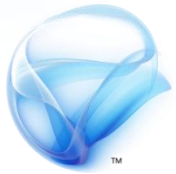
Introduction to Nanotechnology

- Textbook：
  Nanophysics and Nanotechnology
  by:
  Edward L. Wolf

Instructor: ***H. Hosseinkhani***
E-mail: **hosseinkhani@yahoo.com**

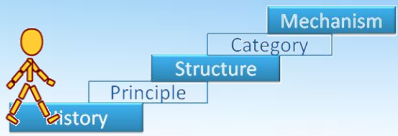
Classroom: A209
Time: Thursday; 13:40-16:30 PM
Office hour: Thur., 10:00-11:30 AM or by appointment



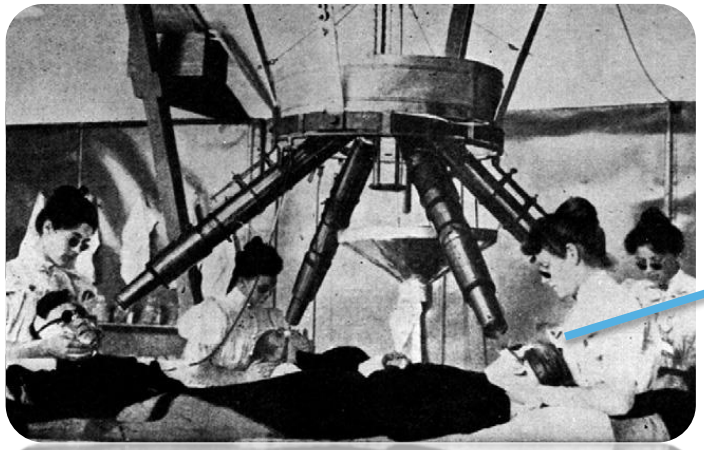
Microsoft® Silverlight™

Light-Emitting Diodes (LEDs)

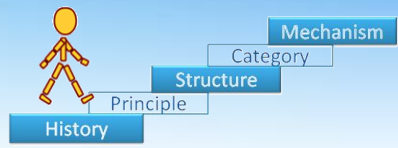
Light Therapy History



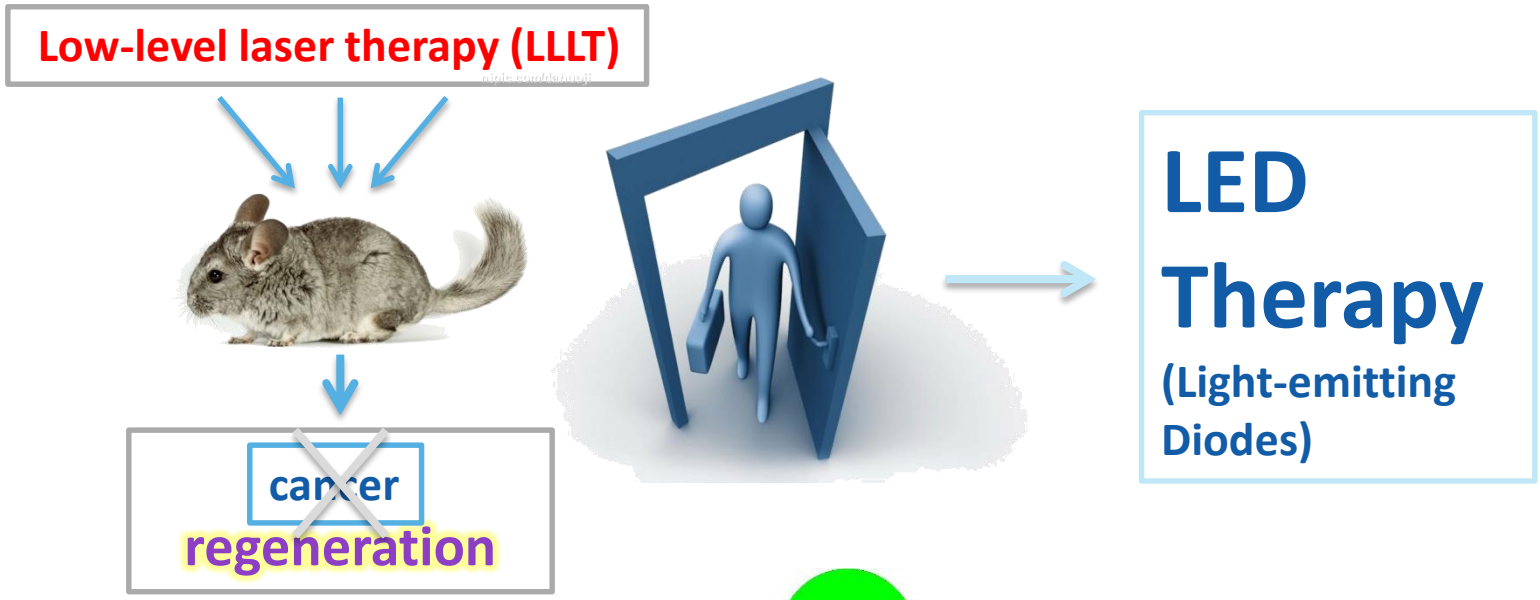
- Thousands of years ago → Used to treat skin diseases.
- 1903, Niels Ryberg Finsen (Nobel Prize) → Treatment of diseases, notably lupus vulgaris.



