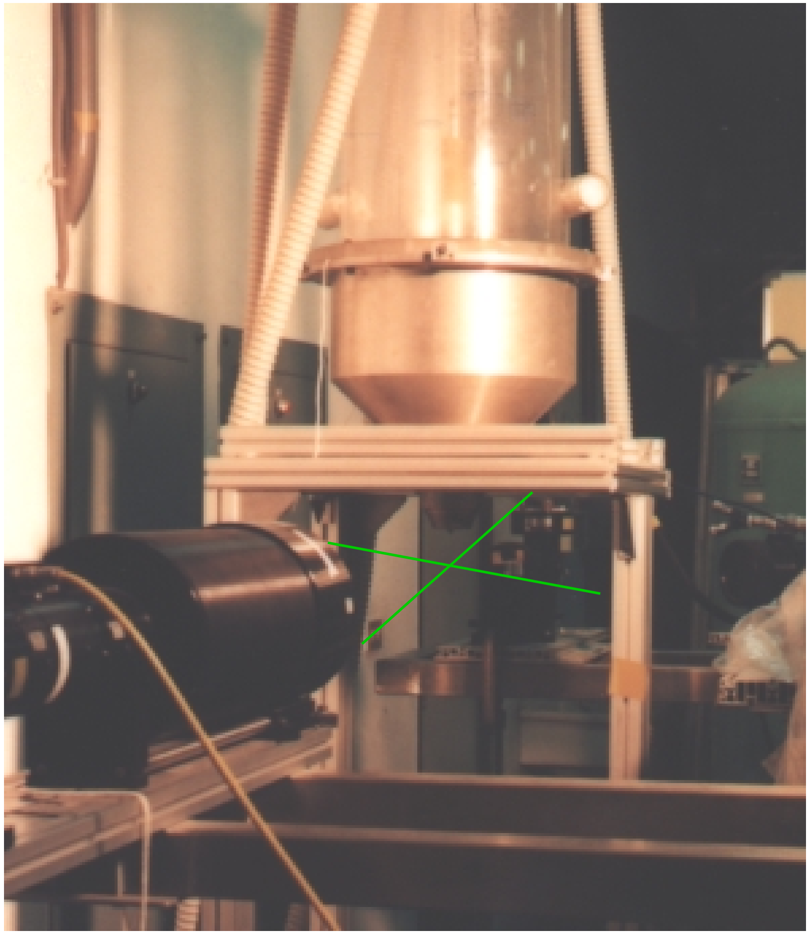
- Seeding
- Illumination
  (twice in succession)
- Image Recording
- Vector processing



Particle/drop size measurement

Optical Measurement for Multi-phase flows

- ☺ Particle size distributions
- ☺ Velocity distributions
- ☺ Refractive index distributions
- ☺ Temperature distributions



Why simulations ?

Advantages:

- In some cases, doing experiment is not possible or too expensive.
- Easy to change controlling parameters
- Simulation is, in general, quicker and cheaper
- Exact boundary conditions

Disadvantages:

- Simulation includes uncertainties of numerical errors and modelling
- Verification test of experimental is always needed

Simulations

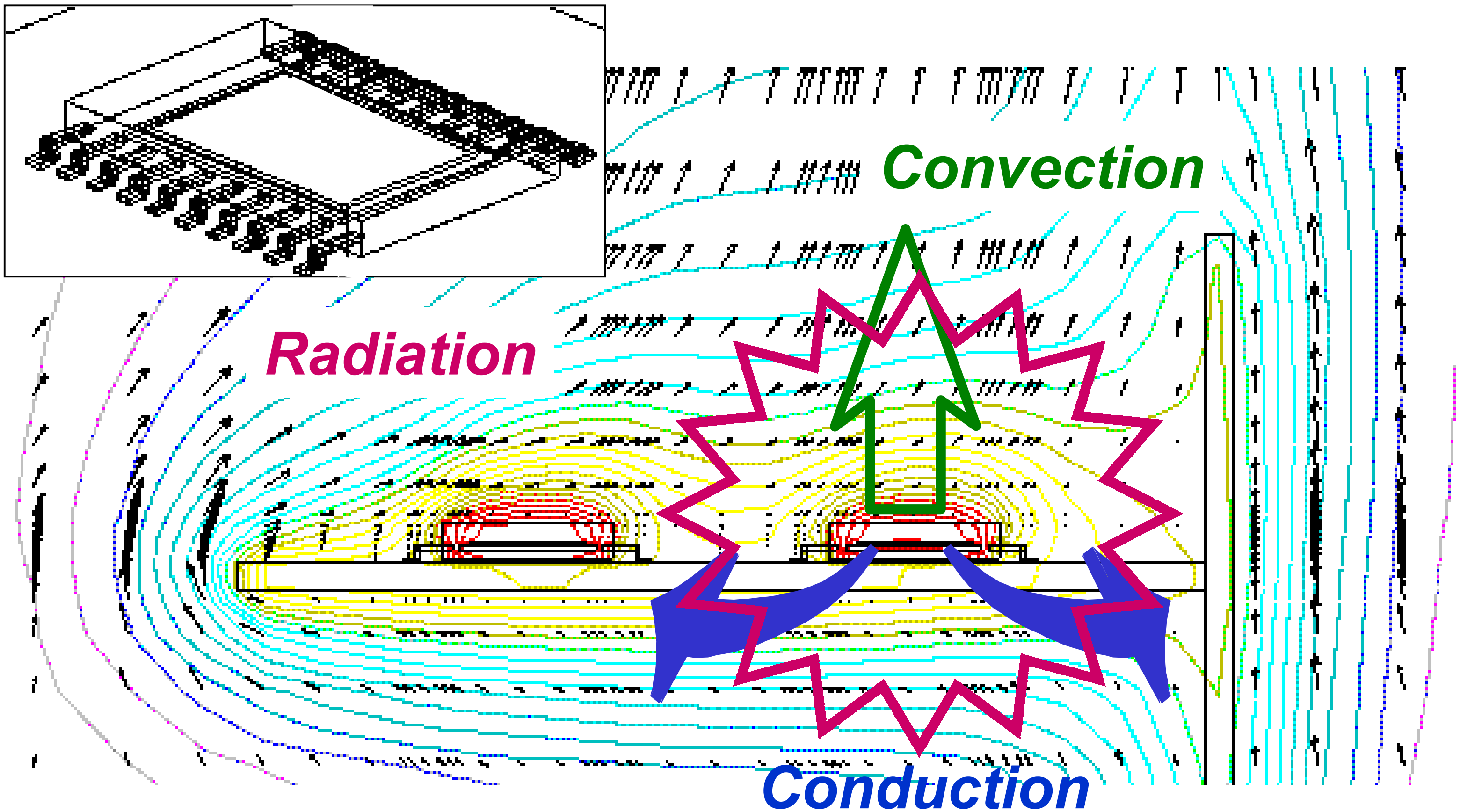
Category:

- Laminar flow simulations
- Turbulent flow simulations

Numerical methods:

- Direct simulation (DS)
- Large eddy simulation
  (large eddies calculated by direct simulation and small eddies by numerical modelling)
- Simulation with turbulent modelling

Thermal simulations



(From G. Chen)