

Materials Science of Electronic and Optoelectronic Devices

Tadao Tanabe

Nov. 16: Photonic Device-Basic

Nov. 23: -Application

Nov.30 Examination

Quiz -Photonic Device-

- 1. What photonic devices do you know? (1~2 devices)**
- 2. Explain the device (structure, function, feature,,, anything OK!)**
- 3. What materials are used in the device?**

Student ID:

Name:

Basic of Photonic devices (Tanabe)

2018/11/16

(1) INTRODUCTION

What is LIGHT?

Application of light to our life

Relation between light and materials

(2) Handling of LIGHT

Generation

Propagation :absorption

Condensing(space)

Condensing(time) / modulating

Amplification

Selecting

Detecting

(3) Understanding of LIGHT for device fabrication

wavelength / frequency

linewidth

pulse duration

beam mode

polarization

power density

(4) Photonic Technology

(5) Applications

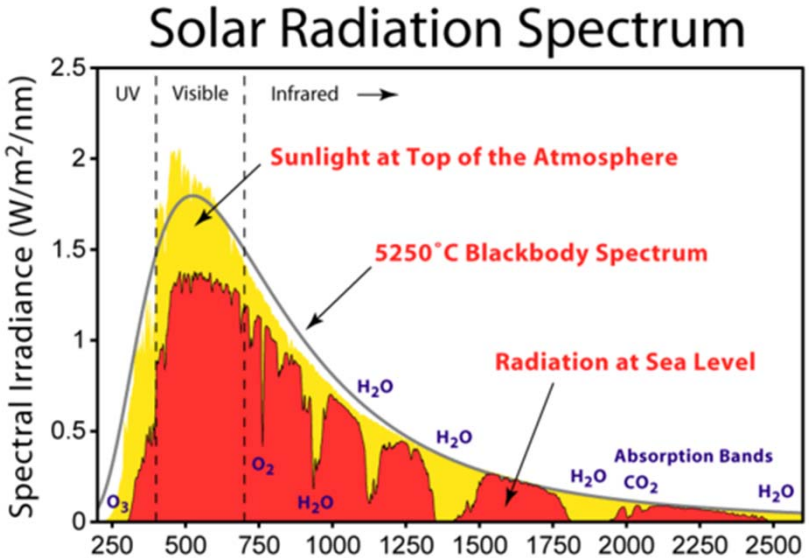
(1) INTRODUCTION

What is LIGHT?

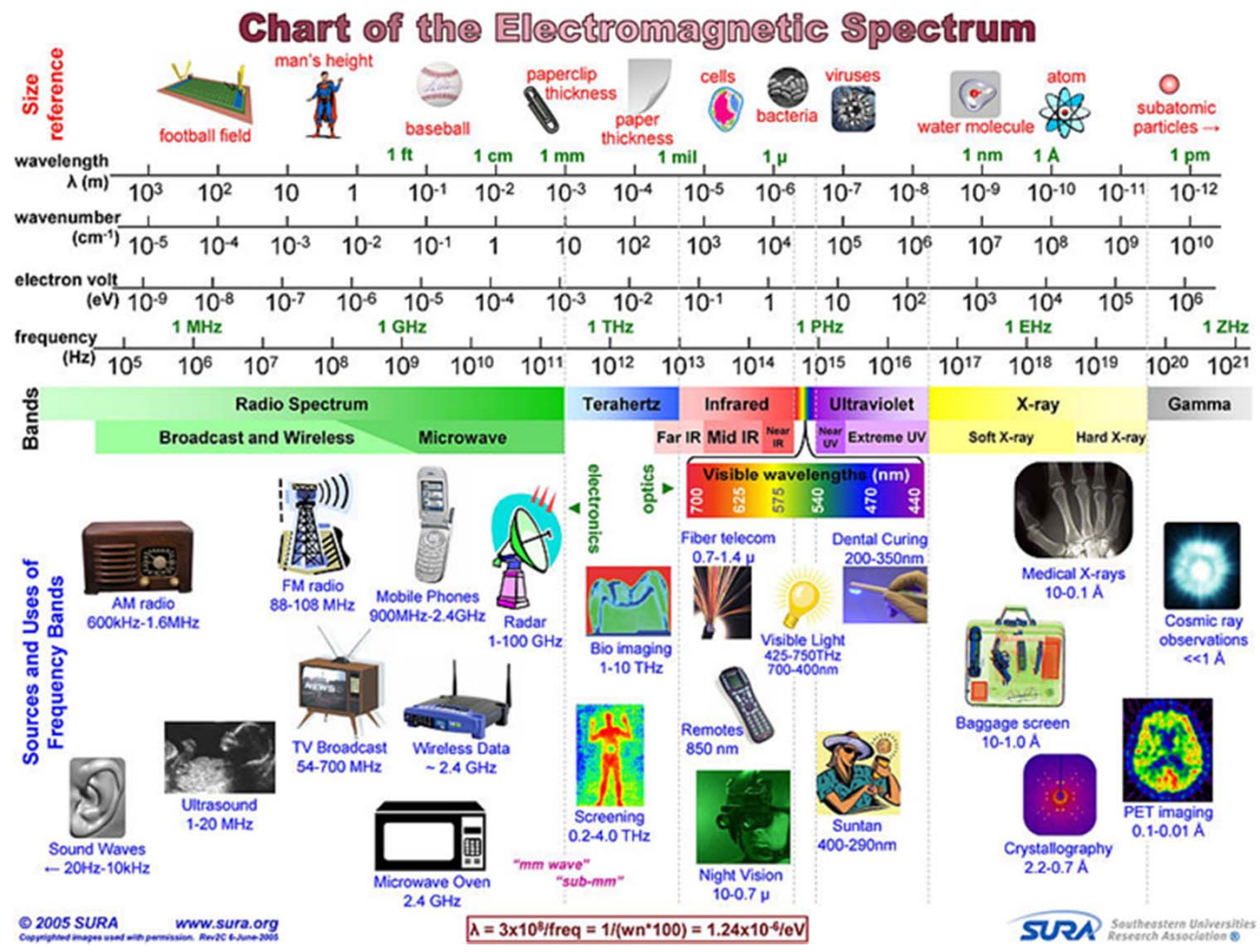
- electric wave ~ light (electromagnetic wave)
- invisible / visible
- straight propagation
- solar-blind
- due to ozone absorbance of sunlight

Laser

- single-frequency
- coherent (coordinate phase)
- high energy density



below 280 nm Wavelength (nm) wikipedia.org



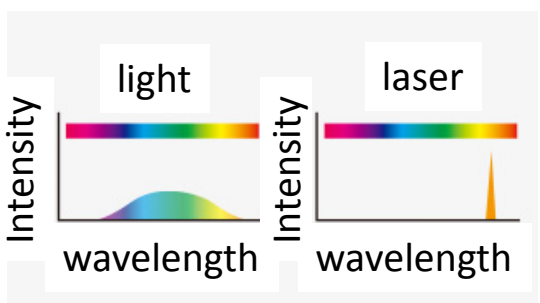
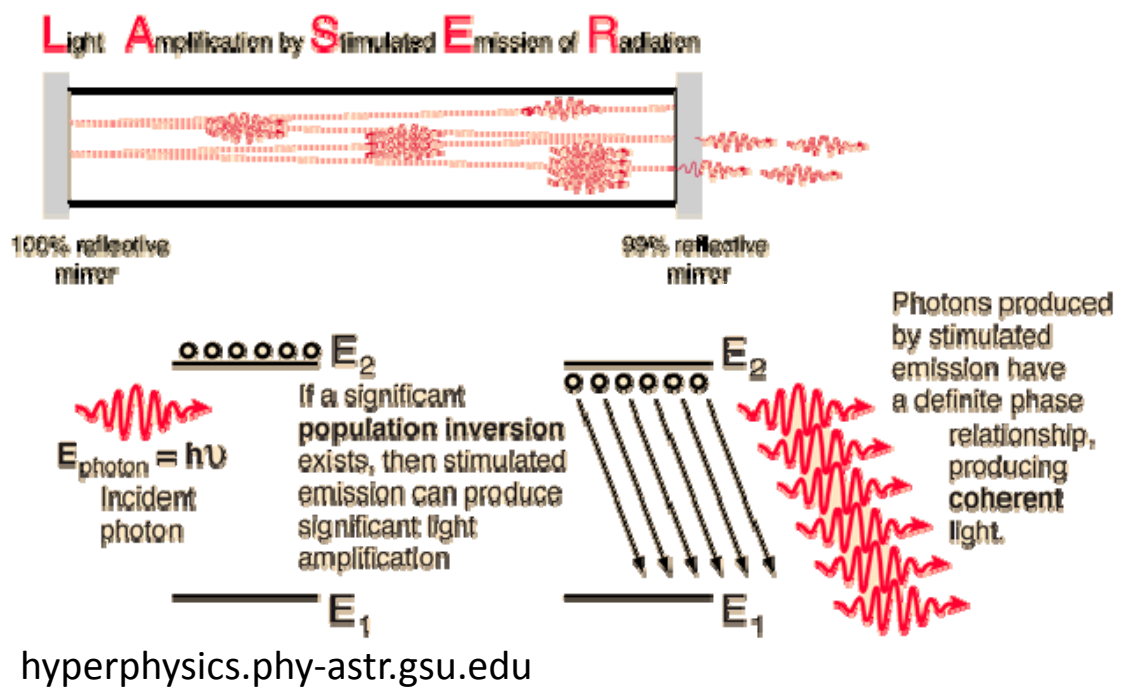
(1) INTRODUCTION

What is LIGHT?