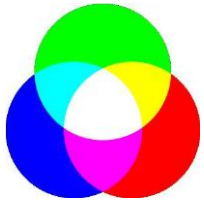
Light Therapy History



- **Late 1960s → Endre Mester**

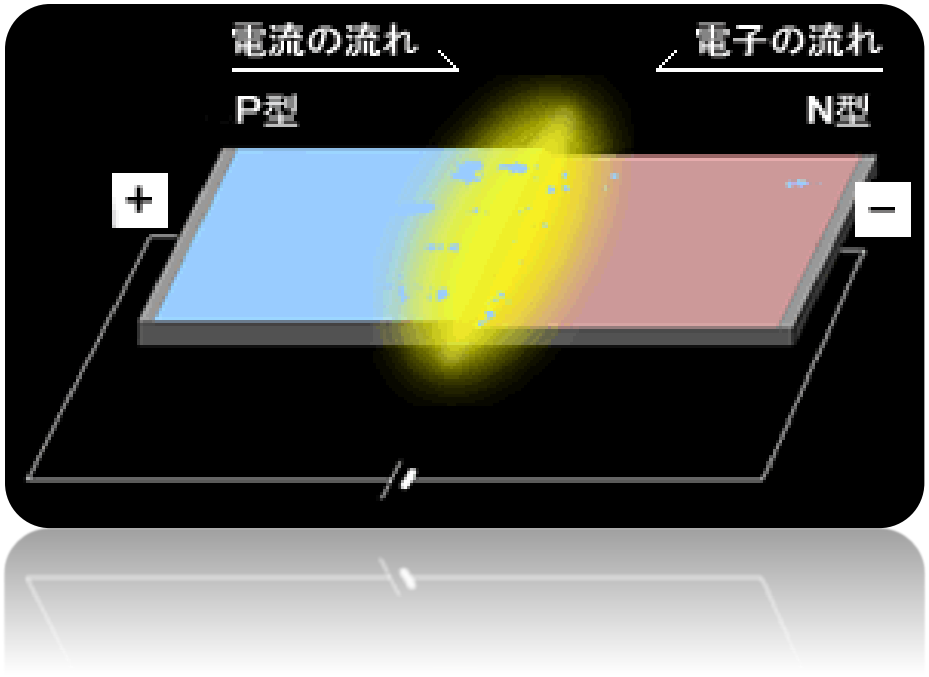


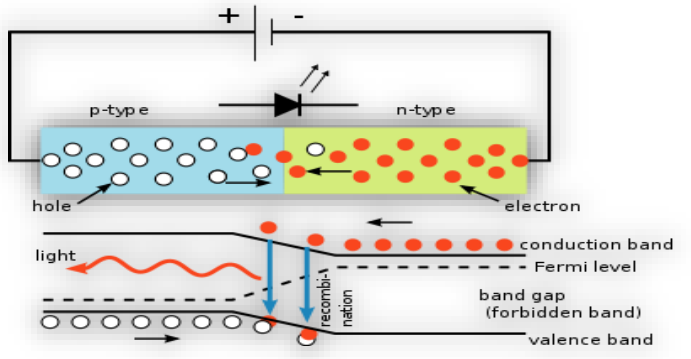
- **1993 → Nichia**
  1. Producing **blue** LEDs
  2. Producing **white** light LEDs (RGB)



LED Industry

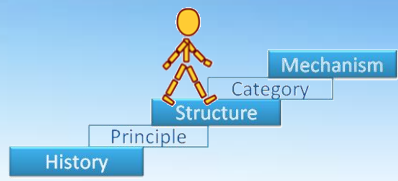
Principle

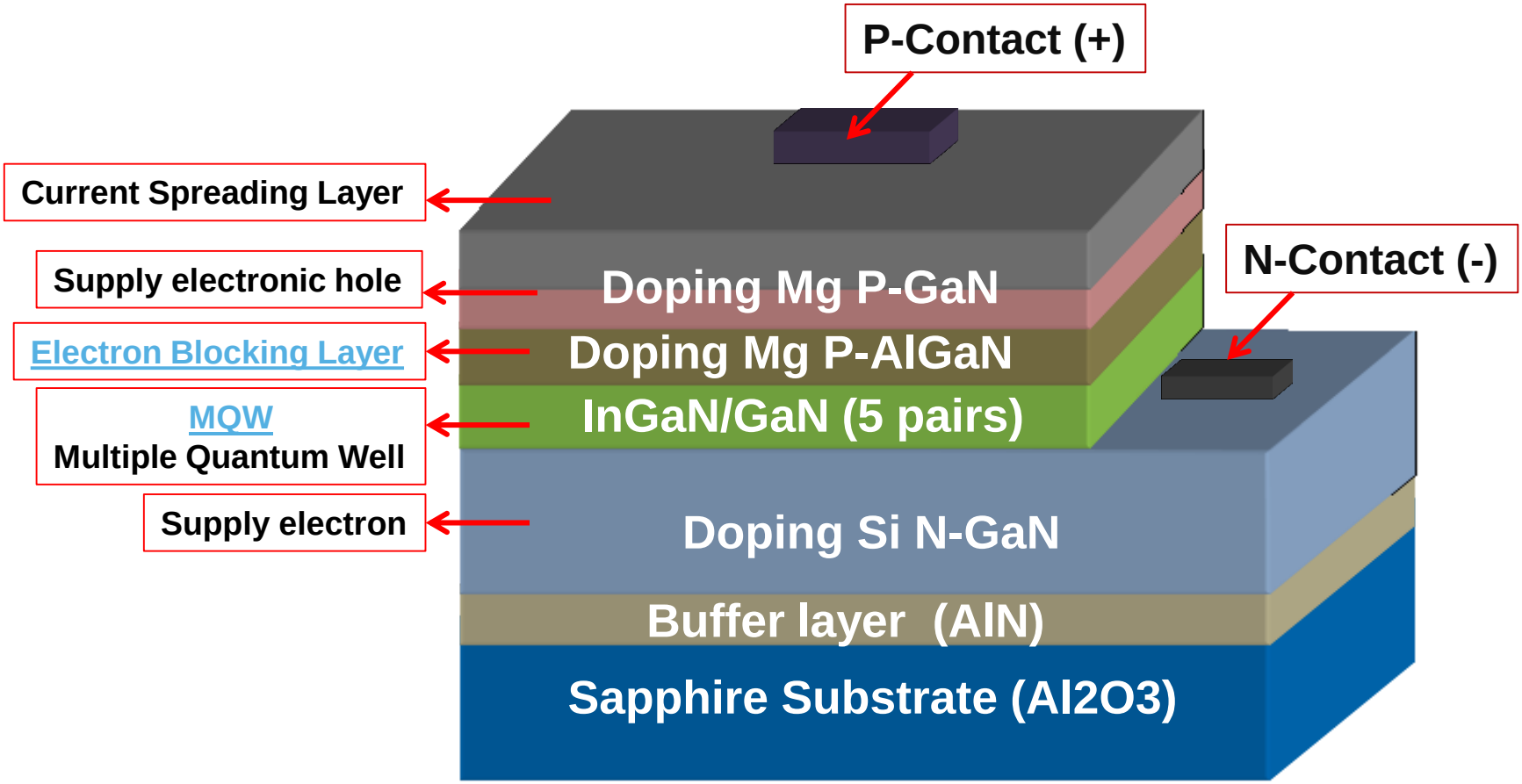




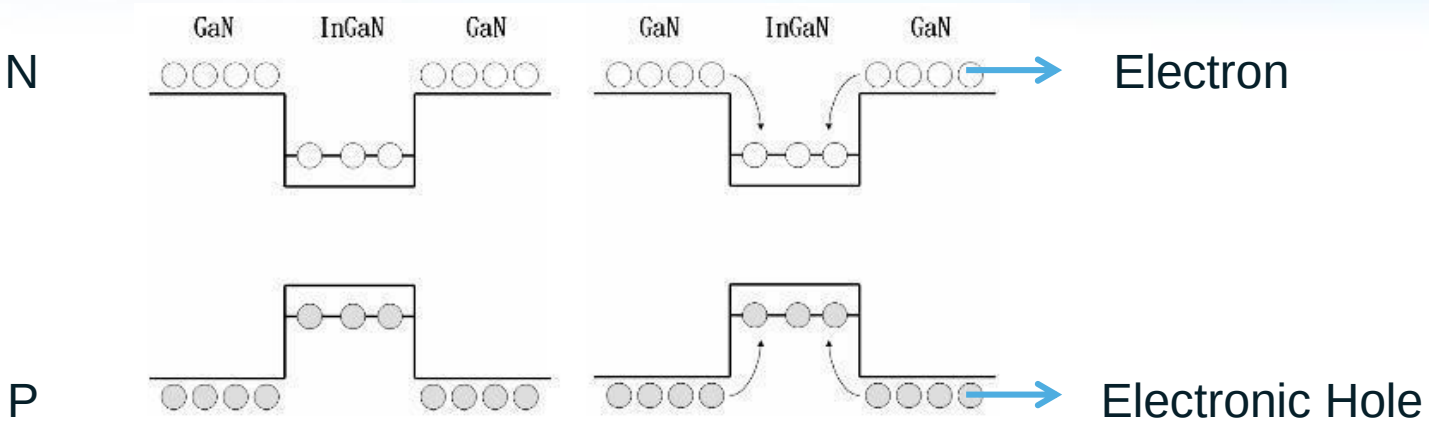
Current flow from P to N.
When an electron meets a hole, it falls into a lower energy level, and releases energy in the form of a photon.

