INTENSE PULSED LIGHT
FOR POWDERED FOOD PASTEURIZATION
WORKSHOP

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IPL FOOD SAFETY

CFANS
COLLEGE OF FOOD, AGRICULTURAL AND NATURAL RESOURCE SCIENCES

INTENSE PULSED LIGHT
FOR FOOD SAFETY
University of Minnesota-Twin Cities

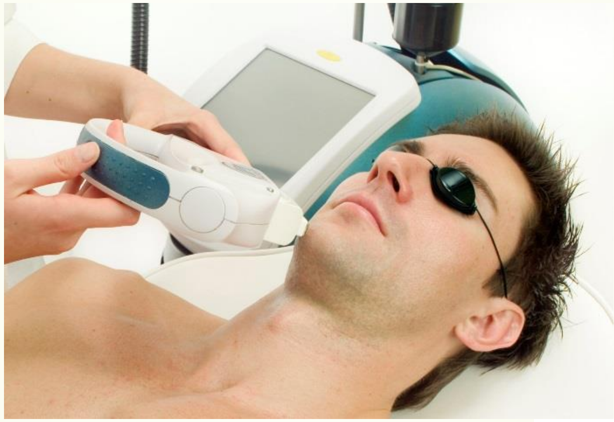
Fundamentals of Intense Pulsed Light (IPL)

for food pasteurization

Vascular Lesions

Pigmented lesions

Skin rejuvenation



Hair removal

Quick facts about IPL

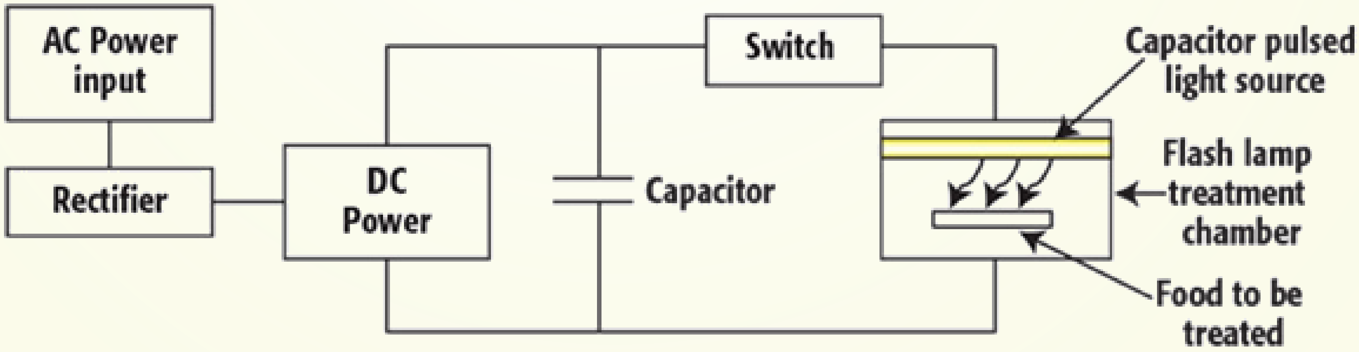
- Pasteurization of food items by using very high-power and very short-duration pulses of light emitted by inert gas flash lamps
- IPL spectra include ultraviolet (UV), visible (VL) and infrared (IR) light
- Approved by FDA in 1996
- Limited commercial applications in the food industry

