Composite Light Curing Units

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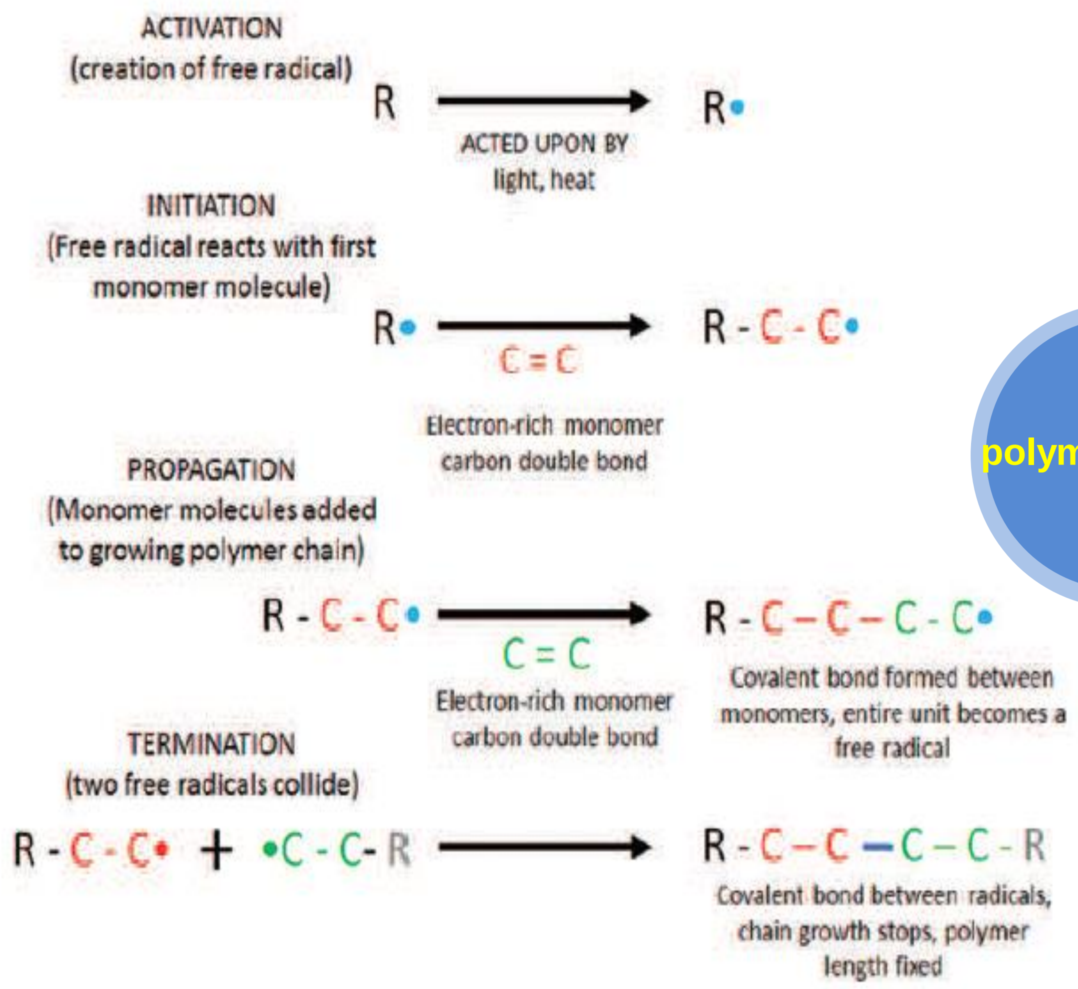
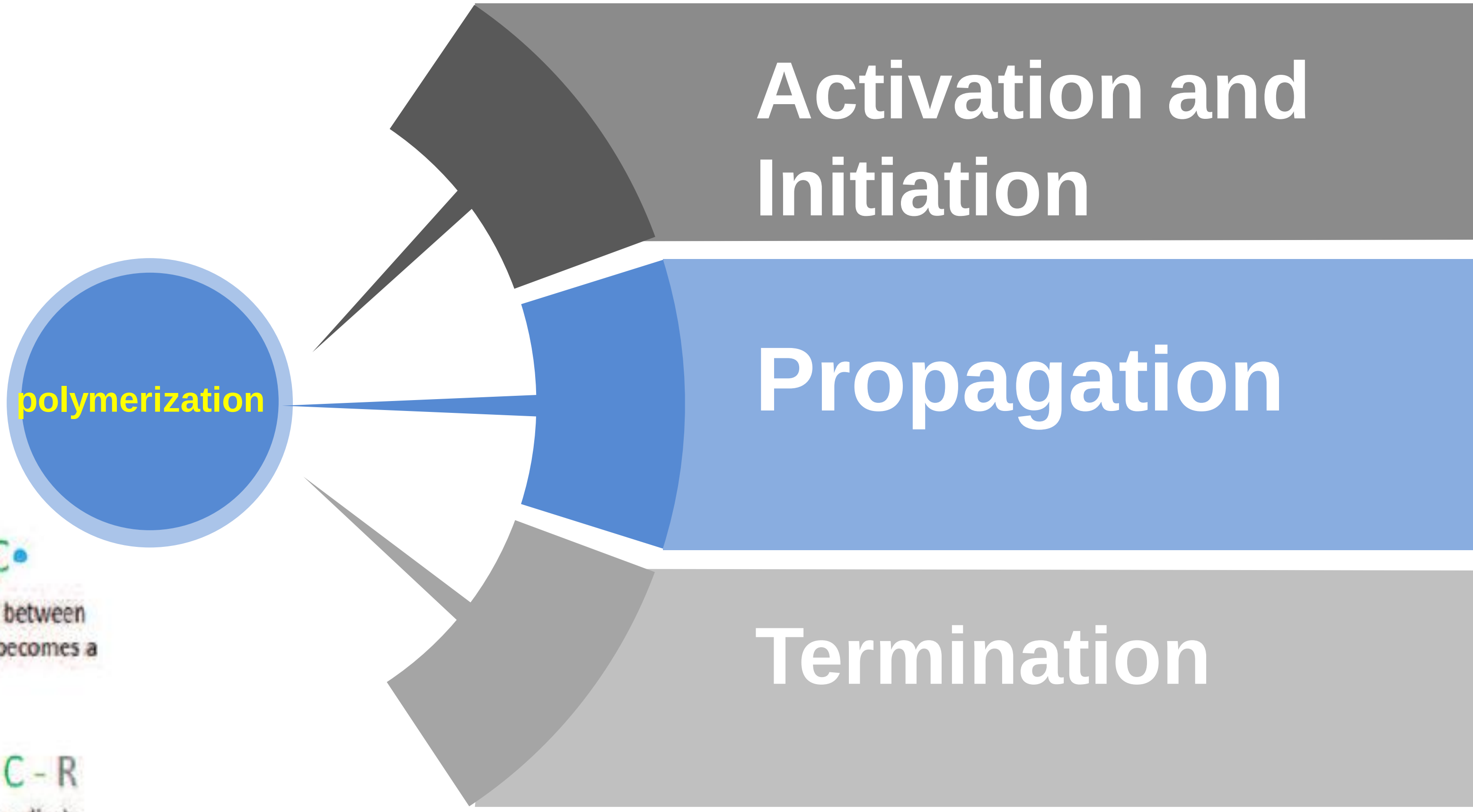
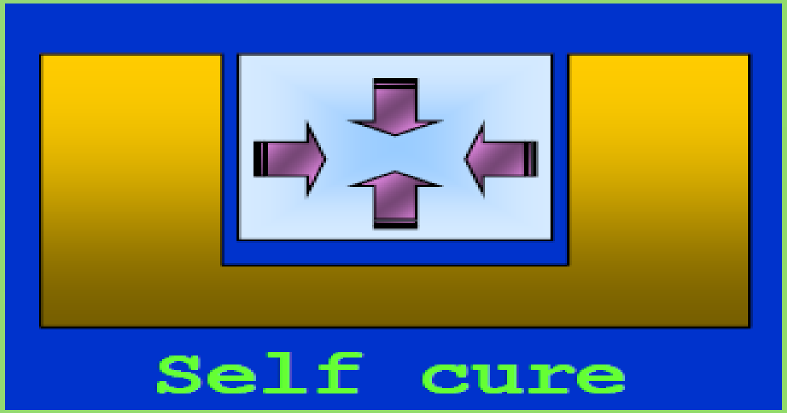
Methacrylate-Baed, Free Radical Polymerization