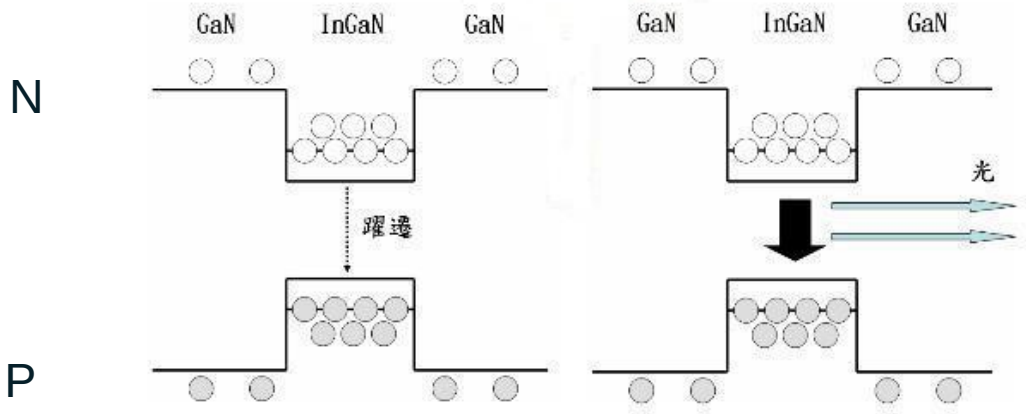
LED Structure





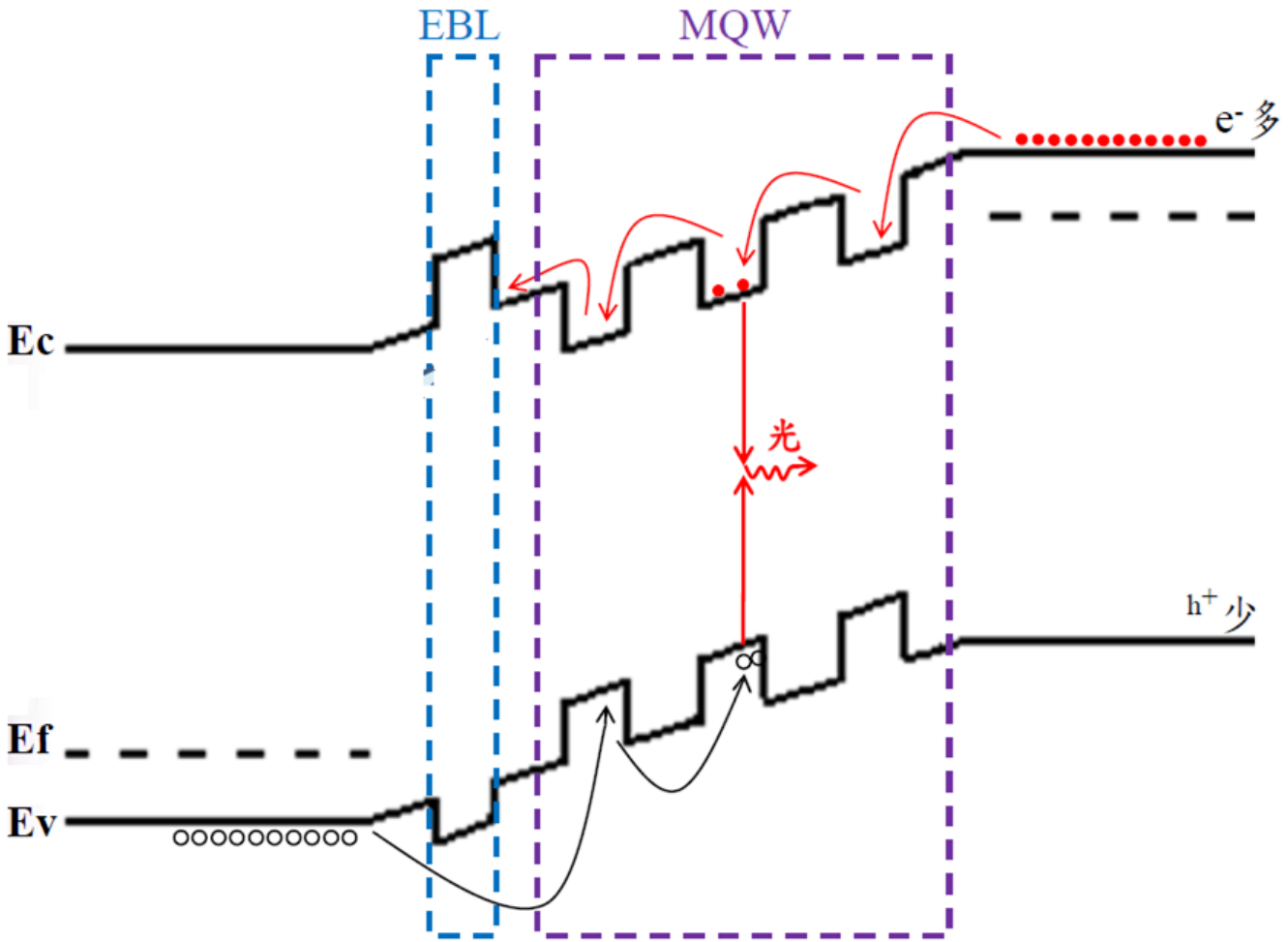
MQW
Multiple Quantum Well



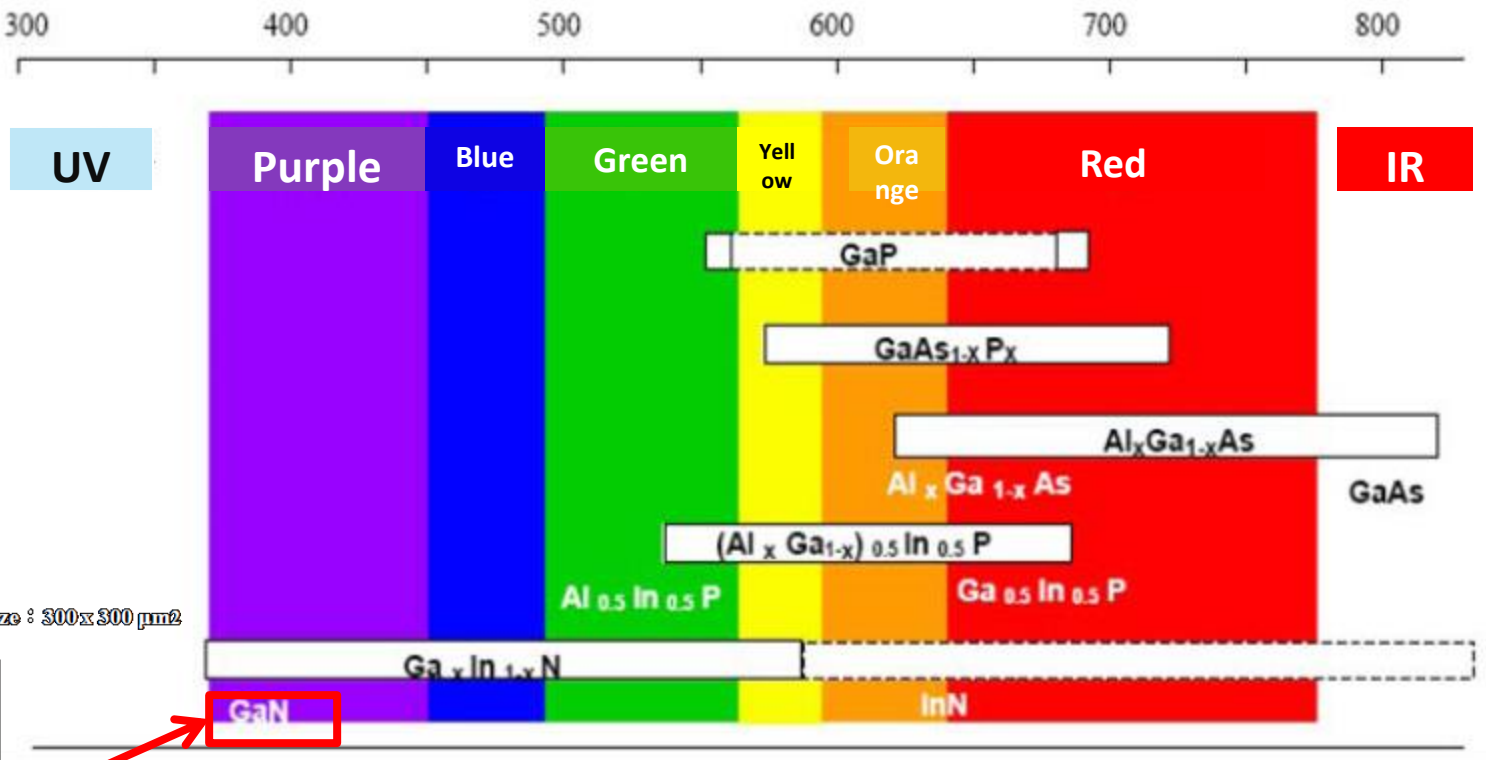


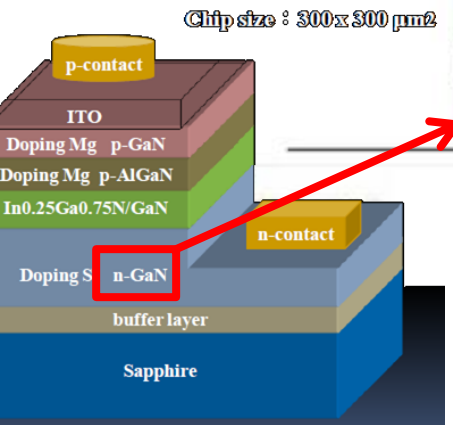
EBL
Electron Blocking Layer

MQW
Multiple Quantum Well



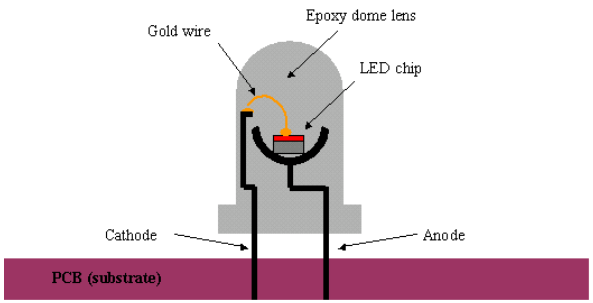
LED Structure-Material





Category

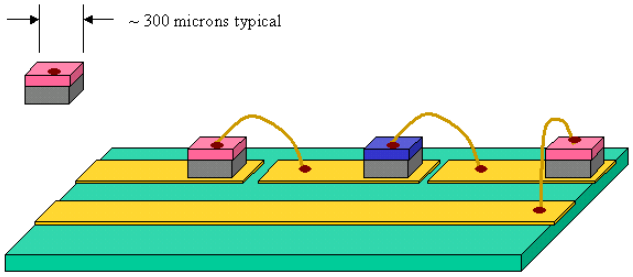
1. Packed LED

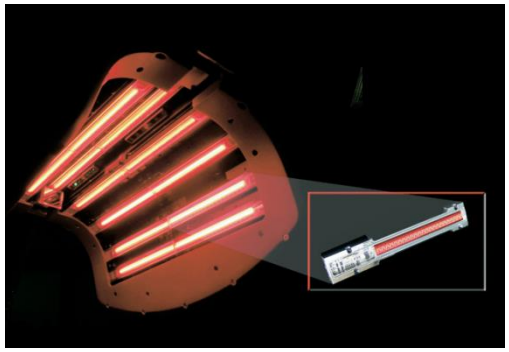