Claranor: Pulsed Light Aseptic Packaging Systems

Dry and non-chemical solutions for inline packaging sterilization

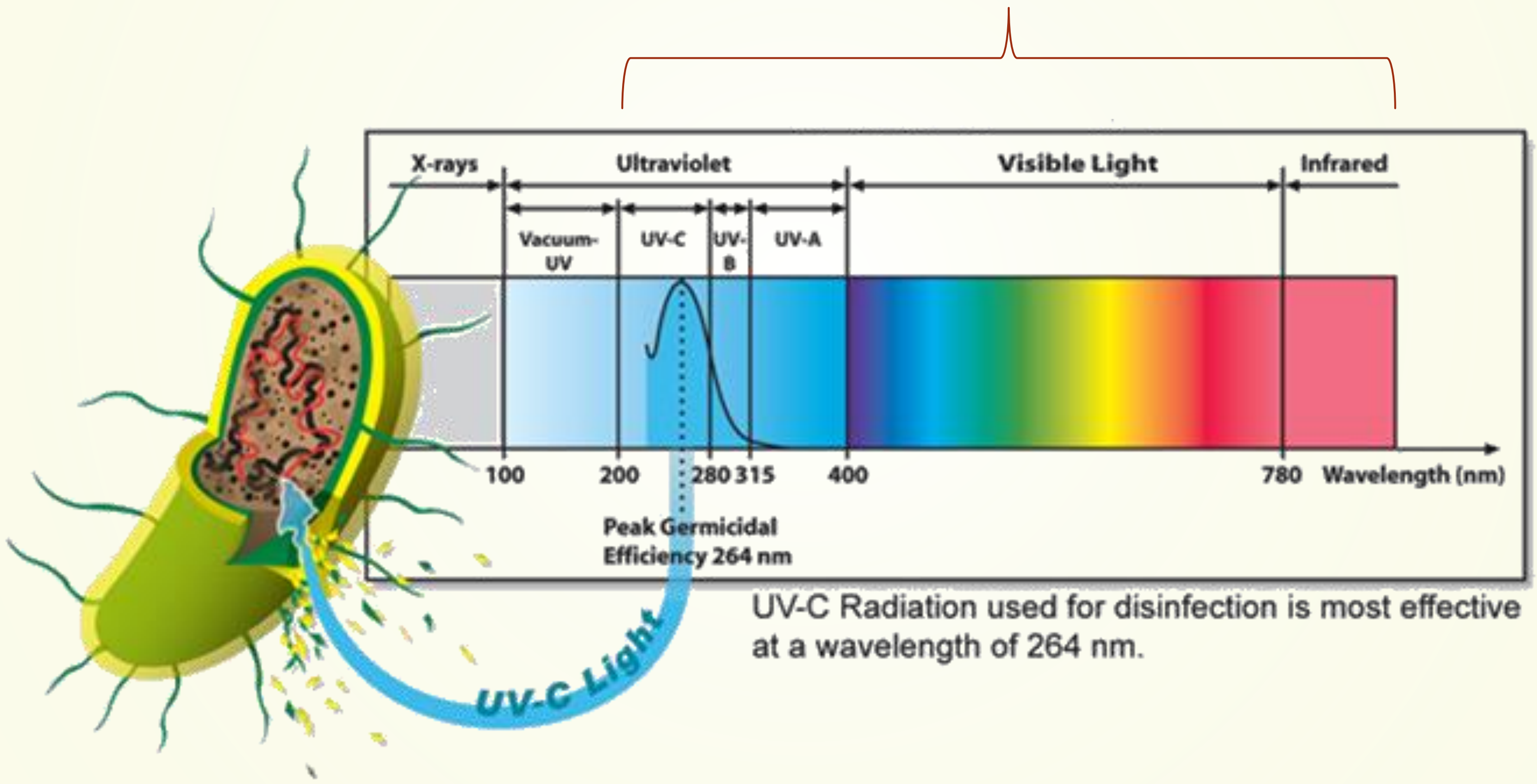
Generation of IPL

- To generate IPL, electromagnetic energy is accumulated in a capacitor within fractions of a second and then released in the form of light within a short time (nanoseconds to milliseconds), resulting in an amplification of power with a minimum of additional energy and intense burst of light in broad spectrum wavelengths from UV to near-infrared.
- The wavelength distribution ranges from 100 to 1,100 nm: UV (100–400 nm), visible light (400–700 nm), and infrared (700–1,100 nm). Pulses of light used for food processing applications typically emit 1 to 20 flashes per second at an energy density in the range of about 0.01 to 50 J cm^{-2} on the surface. The energy of the pulsed light can be up to 20,000 times the energy of the sun ray at sea level.



Schematic diagram of IPL treatment

IPL spectrum



IPL – “mega solar light”