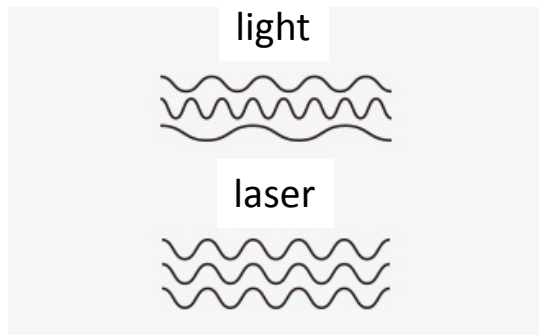
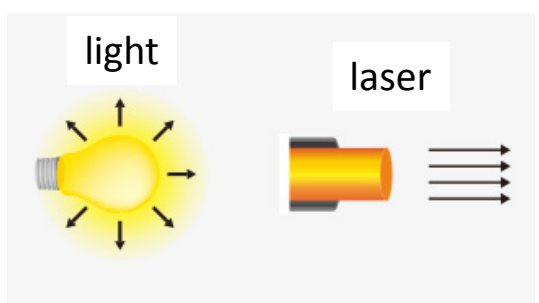
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Laser

- single-frequency
- coherent (coordinate phase)
- high energy density



laserfront.jp



Application of light(photonic device) to our life

- lighting
- photographing
- energy production
- communication
- non-destructive inspection
- medical diagnosis/treatment



digitaljournal.com



mitsubishielectric.co.jp



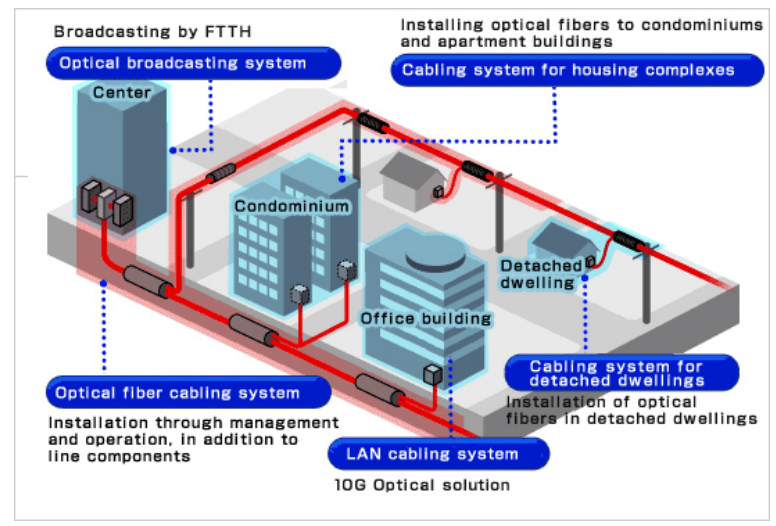
itmedia.co.jp



oneslidephotography.com



canadianground.com



furukawa.co.jp

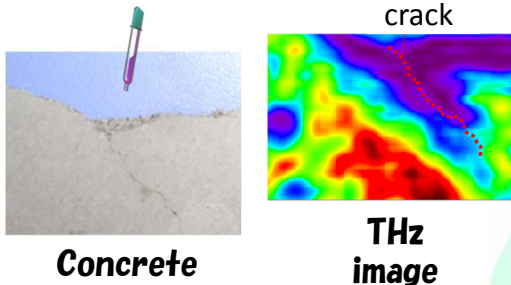


nonin.com

THz Applications: non-destructive inspection

defects in the construction

water diffusion
to cracks in the concrete



Concrete
(10mm thickness)

THz image

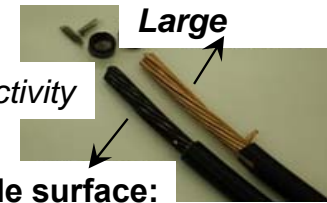
Terahertz = Safety + non-destructive

non-destructive: non-ionized, high-transparency
safety: applicable to practical fields

Evaluation for insulator covered metal surface

Cu cable for Electric power

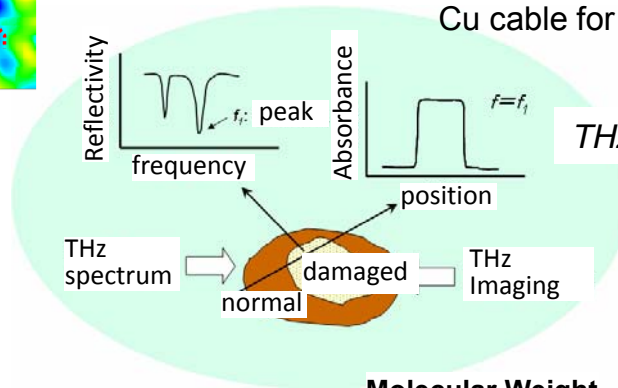
non oxide surface:
Large



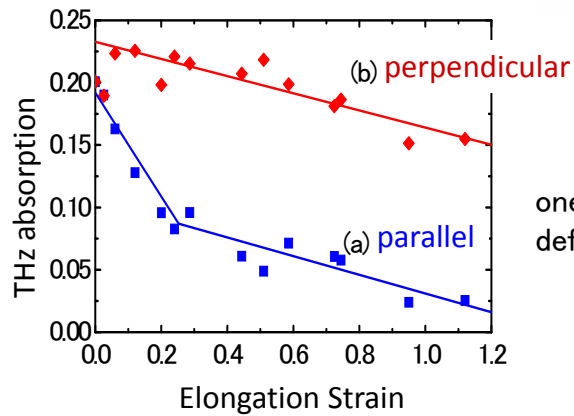
oxide surface:
Small

insulators

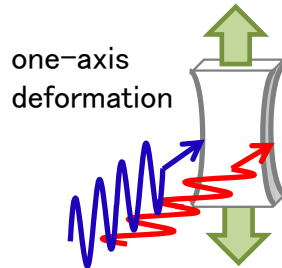
THz transperence : high



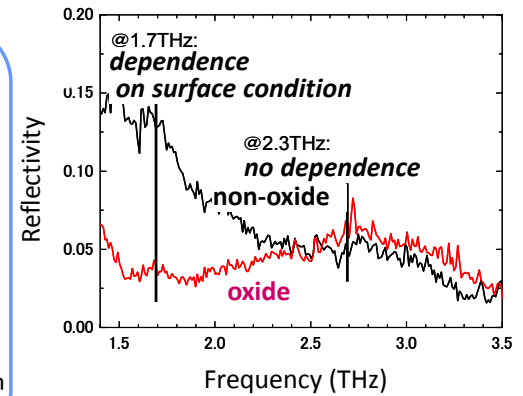
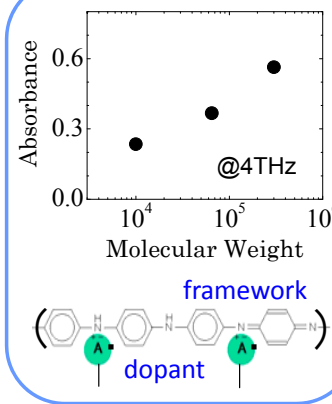
deformed Polyethylene