Disadvantage ：

1. No sufficiently uniform lighting
2. Not Well heat-sinked

2. Chip-on-board





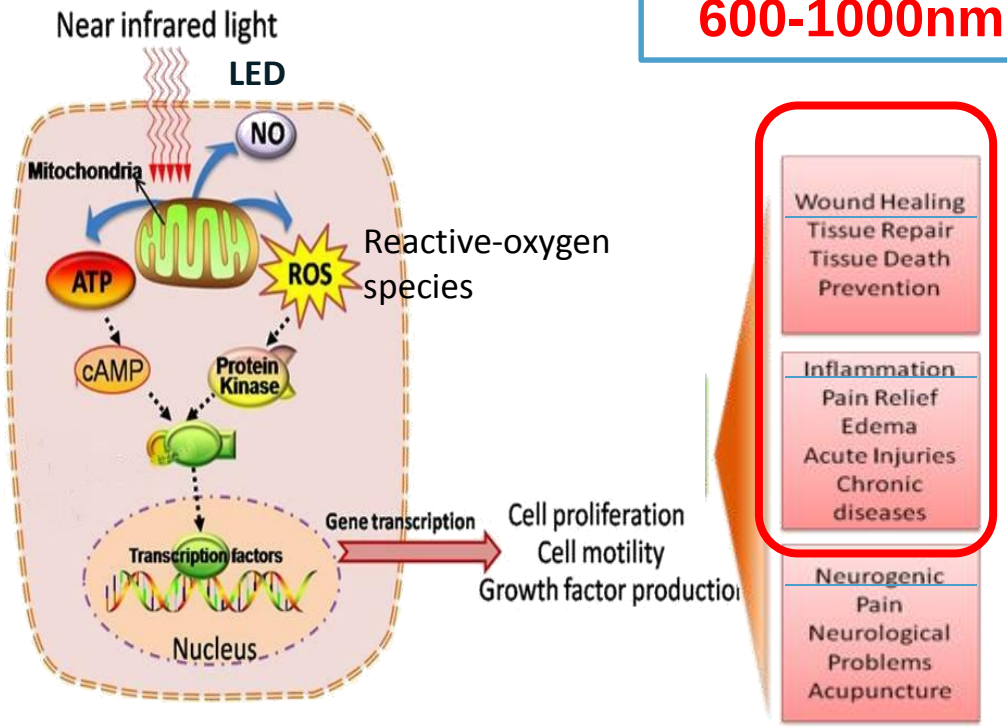
Mechanism of Action

LEDs can trigger natural intracellular photo-biochemical reactions

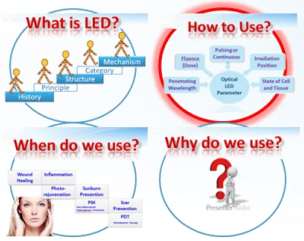
Optimal parameter
600-1000nm

Hypothesis

1. **Mitochondria Mechanism**
2. **NO Mechanism**
3. **Redox Mechanism**



9 July 2009, SPIE Newsroom. DOI: 10.1117/2.1200906.1669



How to Use?