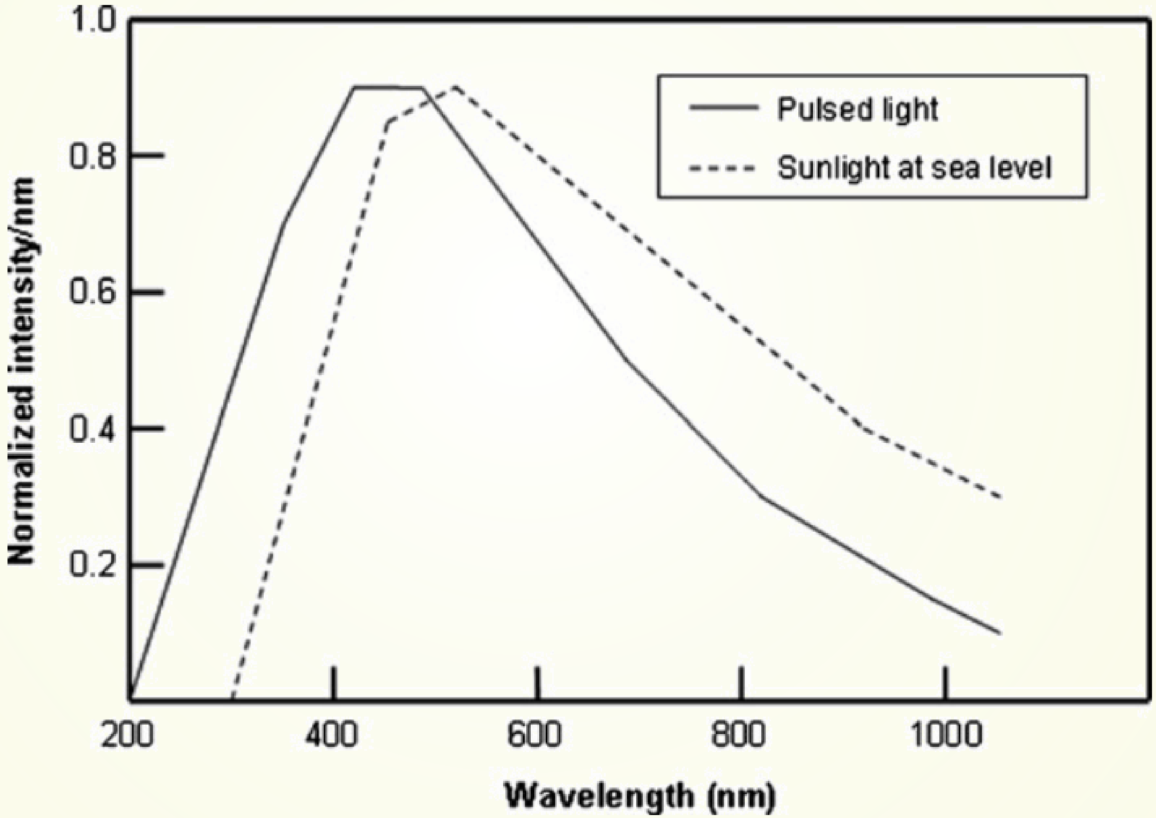
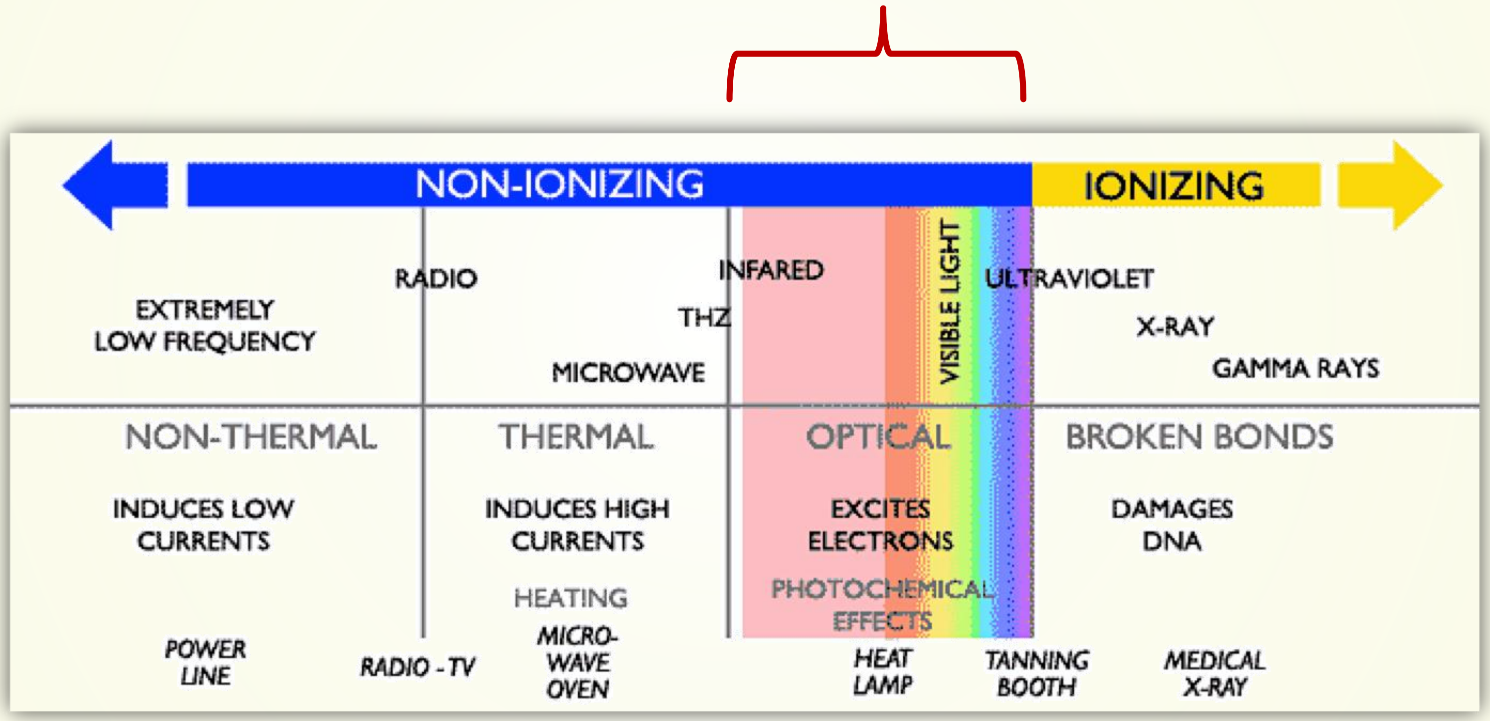