HISTORY

- chemically activated resin based composites .
- benzoyl peroxide free radical generator with an aromatic amine
- incorporating air During mixing.
- no control with the working time.
- Increased finishing time.
- less color stability due to breakdown of tertiary amines..



Self-cure composites

UV light Activation

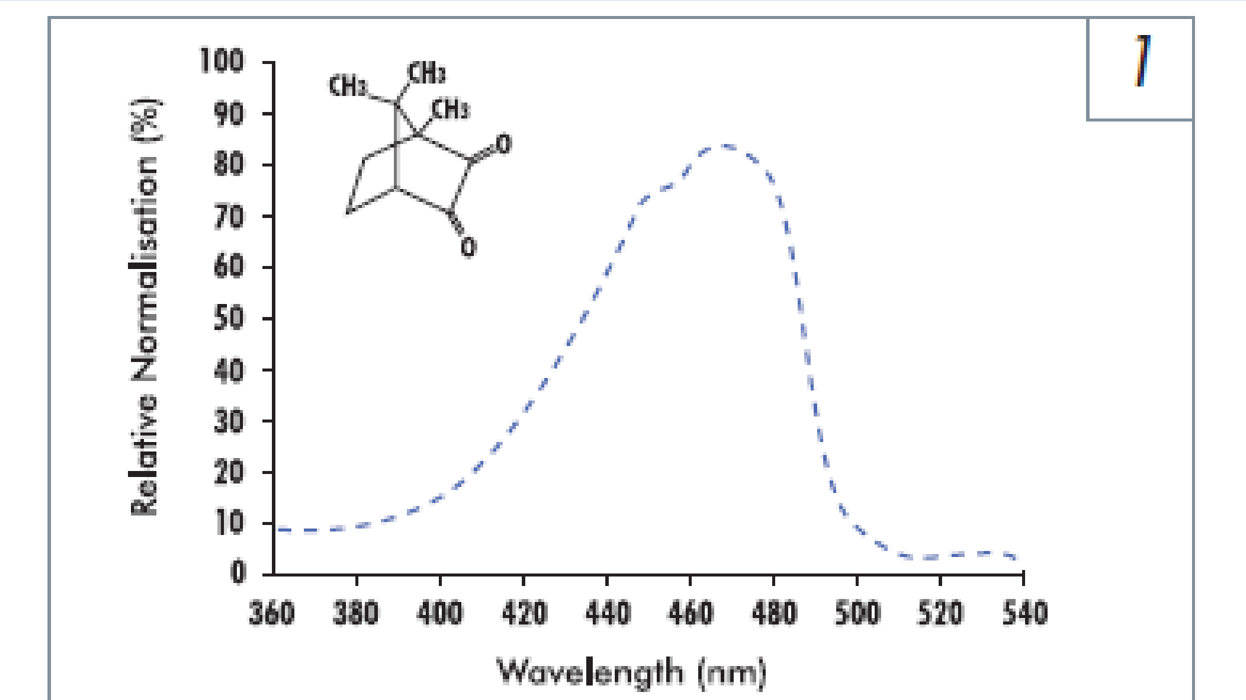
- first introduced to the dentistry in 1970s
- emission of ultraviolet light(about 365nm)through a quartz rod from a high pressure mercury source.
- The photo initiating system relied on benzoine- ether type compounds which broke down into multiple radicals, without need of an intermediary component.
- Limited ability of the light to penetrate deep within the material (1 mm of penetration)
- Altered the oral micro flora.
- Units needed warm up time of 5 minutes.