Pulsing or Continuous

Fluence (Dose)

Irradiation Position

Penetrating Wavelength

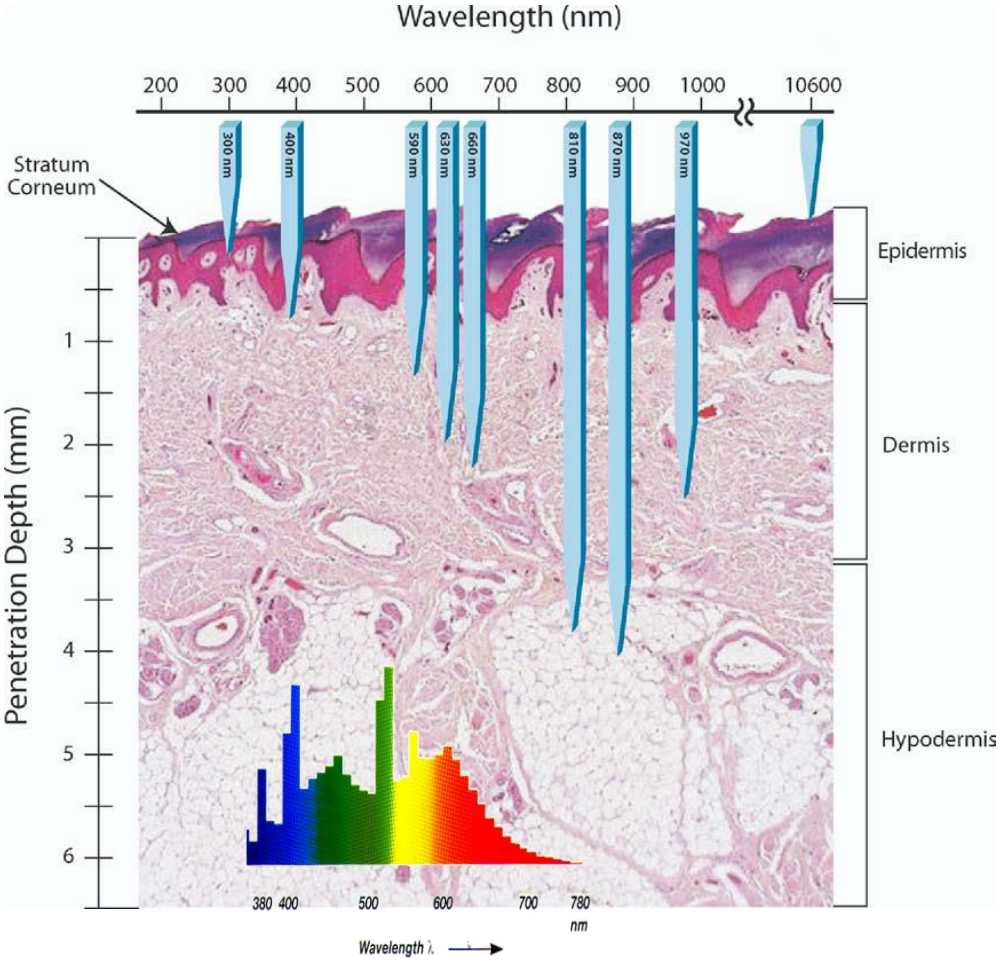
Optimal LED Parameter

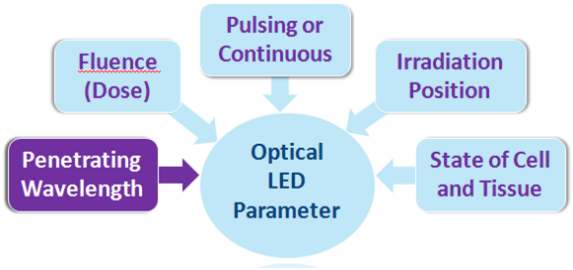
State of Cell and Tissue

Optimal LED Parameter

600-1000 nm

1. Penetrating Wavelength

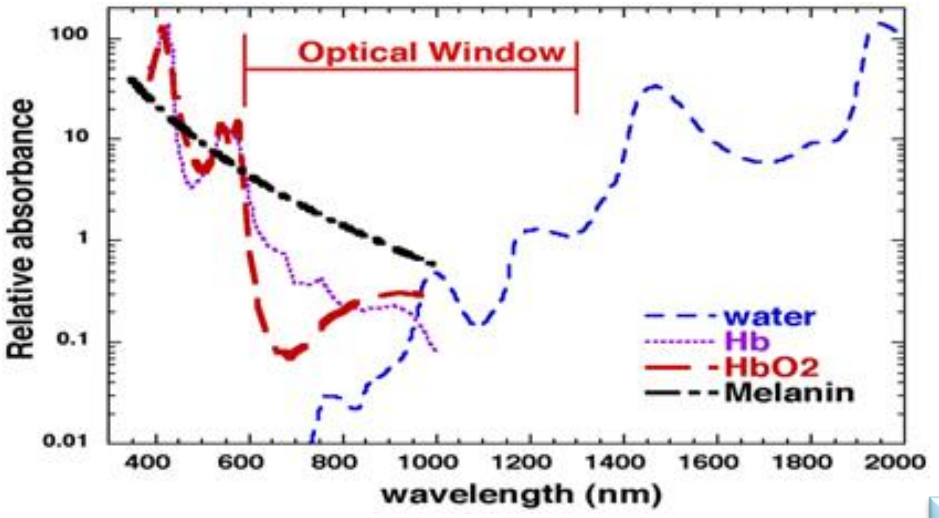


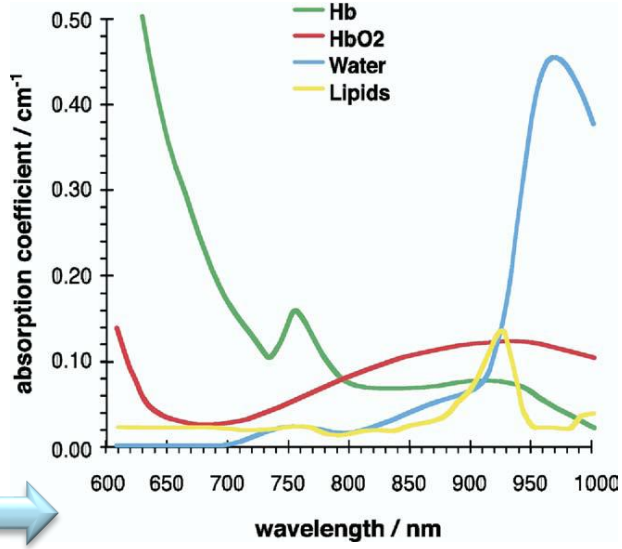


The longer the wavelength, the deeper the penetration into tissues.

Collar	Wavelength
Blue	400-470 nm
Green	470-550 nm
Red	630-700 nm
NIR	700-1200 nm

Optimal LED Parameter





< **600 nm** : Hemoglobin and melanin have high absorption bands.

> **1000 nm** : Water is also absorbing many photons, reducing their availability for specific chromophores located.