Fig. 12.1 Wavelength distributions of pulsed light and sunlight

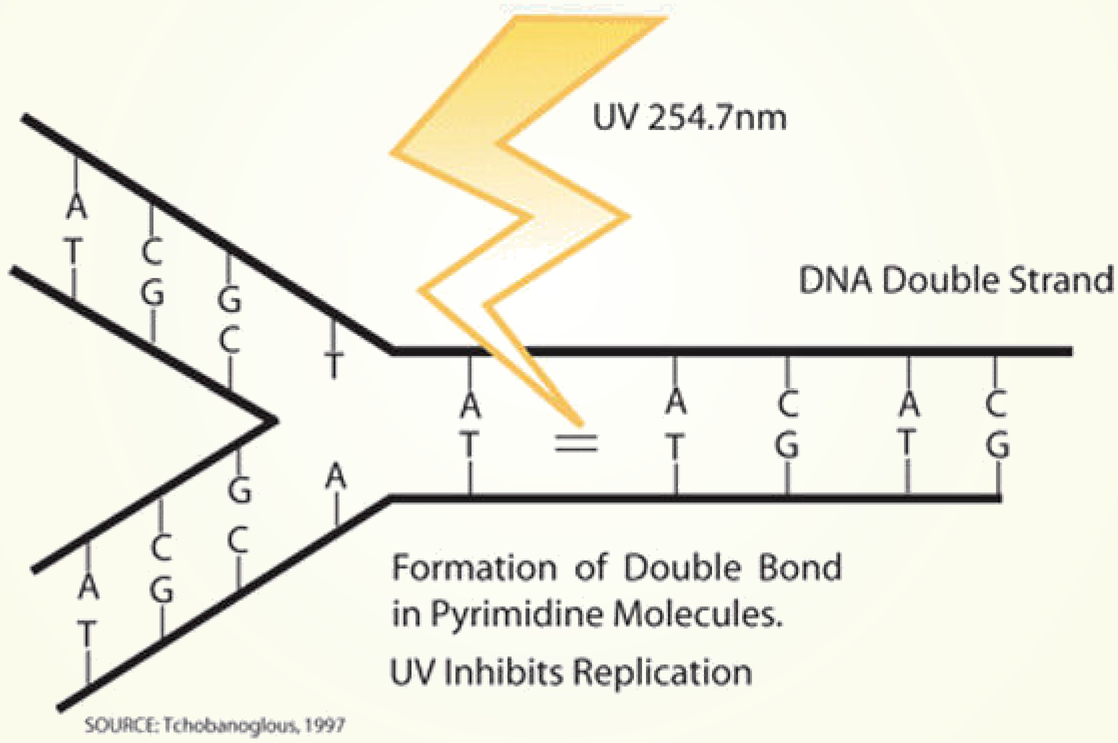
IPL


NON-IONIZING
IONIZING
EXTREMELY LOW FREQUENCY
RADIO
MICROWAVE
THZ
INFARED
VISIBLE LIGHT
ULTRAVIOLET
X-RAY
GAMMA RAYS
NON-THERMAL
THERMAL
OPTICAL
BROKEN BONDS
INDUCES LOW CURRENTS
INDUCES HIGH CURRENTS
EXCITES ELECTRONS
DAMAGES DNA
HEATING
PHOTOCHEMICAL EFFECTS
POWER LINE
RADIO - TV
MICRO-WAVE OVEN
HEAT LAMP
TANNING BOOTH
MEDICAL X-RAY

How IPL inactivates microorganisms

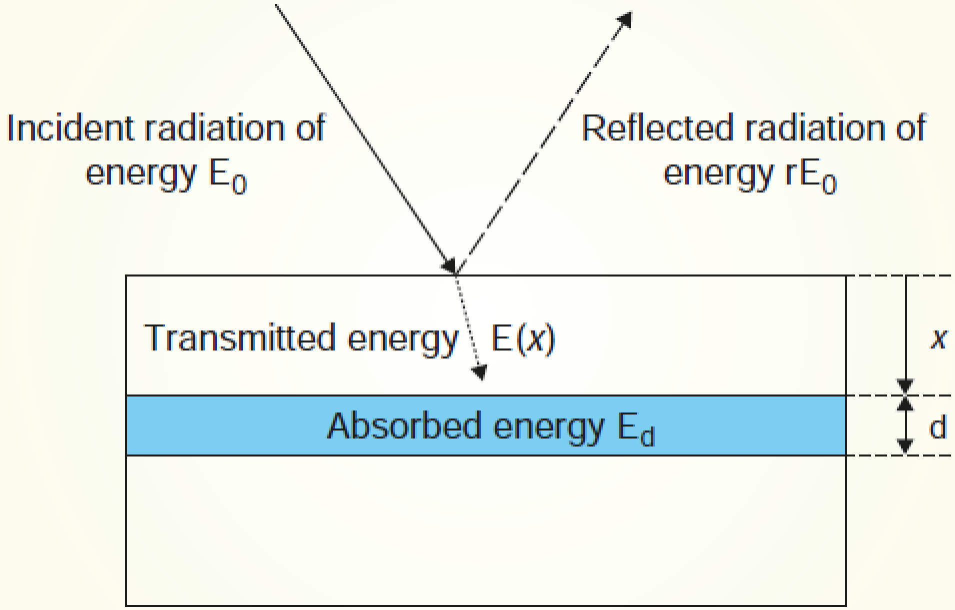
- The mechanisms responsible for microbial inactivation by IPL are believed to be due to
  1) Photochemical – mainly due to UV
  2) Photothermal – localized temperature rise
  3) photophysical – pulsing impact

Photochemical damage



The energy E_d absorbed by a layer of depth *d* below the distance *x* is:

$$E_d = E(x)(1 - e^{-[\alpha]d})$$



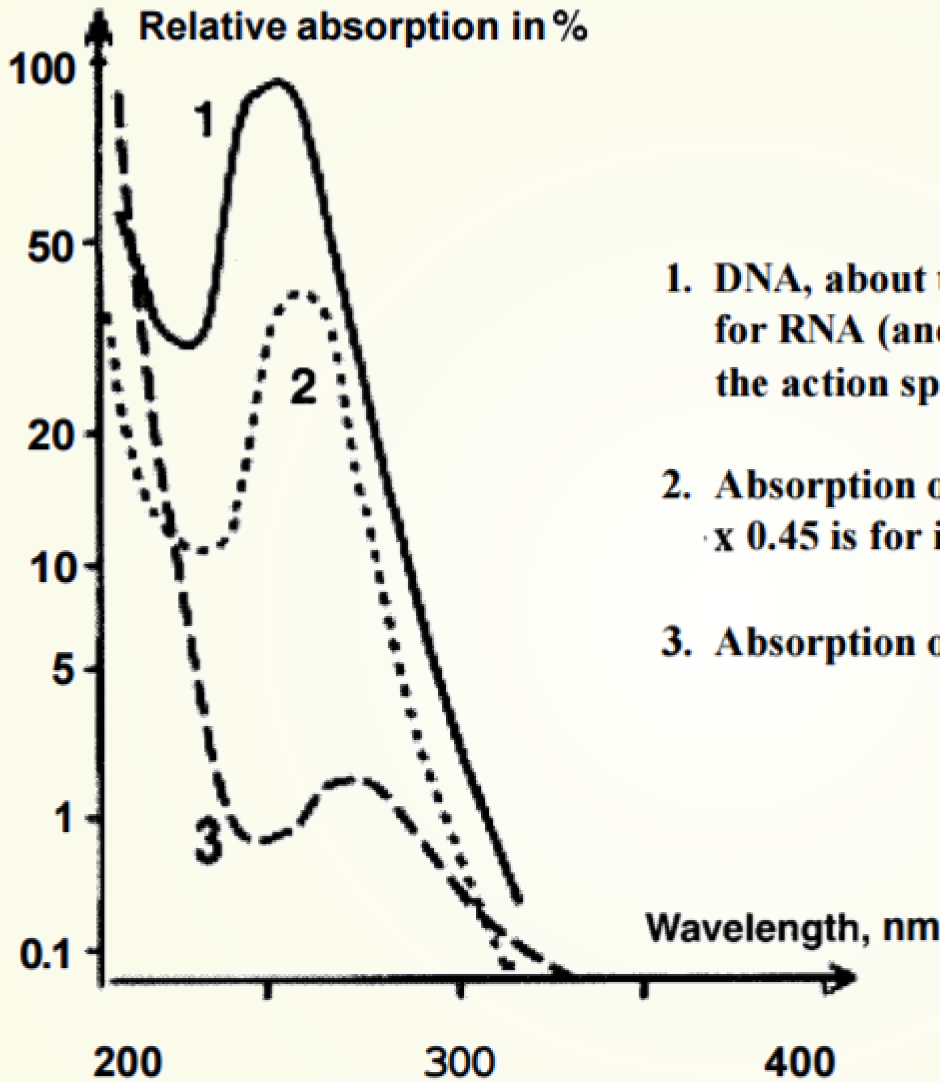
The absorbed light energy is generally dissipated as heat, resulting in a temperature increase equal to:

$$\Delta T = \frac{E_d}{\rho c_p A d}$$

where ρ and c_p are the density and the specific heat of the material and *A* is the surface area.

Photothermal damage

Localized heating of bacteria is induced by pulsed light due to the difference in the heating/cooling rate and absorption characteristics of the bacteria and the surrounding matrix. Thus, the bacterial cell acts as a local vaporization center and may lead to membrane destruction and cell wall rupture. Thermal stress leads to rupture of microbial cells especially at higher flux densities (> 0.5 J/cm^2).



1. DNA, about the same as for nucleic acid and for RNA (and the same shape x 0.25 is for the action spectrum of inactivation of *E. coli*).

2. Absorption of phage T4 (and the same shape x 0.45 is for its inactivation).

3. Absorption of protein.

Difference in absorption of UV light energy among 1) DNA, 2) phage T4, and 3) Protein

Photophysical damage

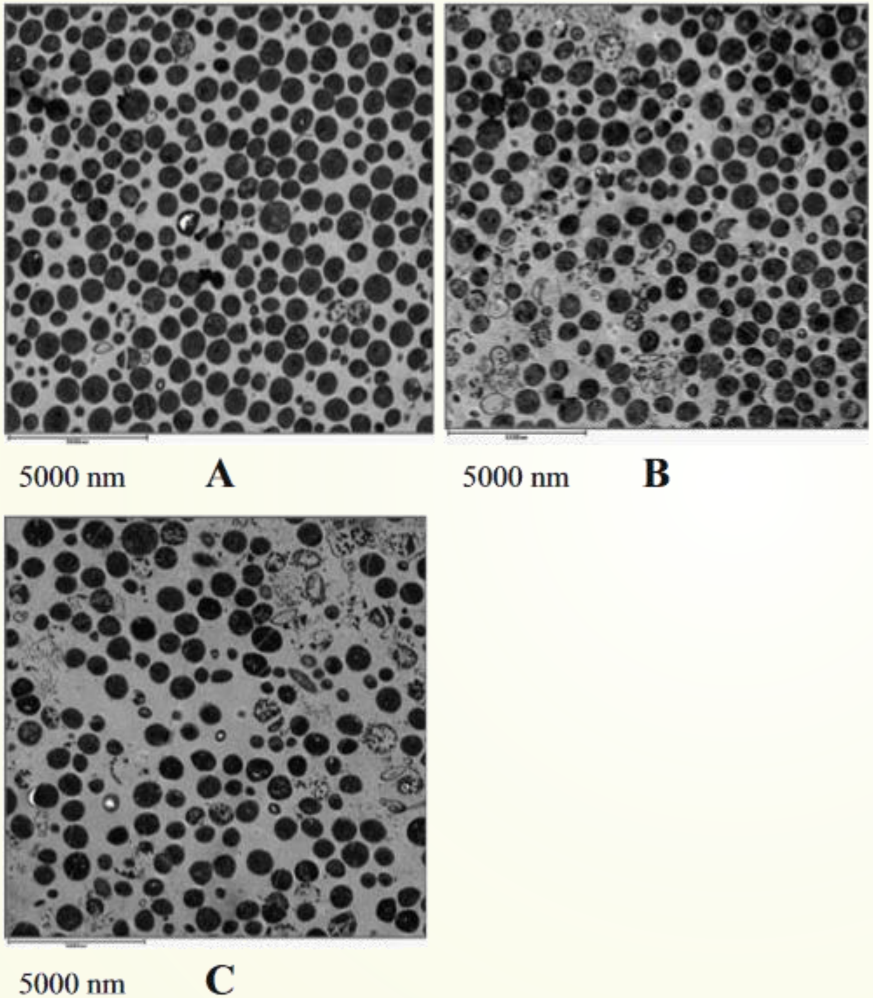
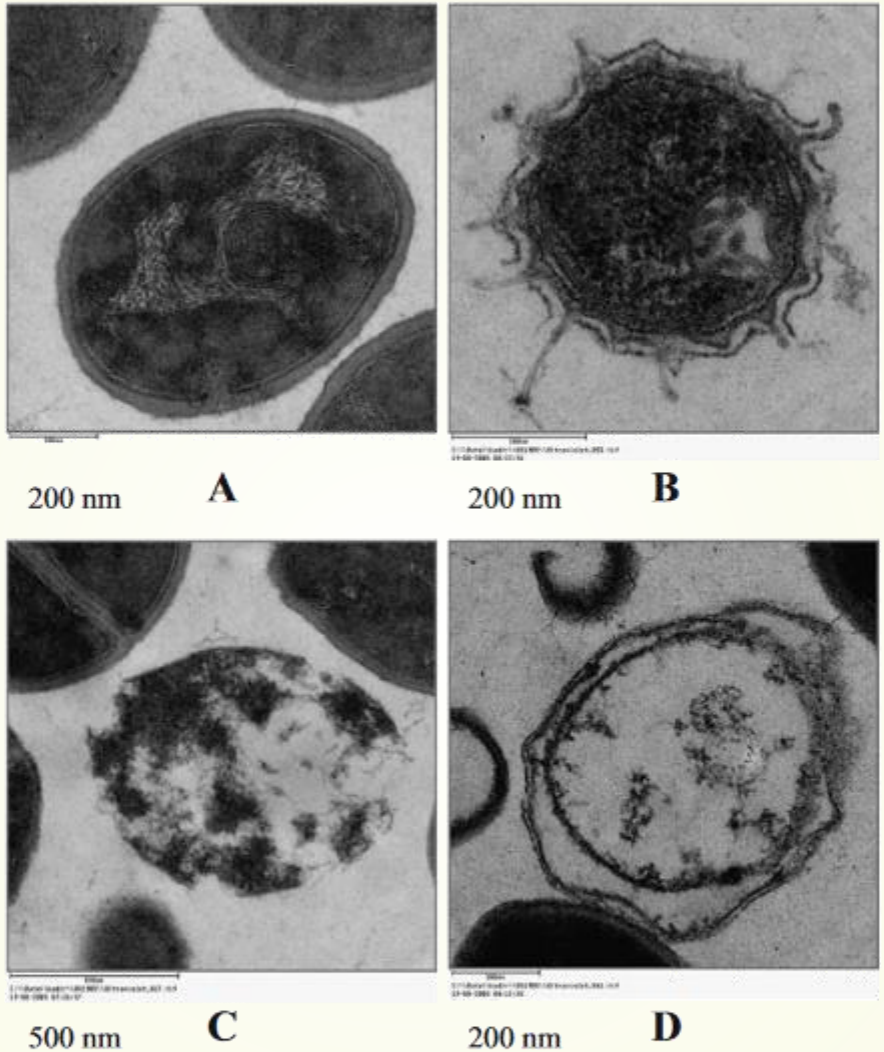