danger of formation of corneal burns and cataract.

Therefore they were replaced by visible blue light-activated systems

THE INNOVATION

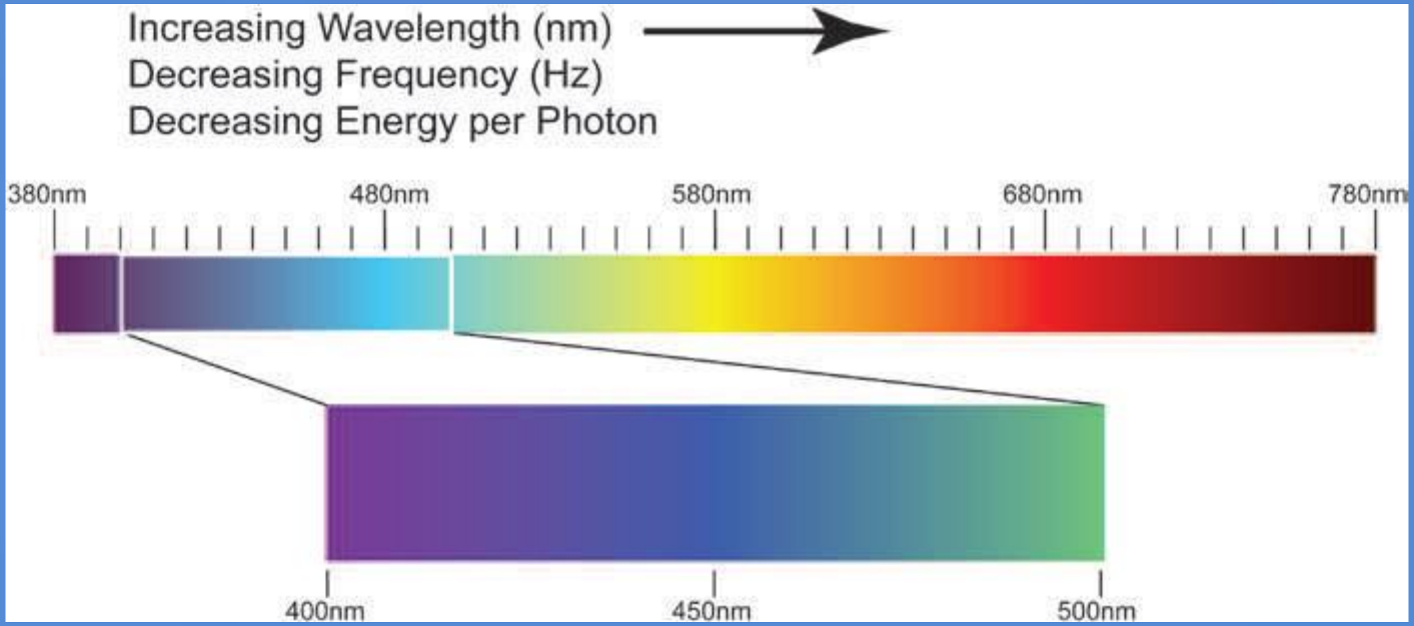
- Early 1980s : **Camphoquinone (CQ)** as an ideal photoinitiator.
- photoinitiators, which break down into radicals when irradiated with light
- The advented CQ's absorption range was found to be between **370-500 nm with a peak at 468 nm**

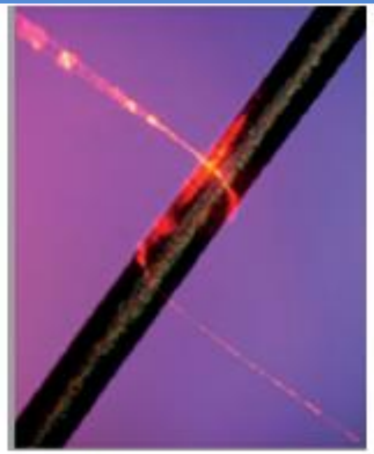


Effective Photocuring

•The ability of a photoinitiator to interact with electromagnetic energy is dependent on **the frequency (wavelength)** of the photon and the very speciic **electron coniguration** of the photoinitiator molecule

•***number of photons*** *of the* ***correct wavelength*** *that are absorbed by the photoinitiator system(s) within the resin composite*





Human hair
~ 100 x thicker
Than Violet light

Type I photoinitiators	Type II photoinitiators
Lucirin TPO	camphorquinone [CQ]
Ivocerin	1-phenyl-1,2-propanedione [PPD]

Type II photoinitiator require an additional secondary electron transfer agent (this is typically an amine electron accepting agent) to generate a free radical