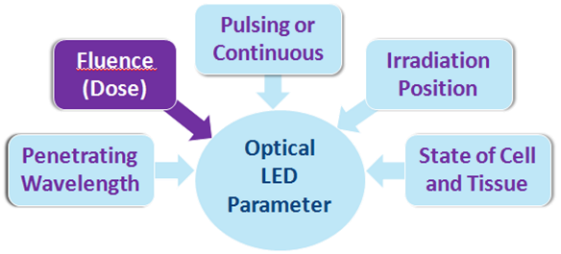
Optimal parameter
600-1000 nm

9 July 2009, SPIE Newsroom. DOI: 10.1117/2.1200906.1669

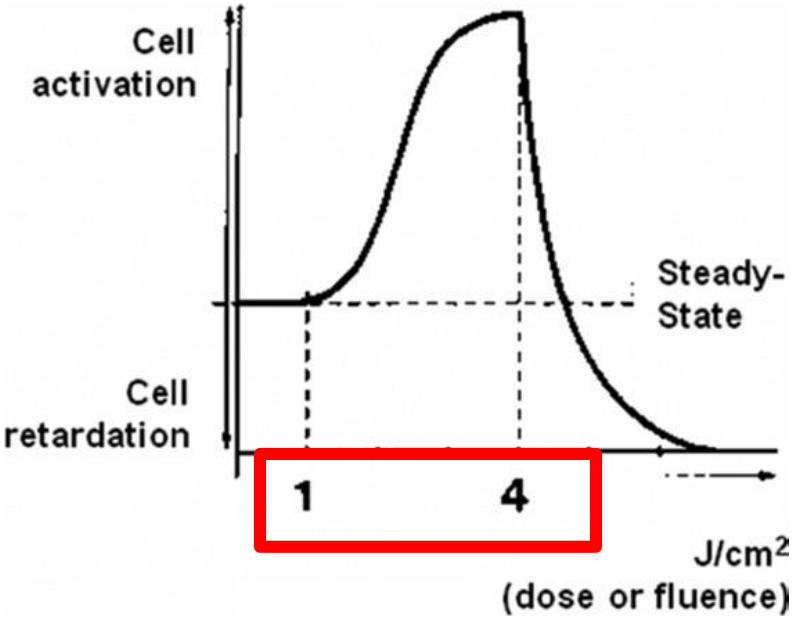
Optimal LED Parameter

1-4J/cm²

2. Fluence and Irradiance



Dose = Intensity X Time
J/cm²= W/cm² X S



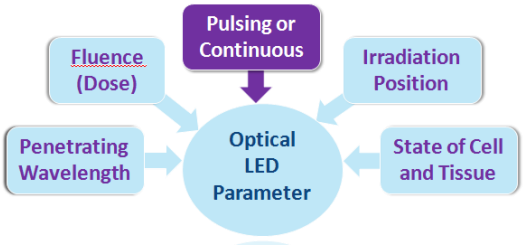
Arndt-Schulz law

- **Weak stimuli accelerate physiologic activity**
- **Medium stimuli inhibit physiologic activity**
- **Strong stimuli halt physiologic activity**

Opmical LED Parameter

Pulsing

3. Pulsing and Continuous Modes



Ultra-short pulses can travel deeper into tissues than CW radiation.

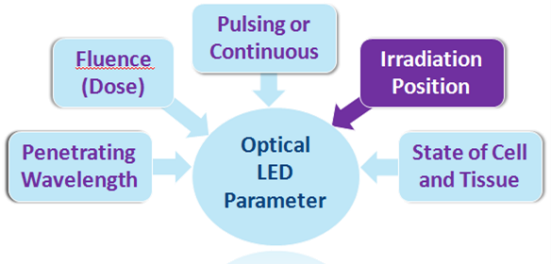
The first part of a powerful pulse may Contain enough photons to take all chromophore molecules in the upper tissue layer to excited states, thus literally opening a road for itself into tissue.

Optical LED Parameter

Precise

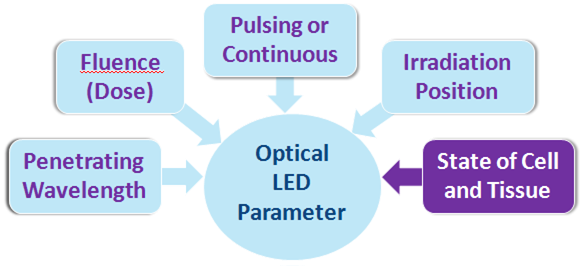
4. Irradiation Positioning

Amount of energy must be delivered to the target to trigger the expected cell response.