Fig. 1 Comparison of damages observed by TEM: **a** control sample, **b** infrared heat-treated sample (5-ml sample treated at 700°C for 20 min), and **c** pulsed UV light-treated sample (12-ml sample treated for 5 s at 8 cm below quartz window)

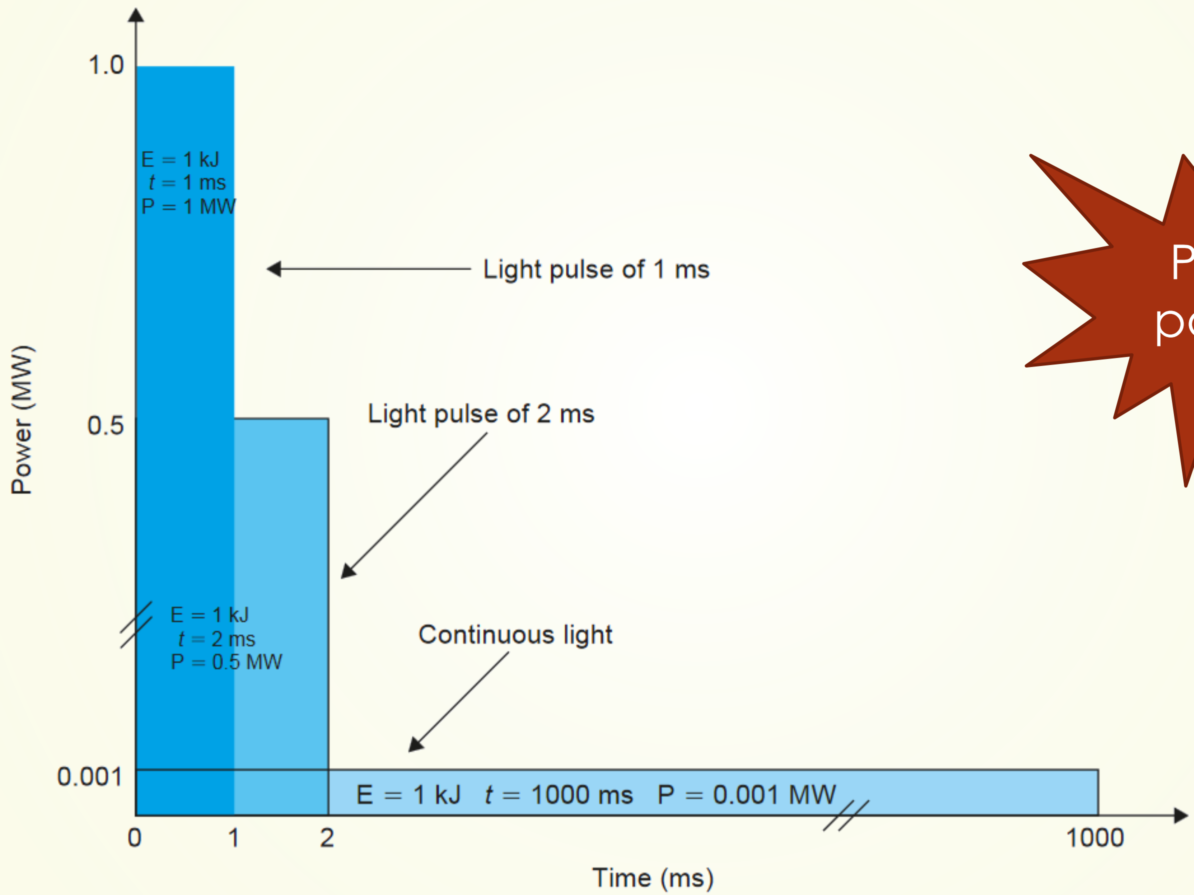
The damages to cells caused by five seconds pulsed UV light were comparable to those from the infrared heat treatment for 20 min at 700°C lamp temperature.