Type I photoinitiator directly break down into one or more free radicals,

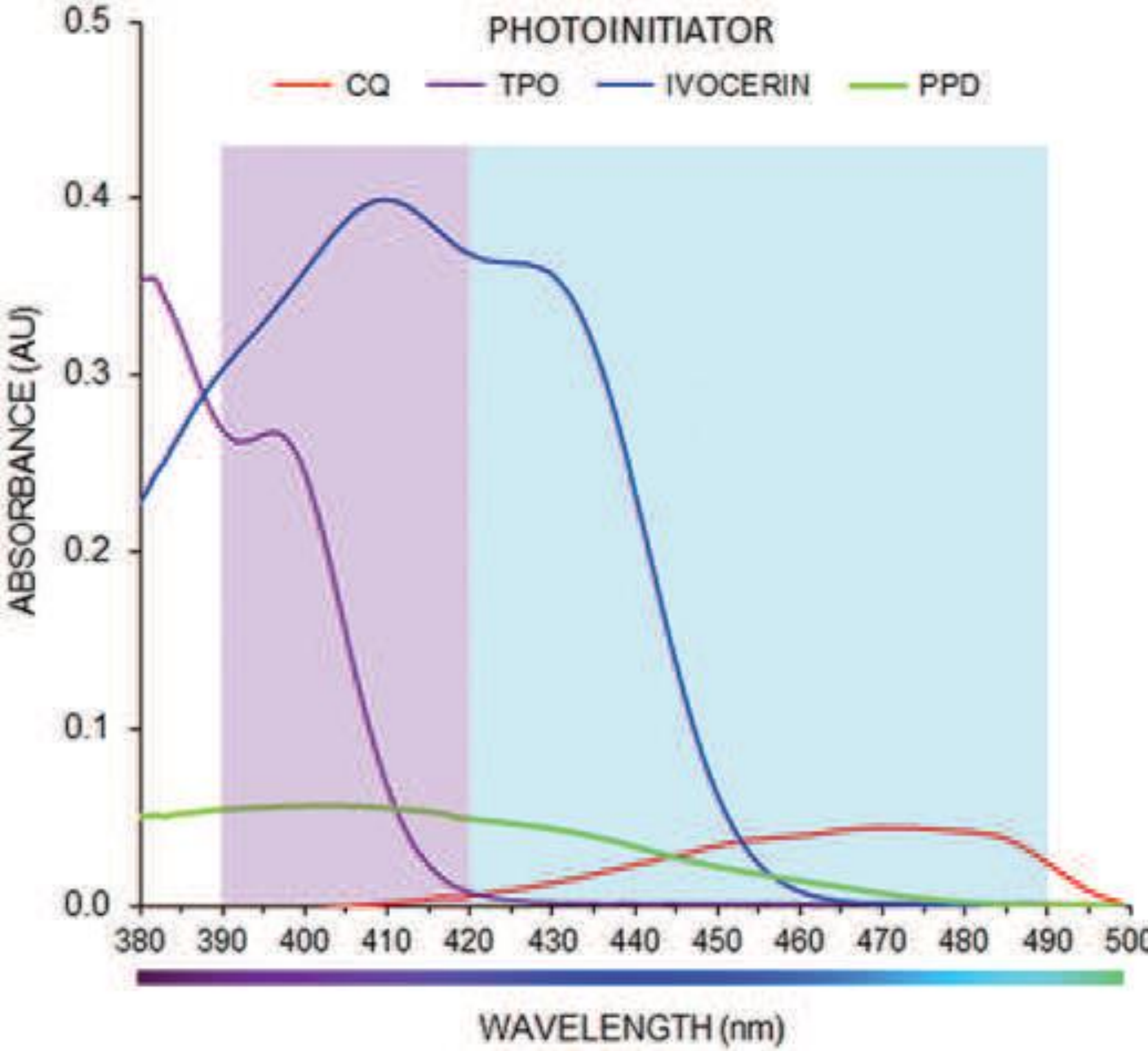
Spectral absorption proiles

CQ is best activated by light in the blue region close to **470** nm

Lucirin TPO absorbs light only within the violet region **below 420 nm**

Ivocerin and **PPD** are reactive to a broader-spectrum both the violet and blue color ranges.

Ivocerin is most reactive **near 410** nm but is still very sensitive to wavelengths of light between 400 and 430 nm



Initiators:

TABLE 6.1 Radiometric Terminology Used to Describe the Emission From Dental Curing Lights