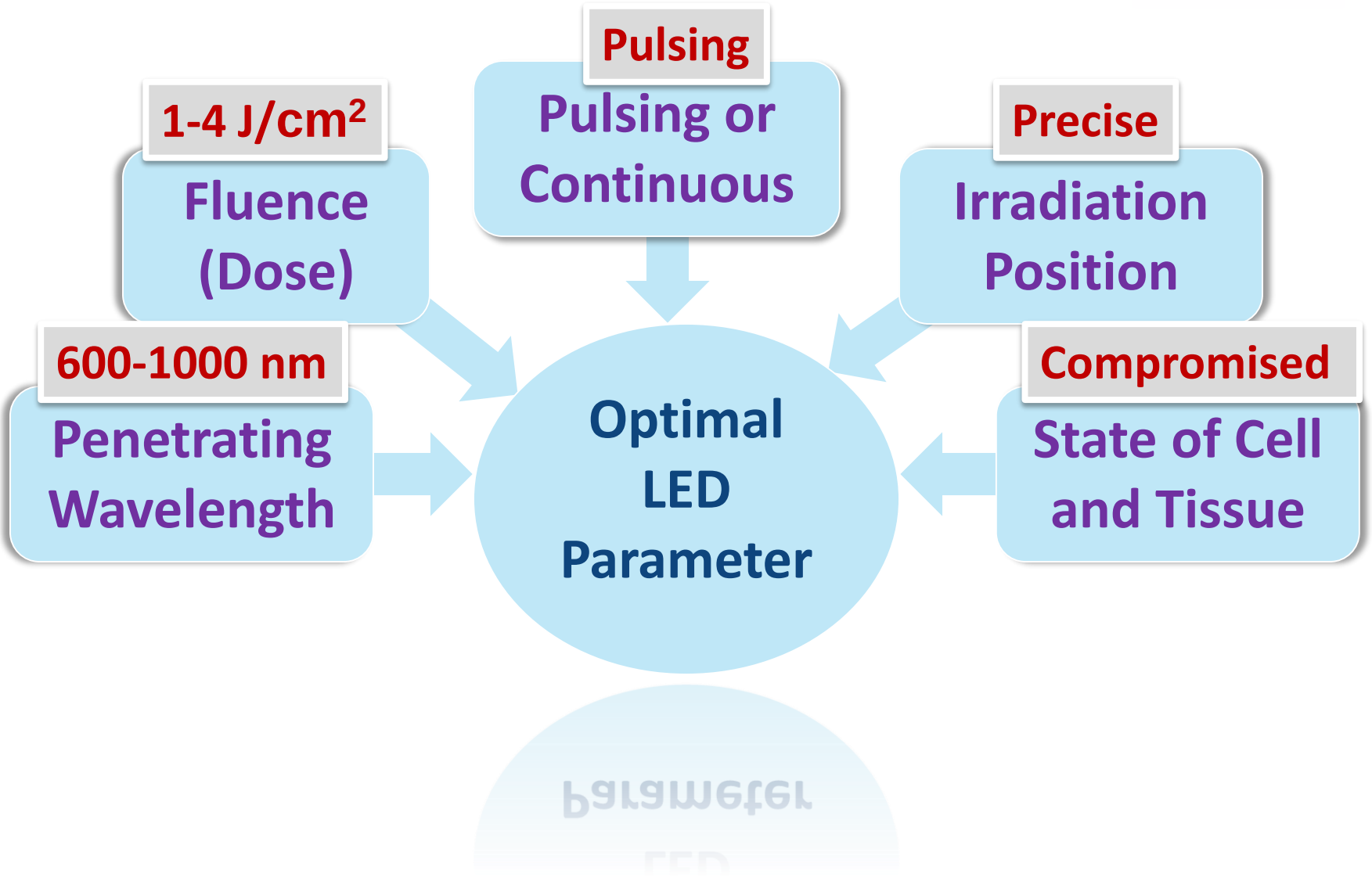
Compromised

5. State of Cells and Tissue

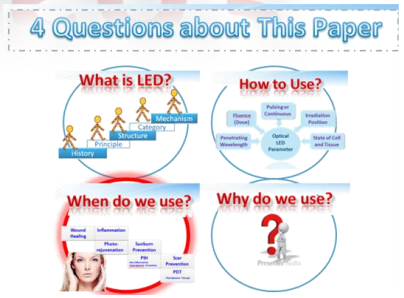


Compromised cells and tissues respond more readily than healthy cells or tissues to energy transfers that occur between LED-emitted photons and the receptive chromophores.

Optimal LED Parameter



When do we use?



Wound Healing

Anti-Inflammation

Photo-rejuvenation

Sunburn Prevention

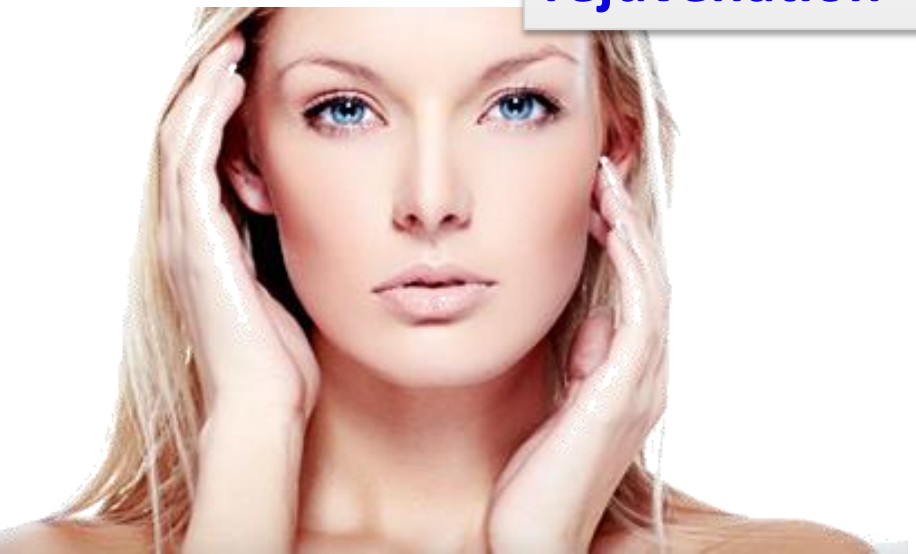
PIH

Post-inflammation Hyperpigment Prevention

Scar Prevention

PDT

Photodynamic Therapy



Wound Healing | Anti-Inflammation | Photo-rejuvenation | Sunburn Prevention | PIH (Post-inflammation Hyperpigment Prevention) | Scar Prevention | PDT (Photodynamic Therapy)

The Appliance of LED

1. Wound Healing

Control

After CO_2 ablative resurfacing

After LED Treatment 48 hours

Applications	Wavelength (nm)	No. of Treatments	Irradiance (mW/cm^2)	Fluence (J/cm^2)	Treatment Time (min;sec)	Interval Treatment Time (hours)	Mode (Pulsed/CW)
Wound healing	660 & 850 combination	3-12	50 (minimal)	4	2:40	24-72	Sequential pulsing**

The Appliance of LED

2. Anti-Inflammation

Typical skin reactions post-RT compared with typical reaction post-RT+LED.

Treatment of Radiation-Induced Dermatitis With Light-Emitting Diode (LED) Photo-modulation.

JAAPA 2005, 11:54–62.

Grade			
0	1	2	3
None	Faint erythema or dry desquamation	Moderate to brisk erythema or patchy moist desquamation, mostly confined to skin folds and creases; moderate edema	Confluent moist desquamation, ≥10 cm diameter, not confined to skin folds; pitting edema

Applications	Wavelength (nm)	No. of Treatments	Irradiance (mW/cm²)	Fluence (J/cm²)	Treatment Time (min;sec)	Interval Treatment Time (hours)	Mode (Pulsed/CW)
Inflammation/erythema/edema	630-660	3-12	50 (minimal)	4	2:40	48-72	Sequential pulsing

The Appliance of LED

3. Photorejuvenation

Applications	Wavelength (nm)	No. of Treatments	Irradiance (mW/cm^2)	Fluence (J/cm^2)	Treatment Time (min;sec)	Interval Treatment Time (hours)	Mode (Pulsed/CW)
Photorejuvenation	630-660	12	50-100	4	2:40-16	48-72	Sequential pulsing

The Appliance of LED

4. Sunburn Prevention

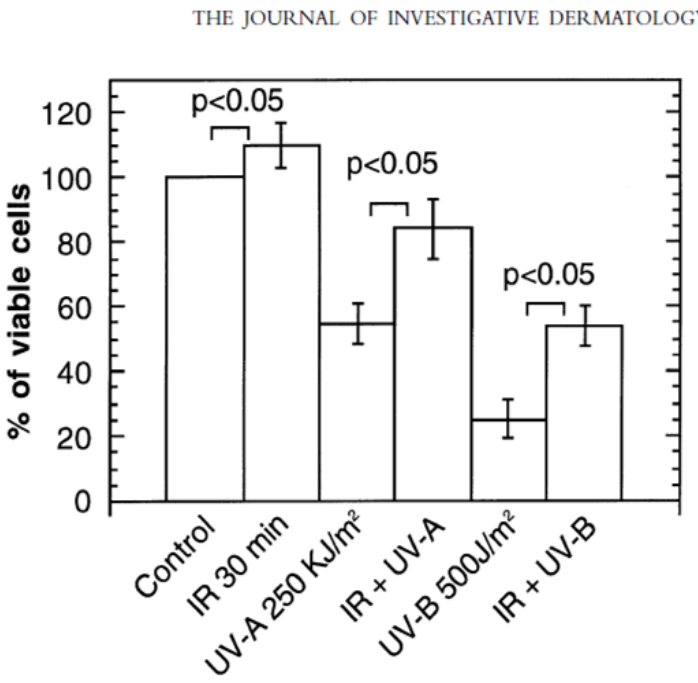
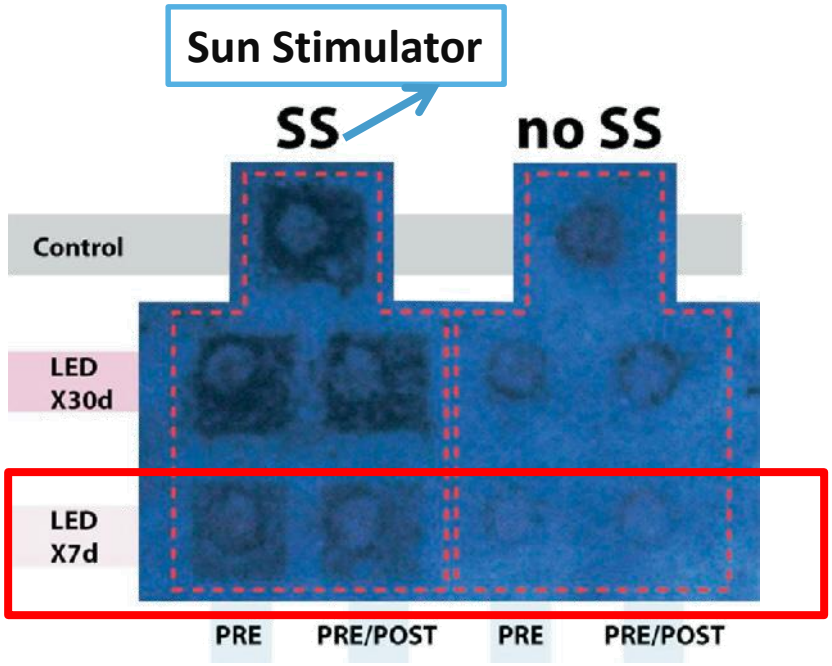