(a)parallel (b)perpendicular

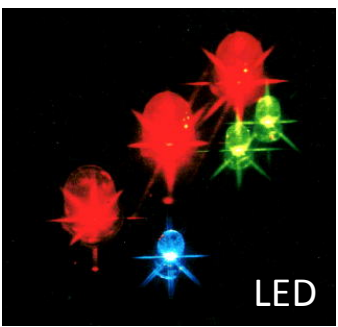


Molecular Weight

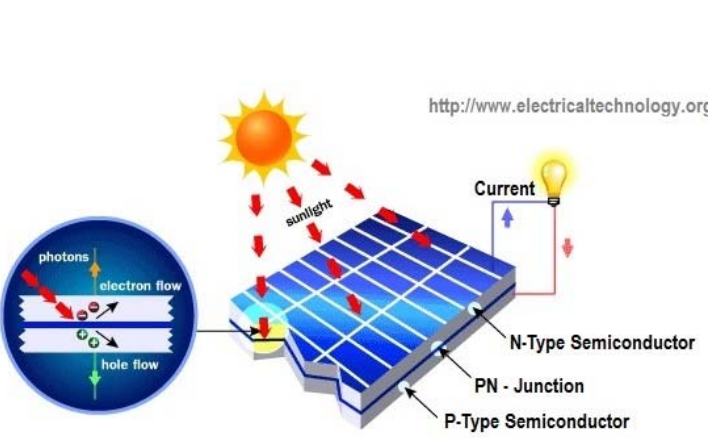


Application of light(photonic device) to our life

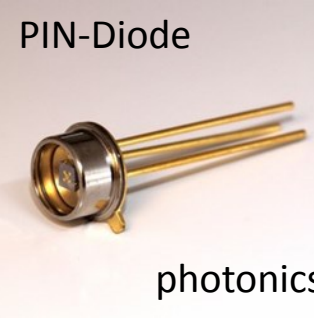
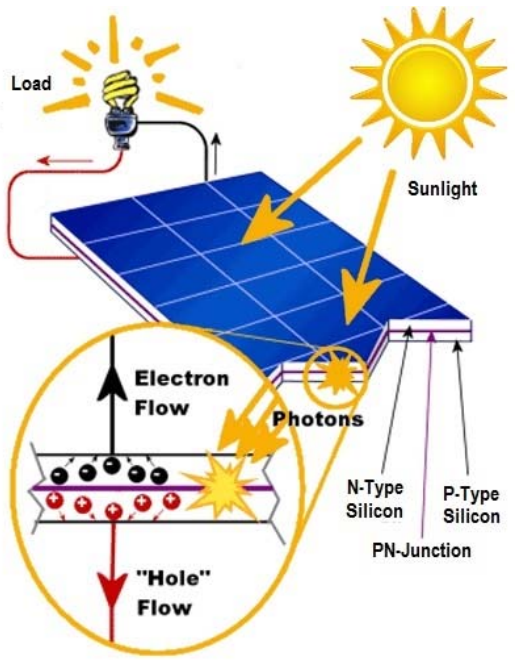
- lighting: Lamp, **LED**
- photographing: **CCD, CMOS**
- energy production: **Solar Cell**
- communication: **LD, PIN-Diode**
- non-destructive inspection: **Infrared-THZ**
- medical diagnosis/treatment: **LED/Laser**



kaden.watch.impress.co.jp



Basic Operating Principle of a Solar Cell



PIN-Diode

photoniconline.com



CCD

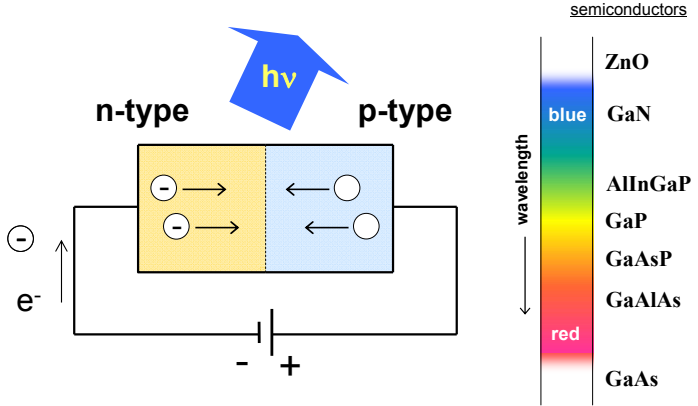


CMOS

oneslidephotography.com

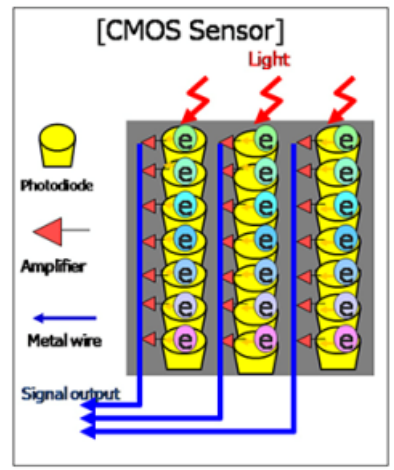
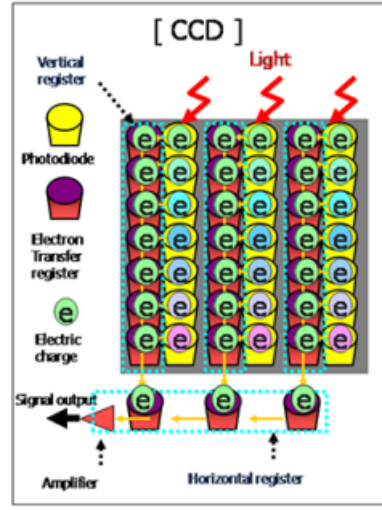
Relation between light and materials

- lighting: Lamp, LED: **GaAsP, GaN**
- photographing: CCD, CMOS: **Si**
- energy production: Solar Cell: **Si, GaAs**
- communication: LD, PIN-Diode: **InP**
- non-destructive inspection: THZ: **GaP, GaSe**
- medical diagnosis / treatment: LED / Laser: **GaAs, CO₂**

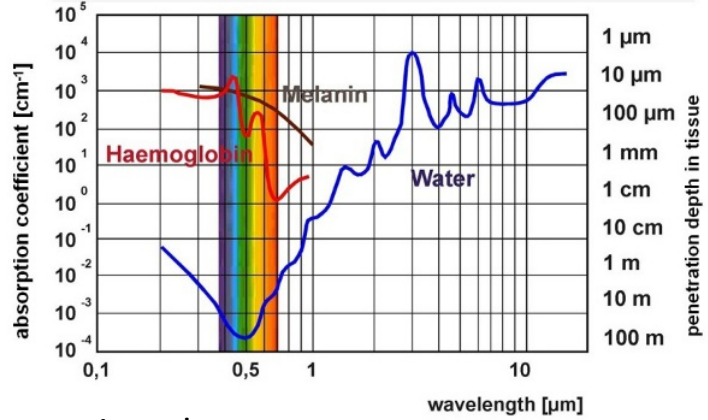


素材	GaAsP系	GaP系	GaAlAs系	AlGaInP系	InGaN系
発光色	黄色～赤色	黄緑色	赤色	黄色～赤色	青色～緑色 (YAGと組み合わせ白)
構造					
発光効率	0.2 ~ 1.0 (lm/W)	2.0 ~ 3.0 (lm/W)	6 ~ 12 (lm/W)	15 ~ 40 (lm/W)	10 ~ 50 (lm/W)