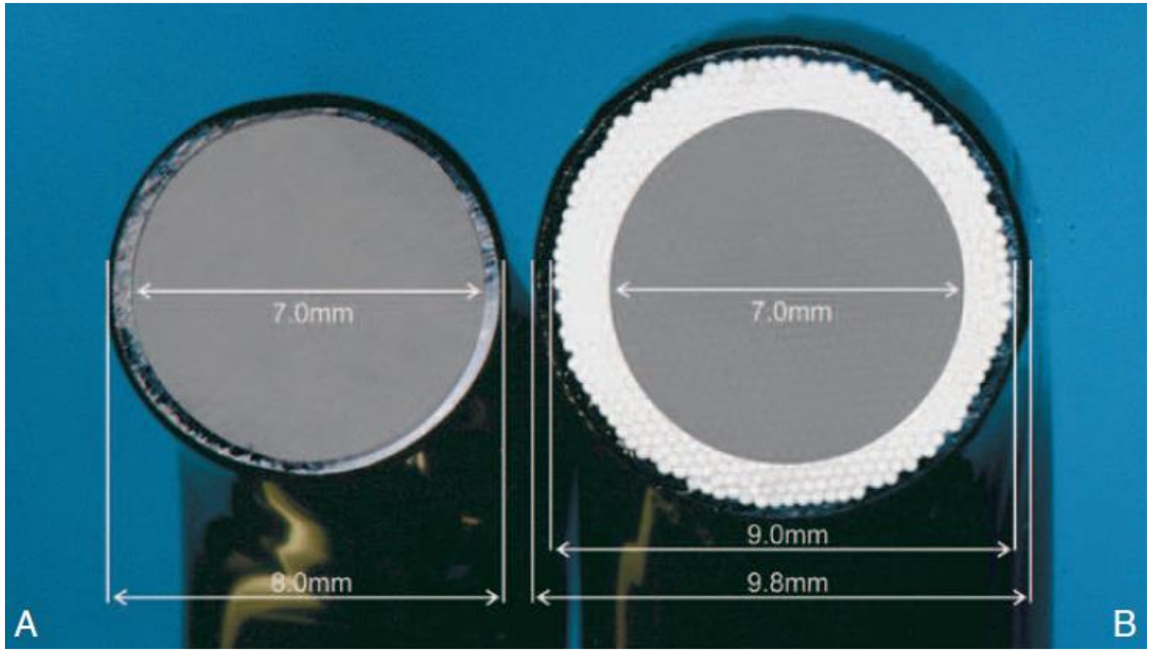
Term	Units	Symbol	Notes
Radiant energy	Joule	J	Describes the energy emitted or received
Radiant exposure	Joule per square centimeter	J/cm^2	Describes the energy emitted or received
Radiant energy density	Joule per cubic centimeter	J/cm^3	The volumetric (cm^3) energy density Not to be confused with the energy density term that has been used in dentistry
Radiant power, or Radiant flux	Watt	W or J/s	Radiant energy per unit time
Radiant exitance, or Radiant emittance	Watt per square centimeter	W/cm^2	Radiant power (flux) emitted from a defined area (e.g., the tip of a light-curing unit)
Irradiance (incident irradiance)	Watt per square centimeter	W/cm^2	Radiant power (flux) incident on a known surface area An averaged value over this surface area
Spectral radiant power	Watt per nanometer	W/nm	Radiant power at each wavelength of light in nm
Spectral irradiance	Watt per square centimeter per nanometer	$W/cm^2/nm$	Irradiance per wavelength of light at each nm
Luminous efficacy	Lumens per watt	lm/W	The ratio of luminous flux to power A measure of how efficiently a light source can produce light in terms of the human eye response to light

ISO 10650 standard

light output is homogeneously distributed across the light tip
radiant exitance : the total radiant power (mW) divided by the optical cross-sectional area (mW/cm$_2$.
This radiant exitance is the same as the irradiance (also in mW/cm$_2$) at the light tip.

radiant exitance in the 380- 515 nm wavelength region should not be greater than 4,000 mW/cm$_2$.

if two curing lights deliver the same radiant power, but one has a 7-mm (0.38 cm2) and the other has a 10-mm tip diameter(0.79 cm2).



There are Four main types of polymerization sources:

Tungsten –halogen (QTH)

LASER

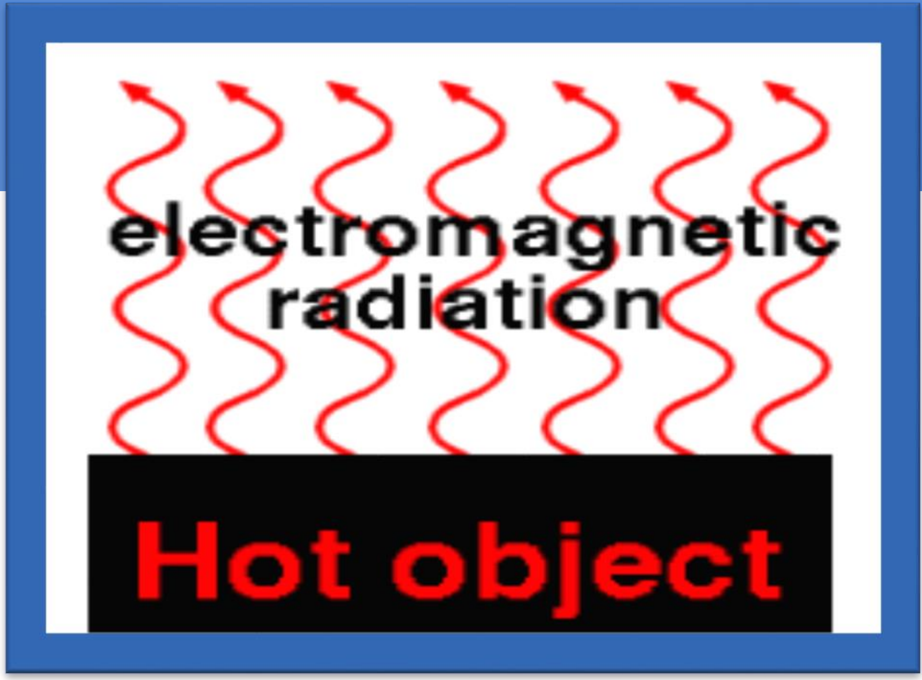
Plasma arc

Light –emitting diode (LED)

Quartz -Tungsten –halogen (QTH)