Figure 1. Pre-irradiation with near-IR protects human skin fibroblasts from solar UV cytotoxicity. The cells were exposed (or not) to 30 min of IR radiation (810 kJ per m^2), washed two times with HBSS, and irradiated immediately with UVA or UVB. After UV irradiations, the cells were washed again with HBSS and incubated in culture conditions with their original medium for 24 h (UVA) or 72 h (UVB), before counting viable cells. The columns represent the mean ± SD of three independent experiments in triplicate. Student's paired t test p values < 0.05 are statistically significant.

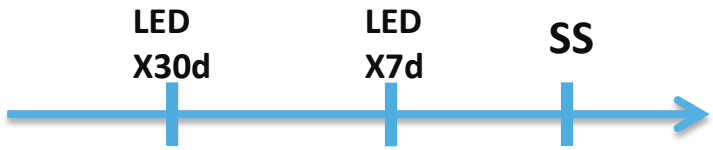
Applications	Wavelength (nm)	No. of Treatments	Irradiance (mW/cm^2)	Fluence (J/cm^2)	Treatment Time (min;sec)	Interval Treatment Time (hours)	Mode (Pulsed/CW)
Sunburn prevention*†	660-970	ad 7	50	4	2:40-15	24-48	Sequential pulsing or CW

The Appliance of LED

5. Post-inflammation Hyperpigment Prevention (PIH)



The 7-day LED treatment before UV insult appears to be the best regimen to prevent PIH.



Applications	Wavelength (nm)	No. of Treatments	Irradiance (mW/cm²)	Fluence (J/cm²)	Treatment Time (min;sec)	Interval Treatment Time (hours)	Mode (Pulsed/CW)
PIH prevention*†	870-970	ad 8	50-80	45-96	15-20	24-48	Sequential pulsing or CW

The Appliance of LED

6. Scar Prevention

After Facelift

Facelift 12 month After

LED Treated 30days **No Treated**

Applications	Wavelength (nm)	No. of Treatments	Irradiance (mW/cm^2)	Fluence (J/cm^2)	Treatment Time (min;sec)	Interval Treatment Time (hours)	Mode (Pulsed/CW)
Scar prevention*	805-970	Multiple	50-80	45-72	15	24	CW

The Appliance of LED

Wound Healing | Anti-Inflammation | Photo-rejuvenation | Sunburn Prevention | PIH (Post-inflammation Hyperpigment Prevention) | Scar Prevention | PDT (Photodynamic Therapy)

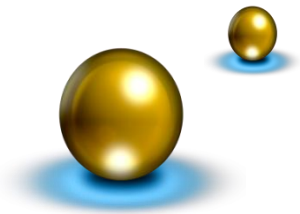
7. Photodynamic Therapy(PDT)

Device Parameters	Blu-U	Omnilux Revive
Wavelength (nm)	417nm	633nm
Power Density (mW/cm2)	10	105
Working Distance Gauge	No	No
Treatment time (sec)	1000	1200-1800

Applications	Wavelength (nm)	No. of Treatments	Irradiance (mW/cm^2)	Fluence (J/cm^2)	Treatment Time (min;sec)	Interval Treatment Time (hours)	Mode (Pulsed/CW)
PDT	405-630	3+	50-100	>50	13-45	3 weeks	CW or pulsed

The Advantages of LED

- Why do we use LED for therapy?
  1. Low-Level Light (Much gentler)
  2. Do not damage tissue and eyes
  3. Safer
  4. None-toxic
  5. None-Invasive



Is there another appliance of LED?
Why did author just use LED in dermatology?

It may the fast and the easiest method to reflect the advantages of LED.

Reference 1
LED in Tissue Regeneration

Title	Disease	Color Wavelength	Energy (J/cm^2)	Model	Reference
The effects of low-level light emitting diode on the repair process of Achilles tendon therapy in rats.	tenotomy →tissue repairing	Red 640±20 nm	20 J/cm2 (120 s)	Thirty albino male Wistar rats	Lasers Surg Med. 2010 Aug
Effect of light-emitting diode (LED) therapy on the development of osteoarthritis (OA) in a rabbit model.	Osteoarthritis	high intensity red 630 nm and IR870 nm	~2 J/cm2 (red) and 2.5 J/cm2 (IR)	14 female New Zealand White rabbits	Biomed Pharmacother. 2011 Jun
Effect of near-infrared light-emitting diodes on nerve regeneration.	injured optic nerve	NIR LED 660nm	1hr total energy 27(J/cm^2)	rat	J Orthop Sci. 2010 Mar

Reference 2
LED in Tumor Therapy

Title	Disease	Color Wavelength	Energy (J/cm^2)	Model	Reference
Photodynamic Therapy-Induced Apoptosis of HeLa Cells.	kills cancer cells	Green 530 ± 15 nm	1.6 J/cm2	HeLa Cells	Ann N Y Acad Sci. 2009 Aug;1171:617-26.
Indocyanine green-based photodynamic therapy with 785nm light emitting diode for oral squamous cancer cells.	Kills oral squamous cancer cells	Green 785nm	50mW/cm2 at 0.5A	oral squamous cancer cells	Photodiagnosis Photodyn Ther. 2011 Dec;8(4):337-42. Epub 2011 Jul 12.

Reference 3
LED in MSC Proliferation

Title	Disease	Color Wavelength	Energy (J/cm^2)	Model	Reference
Increased mobility and stem-cell proliferation rate in Dugesia tigrina induced by 880 nm light emitting diode.	Increased mobility and stem-cell proliferation rate	NIR radiation 880 nm	~0.01 J/cm2	Planarian Dugesia tigrina	J Photochem Photobiol B. 2011 Feb7
The effect of noncoherent red light irradiation on proliferation and osteogenic differentiation of bone marrow mesenchymal stem cells	proliferation and osteogenic differentiation of bone marrow mesenchymal stem cells	red light 620 nm	0, 1, 2 and 4 J/cm2	bone marrow MSCs	Lasers Med Sci. 2012 May
Effects of Red Light-emitting Diode Irradiation on Dental Pulp Cells	Dental repair	red light 653nm	0.149 J/cm2 0.224 J/cm2	dental pulp cells	J Dent Res. 2012 Aug 9.

Why can’t LED be used widely ?

1. Penetrating
   LED can’t reach deeper position.
2. Light Disperse a greater surface area.
   It can not just focus on a point.

The technique of LED still need to be improved .

LEDs in dermatology can treat a variety of cutaneous problems as a stand-alone application or complementary treatment modality or as one of the best photodynamic therapy light source.