led.or.jp



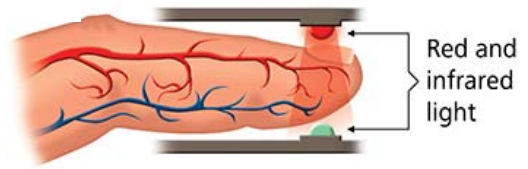
sonyalpharumors.com



intechopen.com



novuslight.com

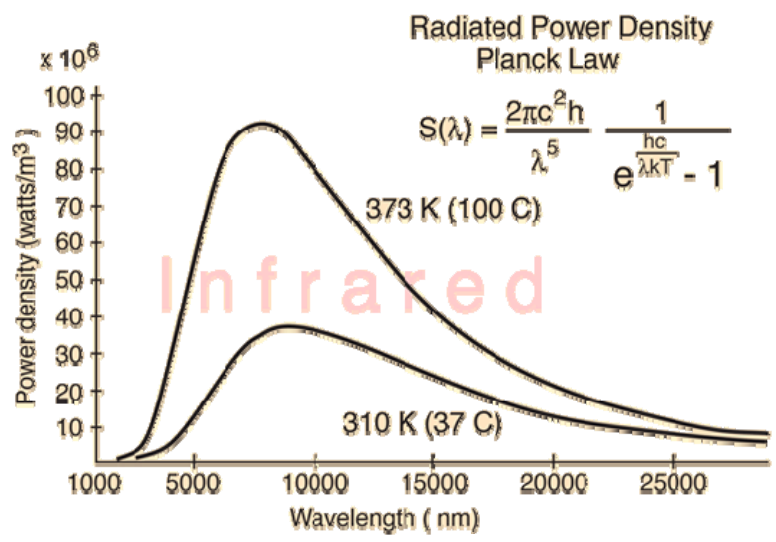


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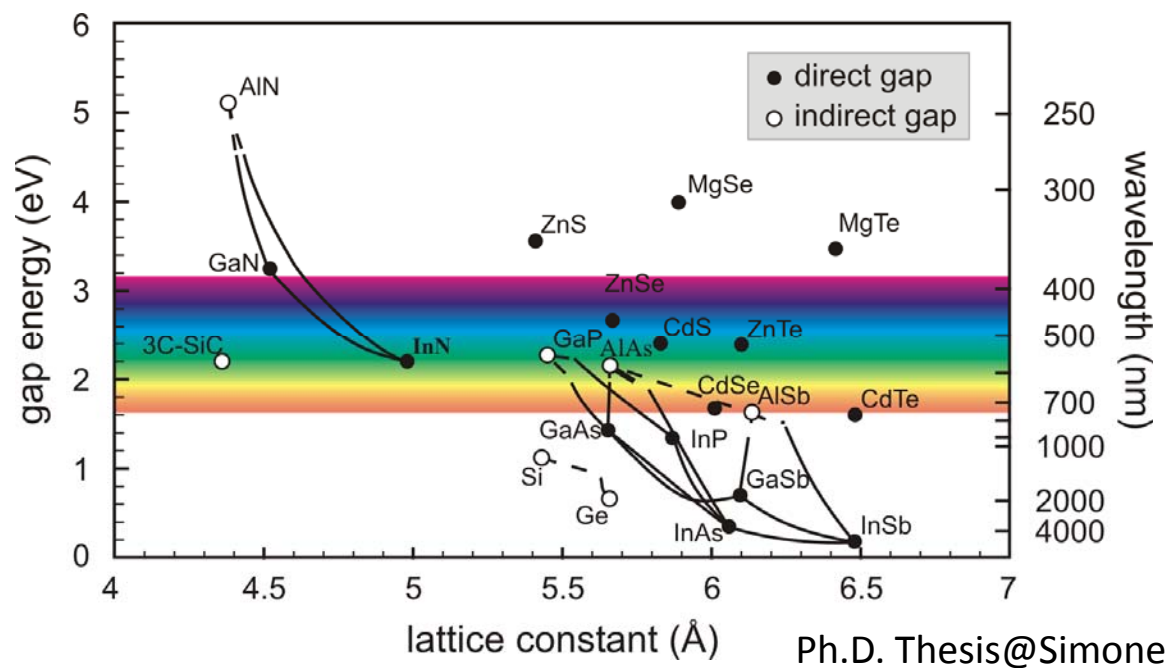
(2) Handling of LIGHT

Generation

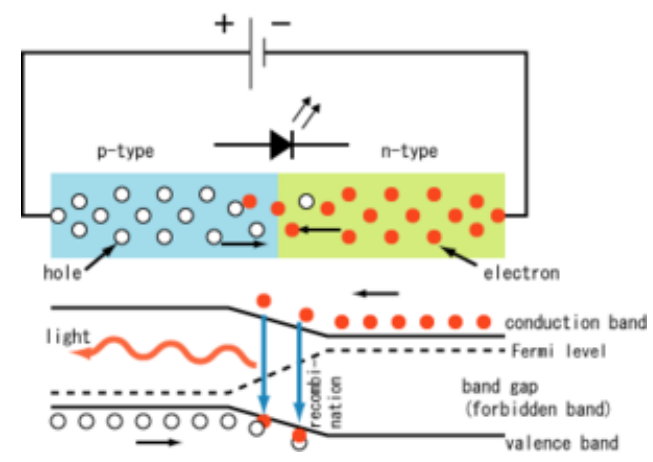
- heating
- energy gap in semiconductor
- nonlinear optical process (frequency-mixing: DFG, SFG, SHG)



hyperphysics.phy-astr.gsu.edu



Ph.D. Thesis@Simone Montanari



Electro Luminescence

todayifoundout.com

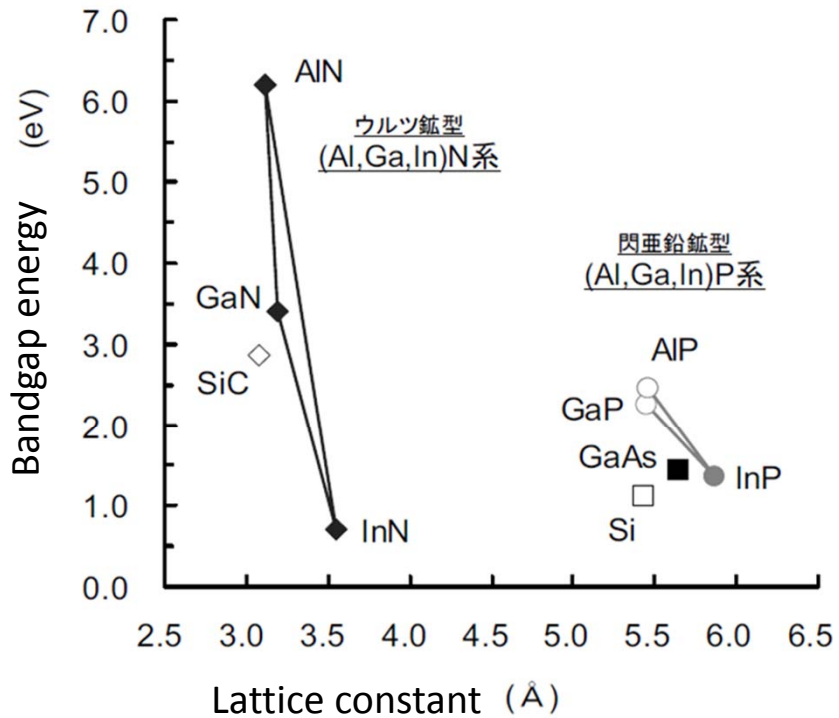
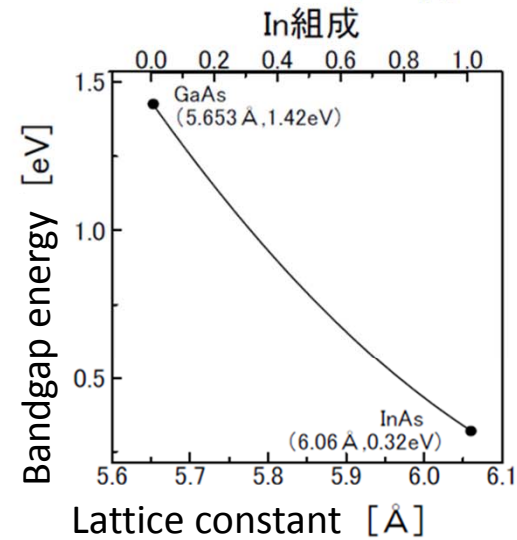


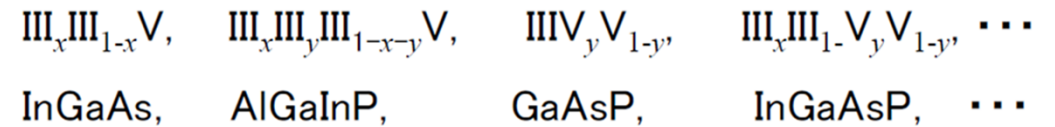
図5 III-V族半導体/(Al, Ga, In)N系, (Al, Ga, In)P系の格子定数とバンドギャップエネルギーの関係

表面技術 61 (2010)
板東 完治

InGaAs ... 正確には $\text{In}_x\text{Ga}_{1-x}\text{As}$ ($0 \leq x \leq 1$) x : In組成