Quartz -Tungsten –halogen

tungsten filament surrounded by the halogen gases



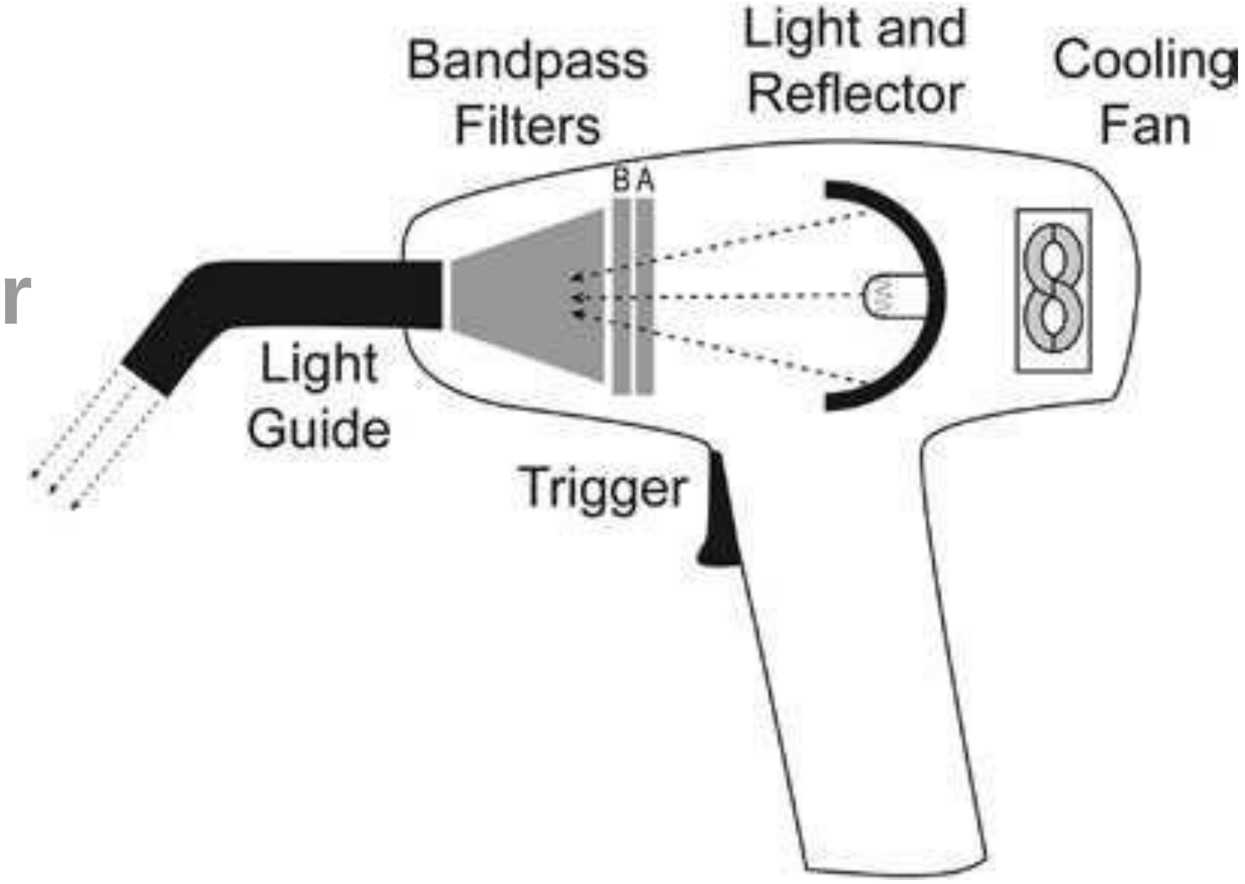
tungsten filament that is surrounded by a quartz bulb containing halogen gas.

light is produced when an electric current flows through a thin tungsten filament (3000ºC).

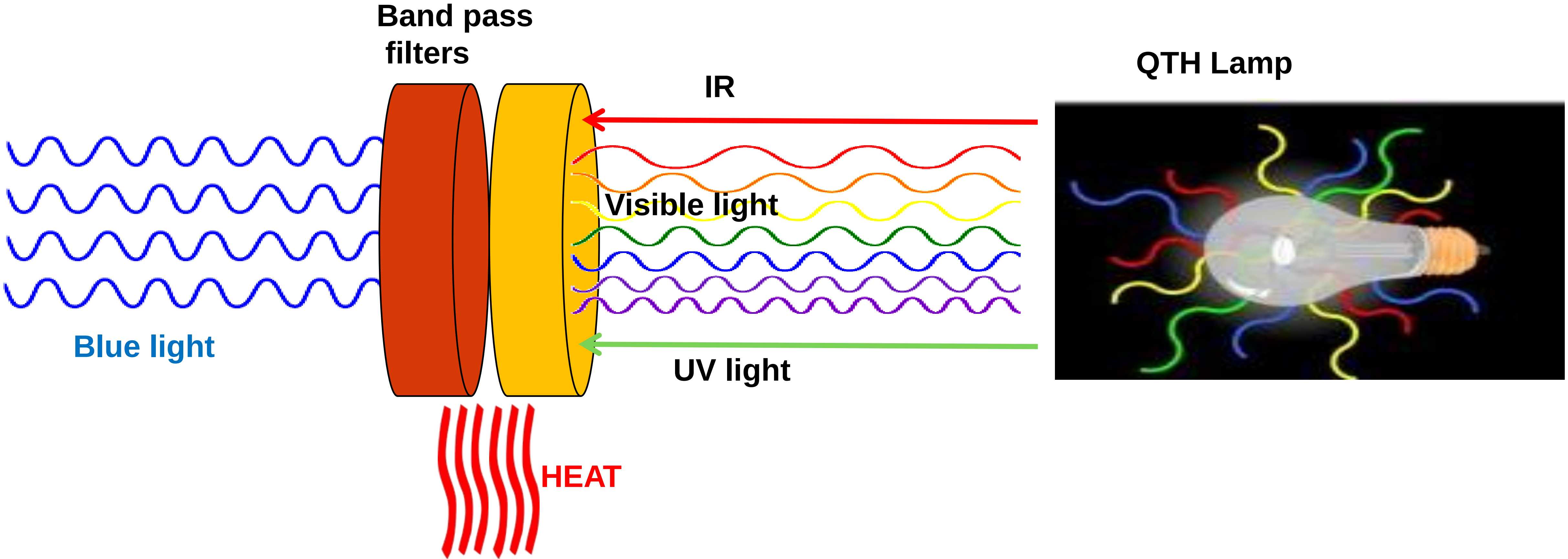
releases of electromagnetic energy most of which falls into the infrared region.