Evaluation of pulsed UV light (12-ml sample treated for 5 s at 8 cm below quartz window) induced damages in *S. aureus* by TEM: **a** control sample, **b** cell wall rupture, **c** lack of cell wall, **d** Cytoplasm shrinkage and cell wall damage.

Why pulsed light instead continuous light?

Continuous UV vs IPL



Power delivered by continuous light and light pulses of different duration, having equal energy content.

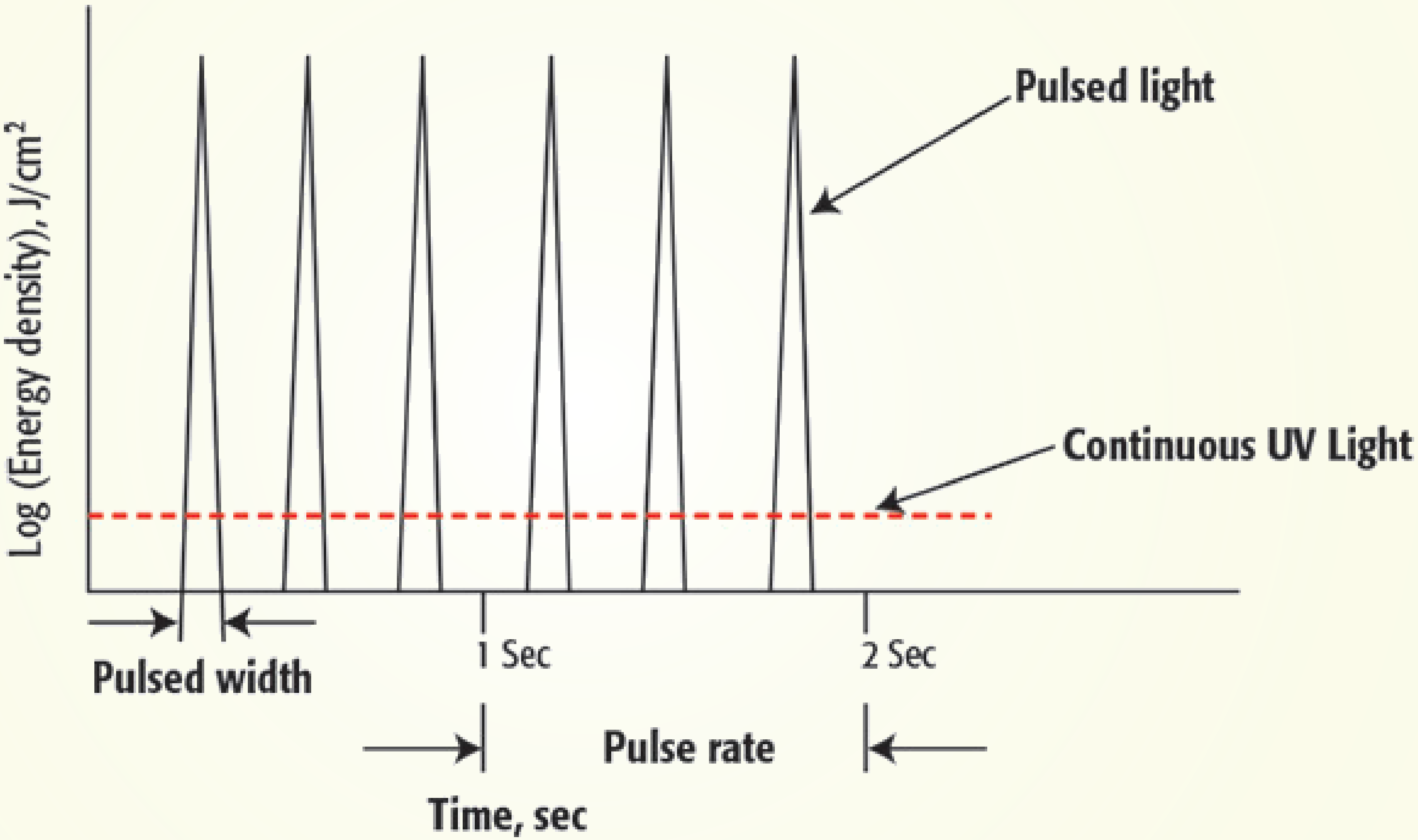


Figure 4: Comparison of Energy Output of Continuous UV Light and Pulsed Light

IPL is more effective than continuous UV

- Greater penetration
- Higher burst power
- Inactivates spores
- Fast
- Short warm-up time