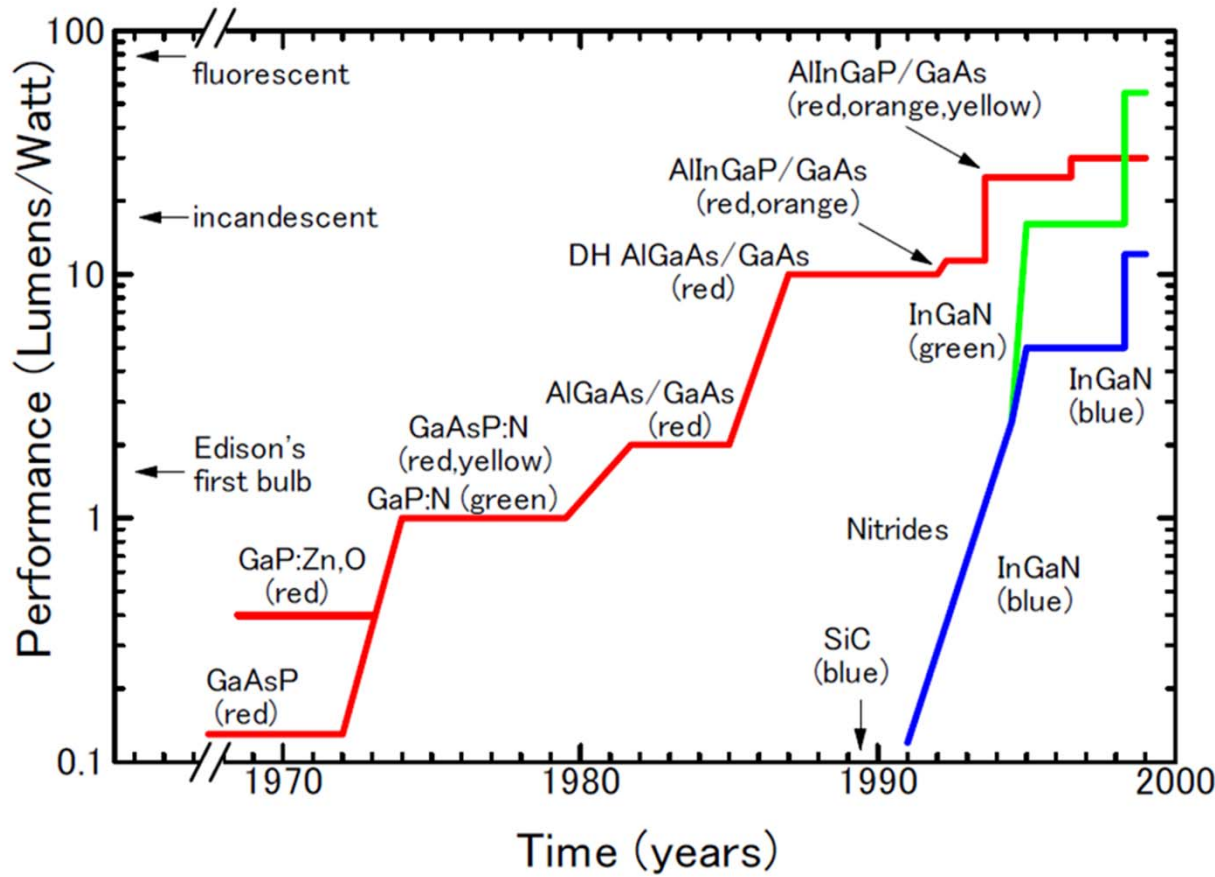


In組成によってバンドギャップと格子定数を連続的に制御できる

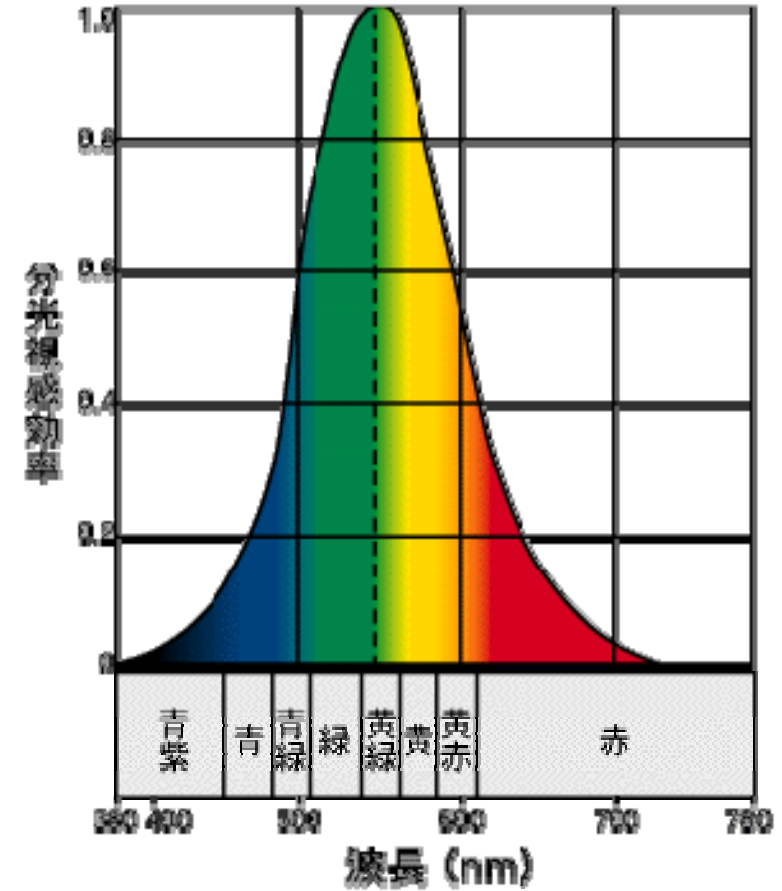


鍋谷暢一先生の資料

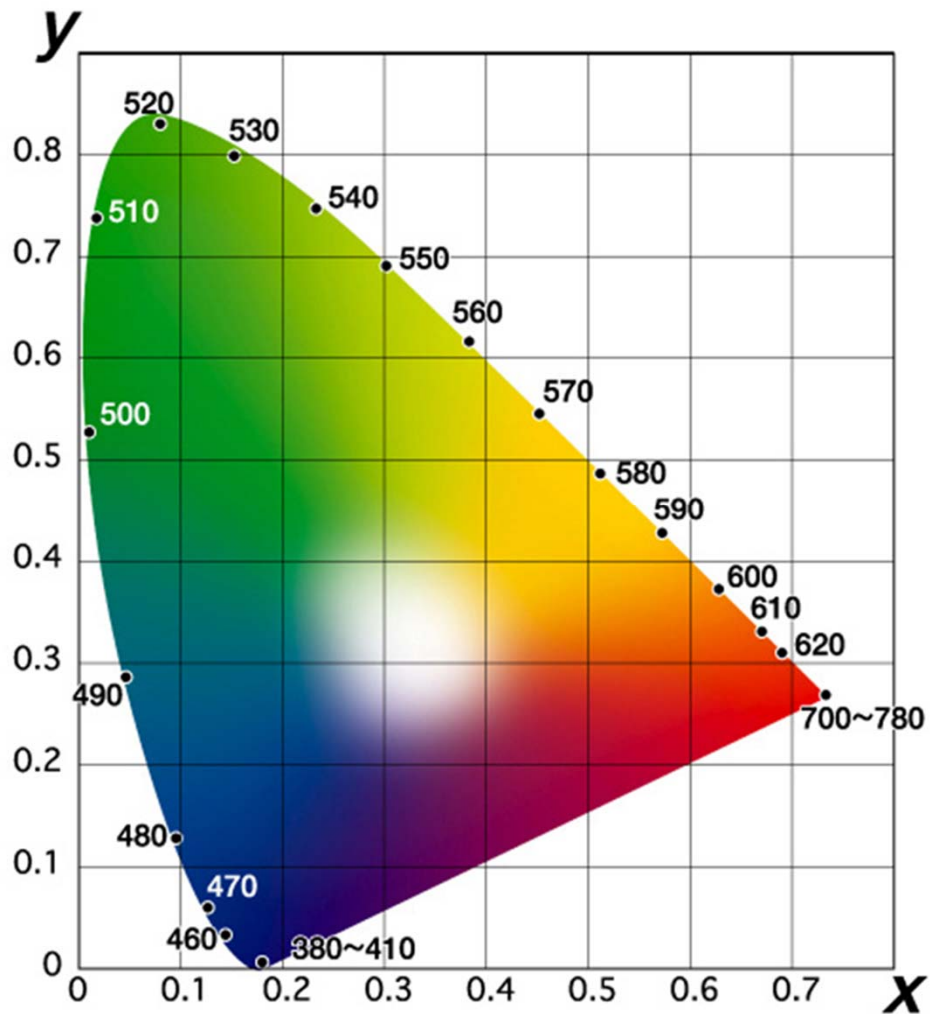
spectral luminous efficiency



T. Mukai *et al*, Jpn. J. Appl. Phys., **38**, p.3976 (1999)



@panasonic