COMPONENTS OF QUARTZ- TUNGSTEN – HALOGEN (QTH)LAMP

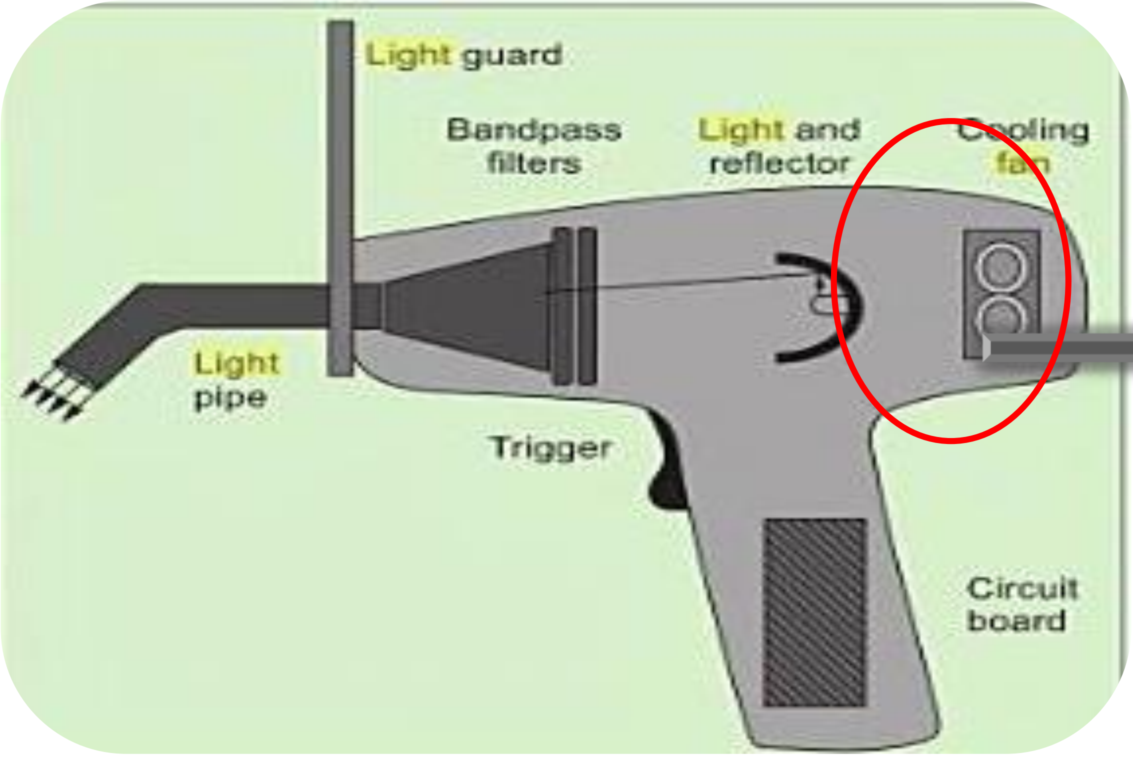
•the optical radiation from the QTH bulb must be filtered.
•silverized **parabolic reflector**
•**infrared** bandpass filter
•**visible light** bandpass filter



NOTE: Since QTH lamps emit a rather wide range of wavelengths, band-pass filters are required to limit the wavelength between 370 and 550 nm in order to fit the peak absorption of Camphorquinone. This approach yields an efficiency rate of only 2%; other 98% of the energy is given out as heat.