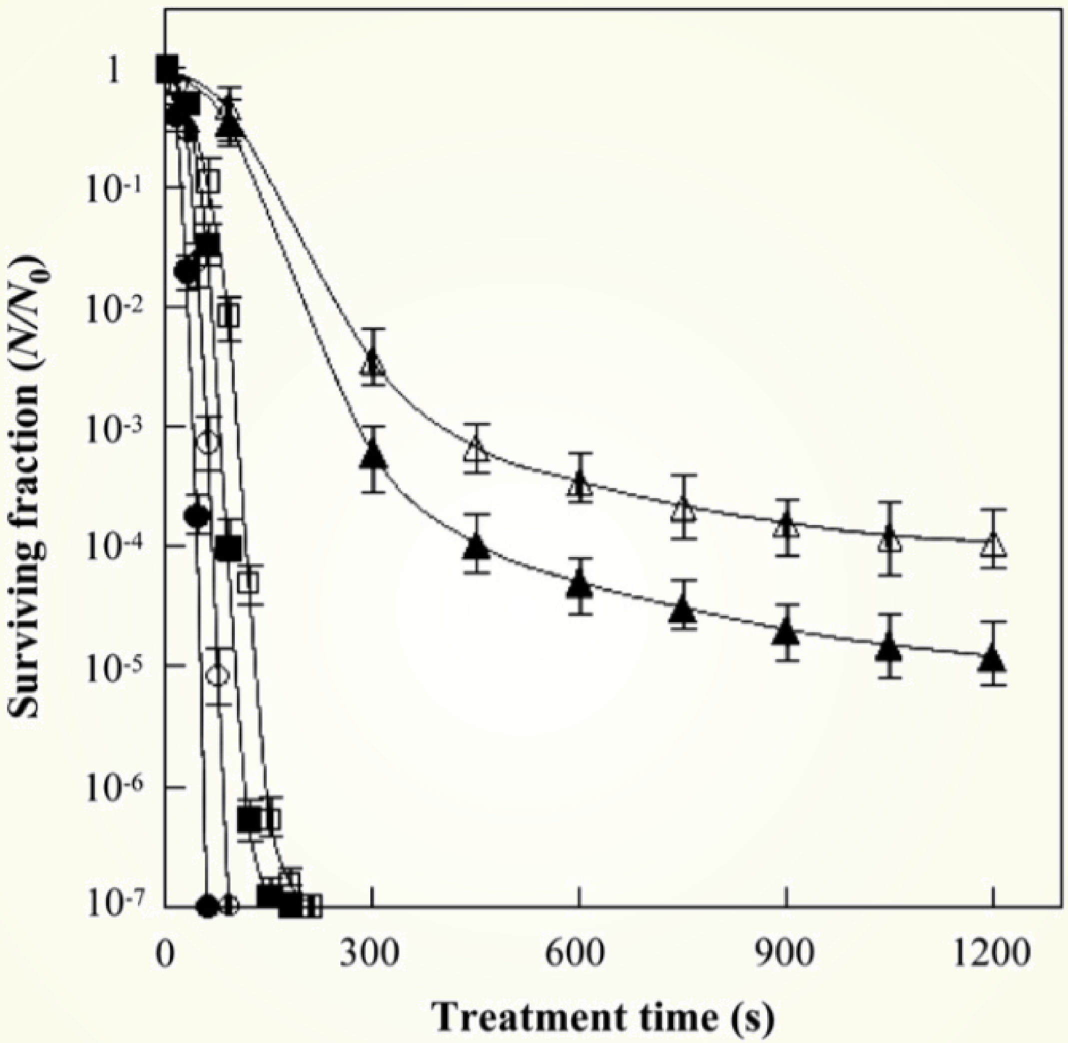


Fig. 1. Inactivation characteristics of *L. monocytogenes* (open symbols) and *E. coli* O157:H7 (closed symbols) by UVC and IPL treatment. △, ▲, UVC treatment at 254 nm; □, ■, IPL treatment at 376 W/m^2; ○, ●, IPL treatment at 455 W/m^2. Experiments were conducted in triplicate. Data are mean and SD values.

FDA approved dosage

- Application of IPL in the food industry has been approved by the FDA (1996) under the code 21CFR179.41.
- According to FDA recommendations, 'the total cumulative treatment shall not exceed 120 kJ/m^2 which is more than sufficient to achieve high inactivation of a wide range of microorganisms including bacterial and fungal spores'.

Key parameters

- Source parameters:
  - spectral distribution
  - total fluence (intensity)
  - pulse duration
  - Frequency
  - Position and distance
- Target (food) parameters
  - Optical characteristics
  - Size
  - shape
  - Smoothness
  - Initial microbial loads

Microbial considerations

- Microbial species has a different resistance to IPL
- Gram-positive bacteria are more resistant than Gram-negative
- Mold spores are more resistant than bacterial spores
- Smaller microorganisms were more resistant than the larger ones
- Spores and virus can be inactivated.

Further reading

- FDA: Kinetics of Microbial Inactivation for Alternative Food Processing Technologies -- Pulsed Light Technology, http://www.fda.gov/Food/FoodScienceResearch/SafePracticesforFoodProcesses/ucm103058.htm
- High Intensity Pulsed Light Technology, *Luigi Palmieri and Domenico Cacace, Stazione Sperimentale per l'Industria delle Conserve Alimentari, (Experimental Station for the Food Preserving Industry), Angri (SA), Italy*
- Shedding Light on Food Safety: Applications of Pulsed Light Processing, By Larry Keener and Kathiravan Krishnamurthy, Ph.D., http://www.foodsafetymagazine.com/magazine-archive1/junejuly-2014/shedding-light-on-food-safety-applications-of-pulsed-light-processing/

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Comments and questions

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