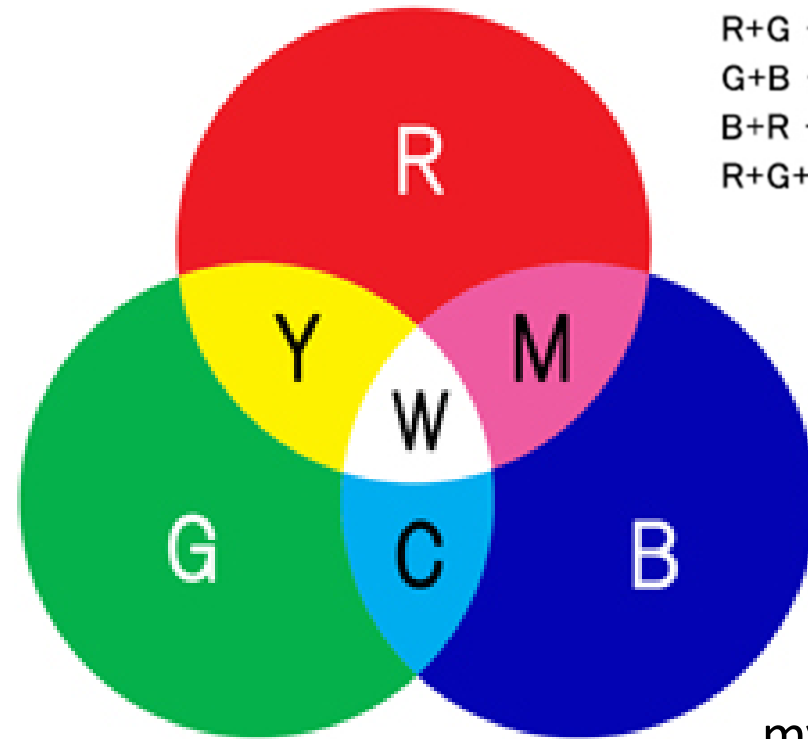
■ 光の三原色

R+G → Y(イエロー)

G+B → C(シアン)

B+R → M(マゼンタ)

R+G+B → W(ホワイト)



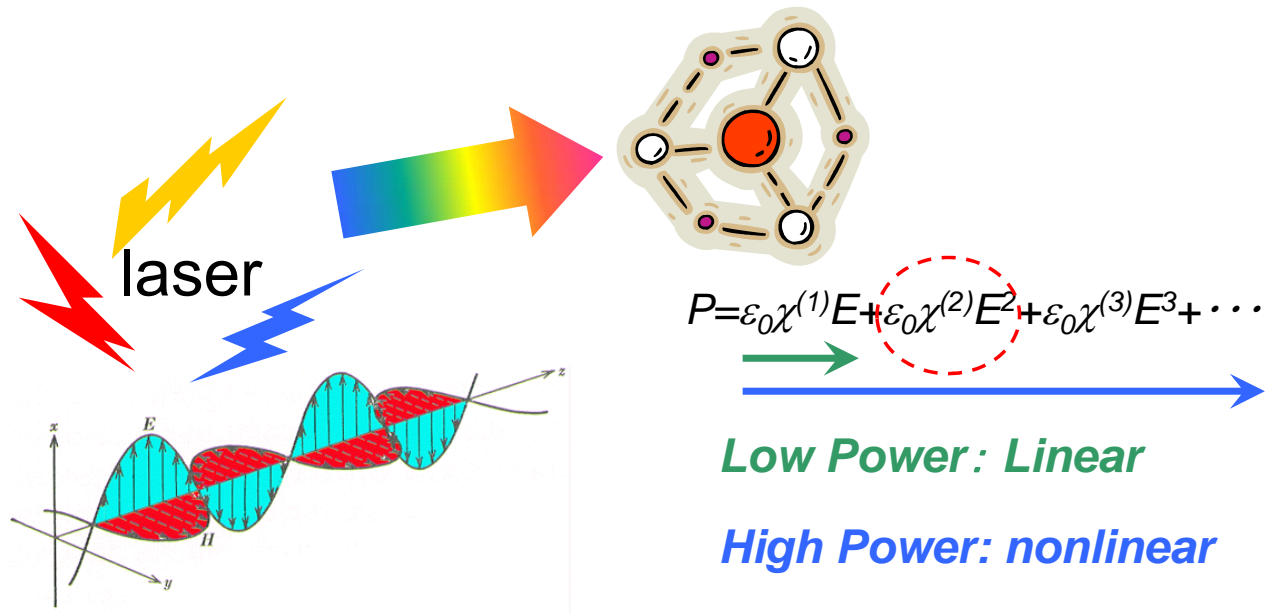
my-craft.jp

$$R + G + B = 1 (100\%)$$

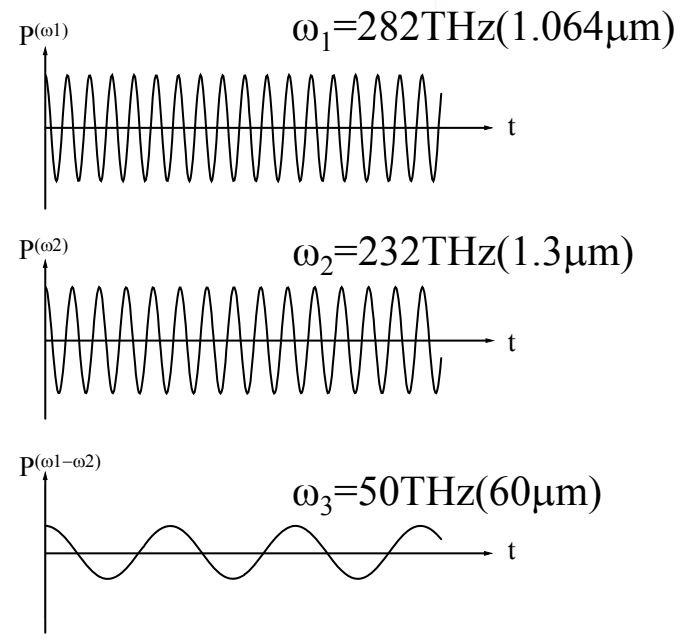
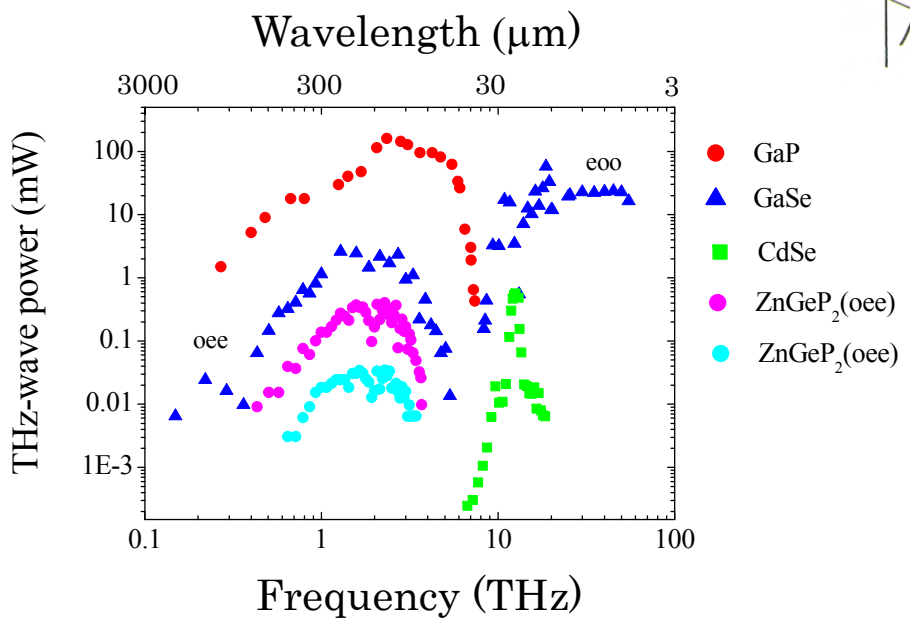
dic-color

(2) Handling of LIGHT

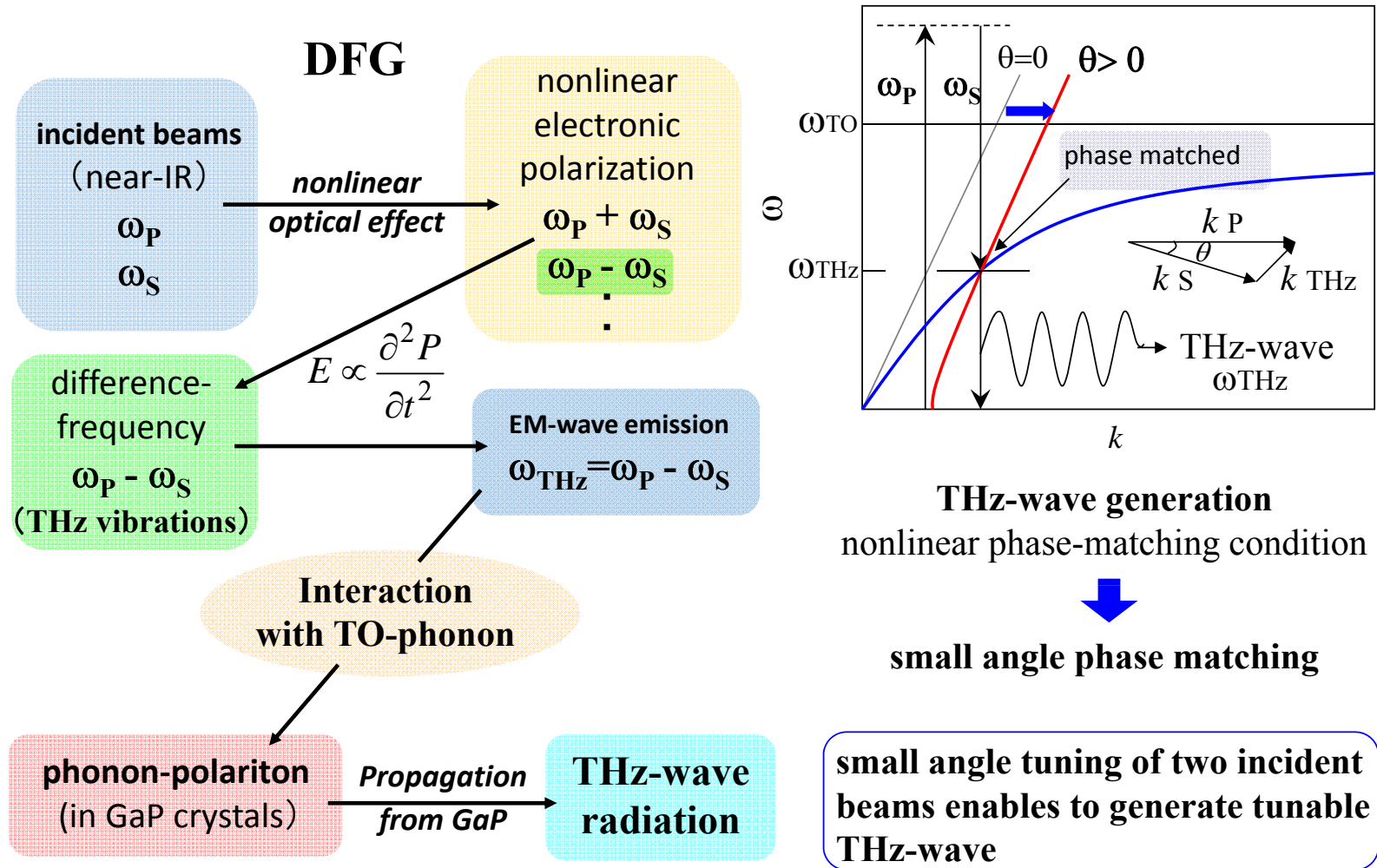
Generation
 heating
 energy gap in semiconductor
 nonlinear optical process
 (frequency-mixing: DFG, SFG, SHG)



difference-frequency generation (DFG)

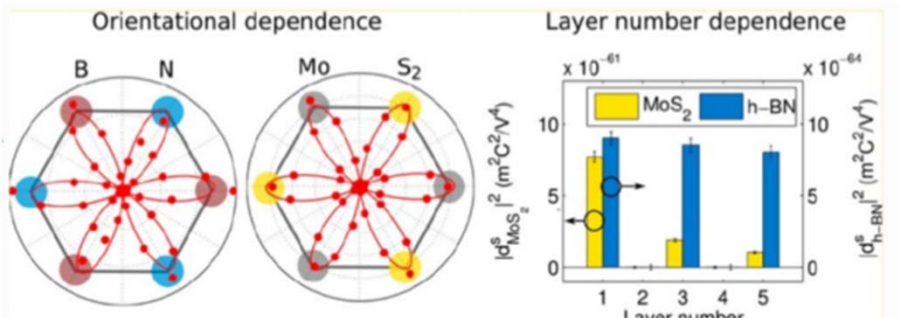
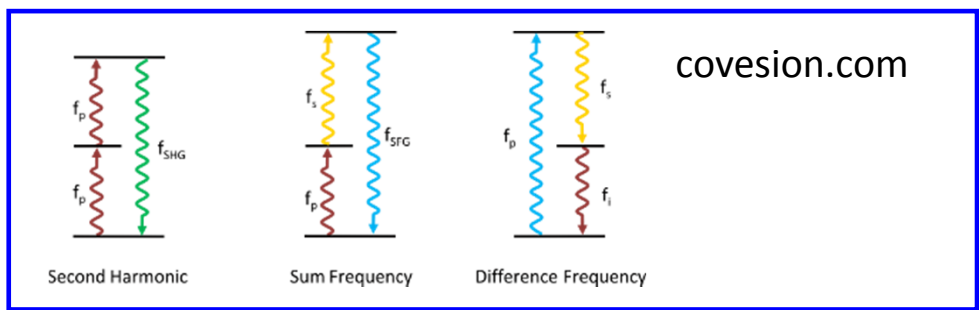


THz-wave generation based on non-collinear phase-matched DFG in phonon-polariton of GaP

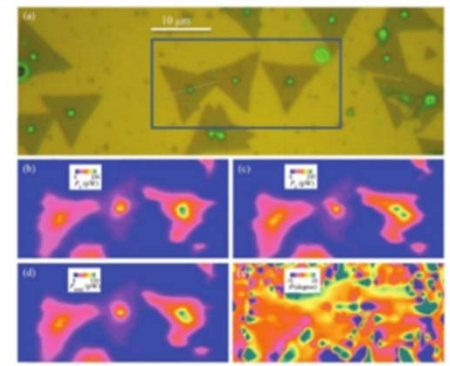


(2) Handling of LIGHT

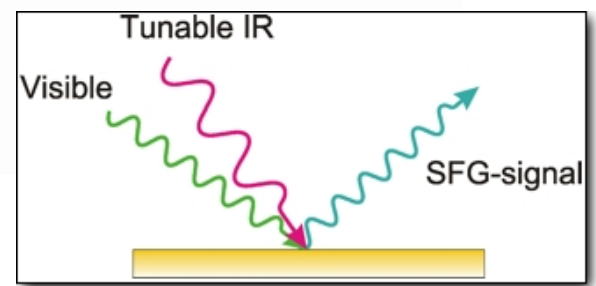
Generation
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Probing Symmetry Properties of Few-Layer MoS₂ and h-BN by Optical Second-Harmonic Generation Nano Lett. 13, 3329 (2013)



Second harmonic microscopy of MoS₂ PRB 87, 161403 (2013)



Claudio Attacalite, CNRS researcher at Neel Institute Grenoble

nb.uw.edu

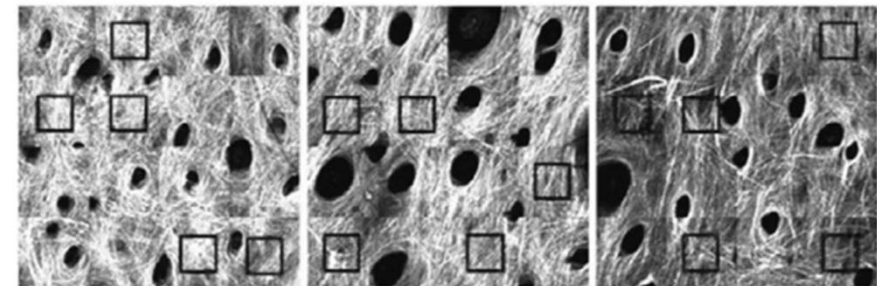
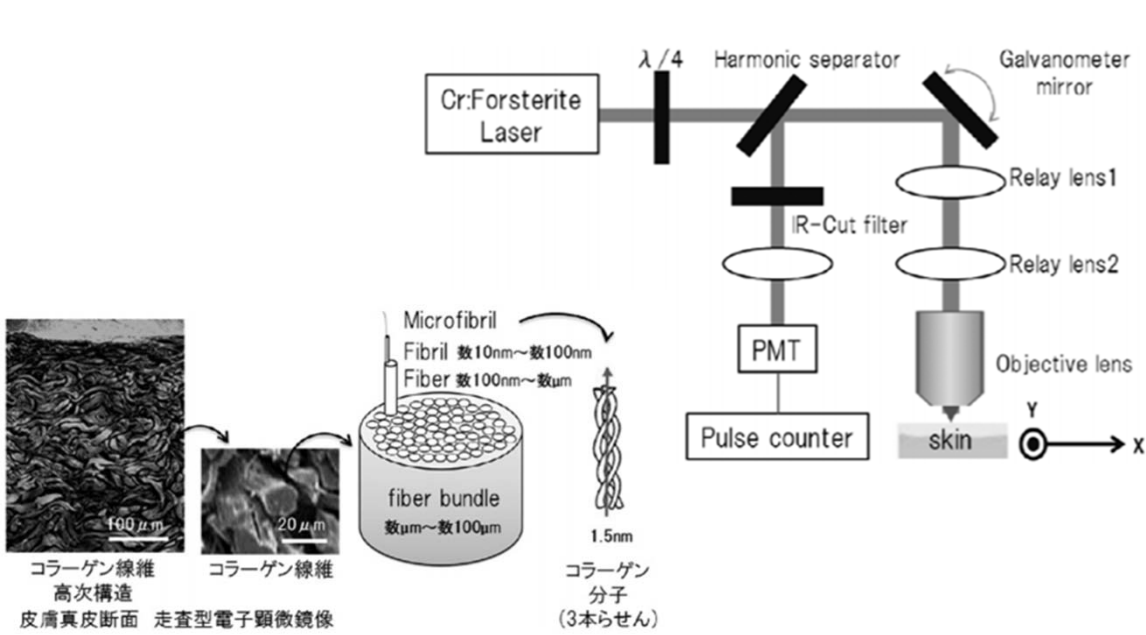
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 (frequency-mixing: DFG, SFG, SHG)

Transactions of Japanese Society for Medical and Biological Engineering
 Vol. 55 (2017) No. 2 p. 91-96

Quantitative Evaluation of Collagen Fiber Structure in Human Dermis Based on Two-Dimensional Auto-Correlation Analysis of SHG (Second Harmonic Generation) Image



(a)20's (b)40's (c)60's

図6 各年代被験者における頬皮膚の大面積 SHG イメージと画像解析に用いた領域 (黒枠).

Fig. 6 Large-area SHG images (image size = 1.6 mm × 1.6 mm, pixel size = 512 pixel × 512 pixel), probing depth (= 70-100 μm from epidermis) of subjects in their 20s, 40s, and 60s. Black holes indicate appendages (including hair follicles)

図1 コラーゲン線維の高次構造.

Fig. 1 Hierarchical structure of collagen fiber.

(2) Handling of LIGHT

Propagation :absorption in air, liquid and solid

:reflection, refraction, diffraction, absorption and scattering waveguide optical fiber

Properties of Light

❖ **Reflection** = when light strikes smooth shining surface it returns back into same medium.

❖ **Refraction** = When light enters from one transparent medium into another , it changes its path.



Absorption

$$\alpha = -\frac{\ln\left(\frac{T_1}{T_2}\right)}{x_1 - x_2}$$

T : Transmittance
X₁, x₂ : Thickness

$$T\% = (100 - R) e^{-\alpha \cdot x}$$

Diffraction

White Light

Diffraction Grating

flinnsci.com

White light

Refraction through a prism

physics.louisville.edu

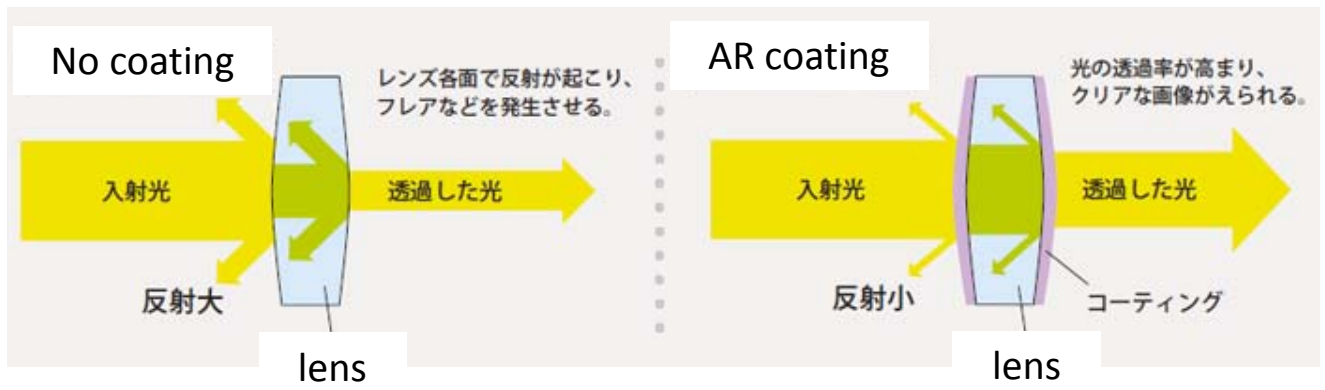
(2) Handling of LIGHT

Propagation :absorption
in air, liquid and solid

:reflection, refraction, diffraction, absorption and scattering

waveguide
optical fiber

Anti-Reflection coating



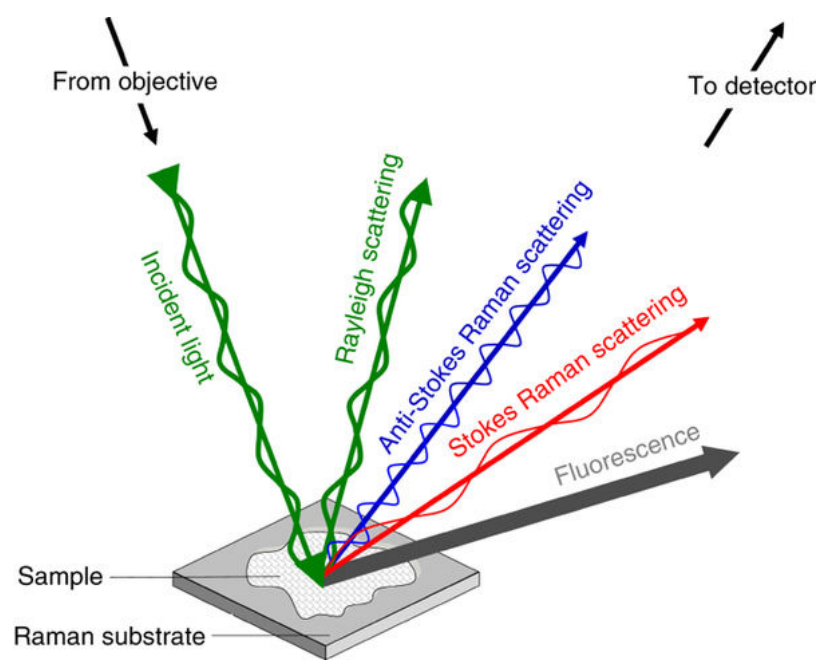
panasonic.com

(2) Handling of LIGHT

**Propagation :absorption
in air, liquid and solid**

:reflection, refraction, diffraction, absorption and scattering

**waveguide
optical fiber**



Nature Protocols 11, 664–687 (2016)

Particle <math>< \frac{1}{10} \lambda</math>
(<50nm)
Rayleigh's Scattering

$$Q \propto \frac{r}{\lambda}$$



$\frac{1}{10} \lambda < \text{Particle} < \lambda$
(50-500nm)
Mie Scattering

$$Q \propto C + \cos\left(\frac{r}{f}\right) e^{-k\left(\frac{r}{f}\right)}$$



Particle >math> > \lambda</math>
(>1μm)
Optical Scattering

$$Q \propto C$$



iLectureonline

ccs-inc.co.jp