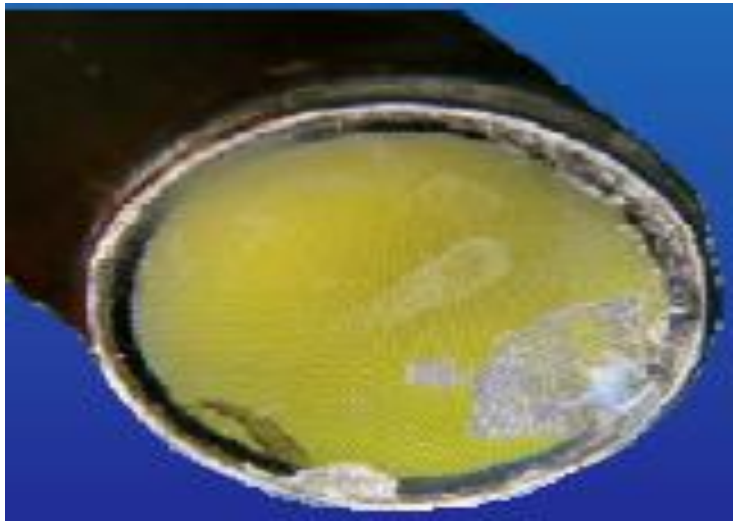


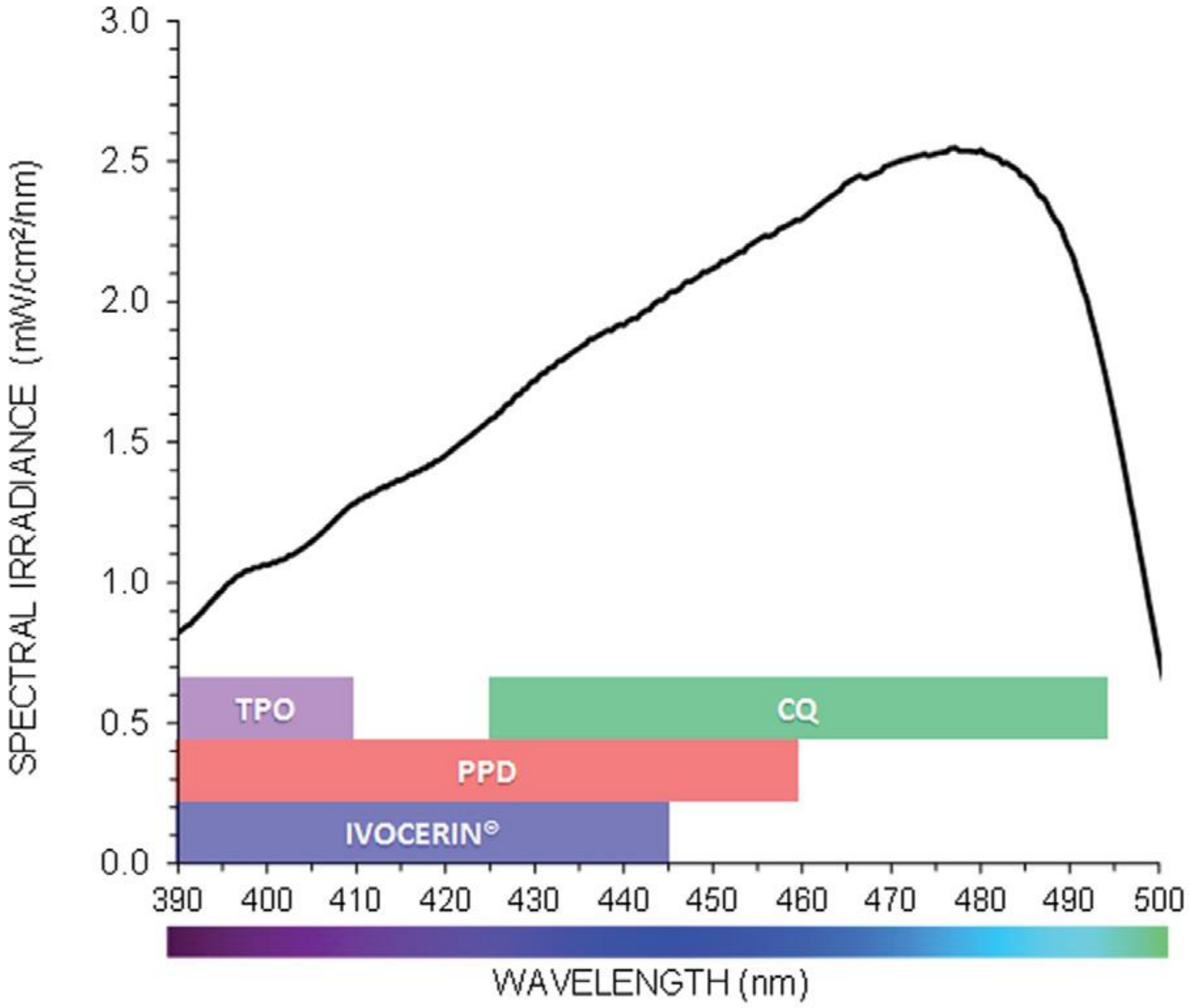
- So, the central drawback of the halogen lights is the need to overcome waste heat produced during a wide spectrum light production. Therefore, a cooling fan is required for heat dissipation, which makes the curing unit noisy and produces vibrations.



NOTE: Halogen curing lights must not be turned off until the fan has stopped running, as it will overheat.

- QTH lamps have a limited lifespan of 50 hours.
- The lamp reflector may lose its reflective properties because of loss of reflective material, or deposition of surface impurities.





Spectral emission profile of a typical QTH light with absorption wavelength ranges for typical dental photoinitiators

HALOGEN LAMPS

	Manufacturer	mW/cm²	nm
Conventional (low intensity)			
Astralis 5	Ivoclar/Vivadent	500	400–500
Astralis 7	Ivoclar/Vivadent	750	400–500
Optilux	Demetron-Kerr	550–800	400–500
OXL-75	Dentsply DeTrey	450	400–500
Espectrum 800	Dentsply DeTrey	300–800	400–500
Coltolux	Coltene		
Elipart Trilight	3M ESPE	800	400–515
Elipart Classic		800	400–500
Acta	Satelec	380	400–515
High intensity			
Astralis 10	Ivoclar Vivadent	150–1,200	400–500
Optilux 501	Demetron Kerr	100–1,000	400–500
Demetron LC		600–100	400–525
Blue Luxcer M835	Monitex	200–950	400–510

* Low intensity: Below 1,000 wM/cm²; high intensity: over 1,000 mW/cm².

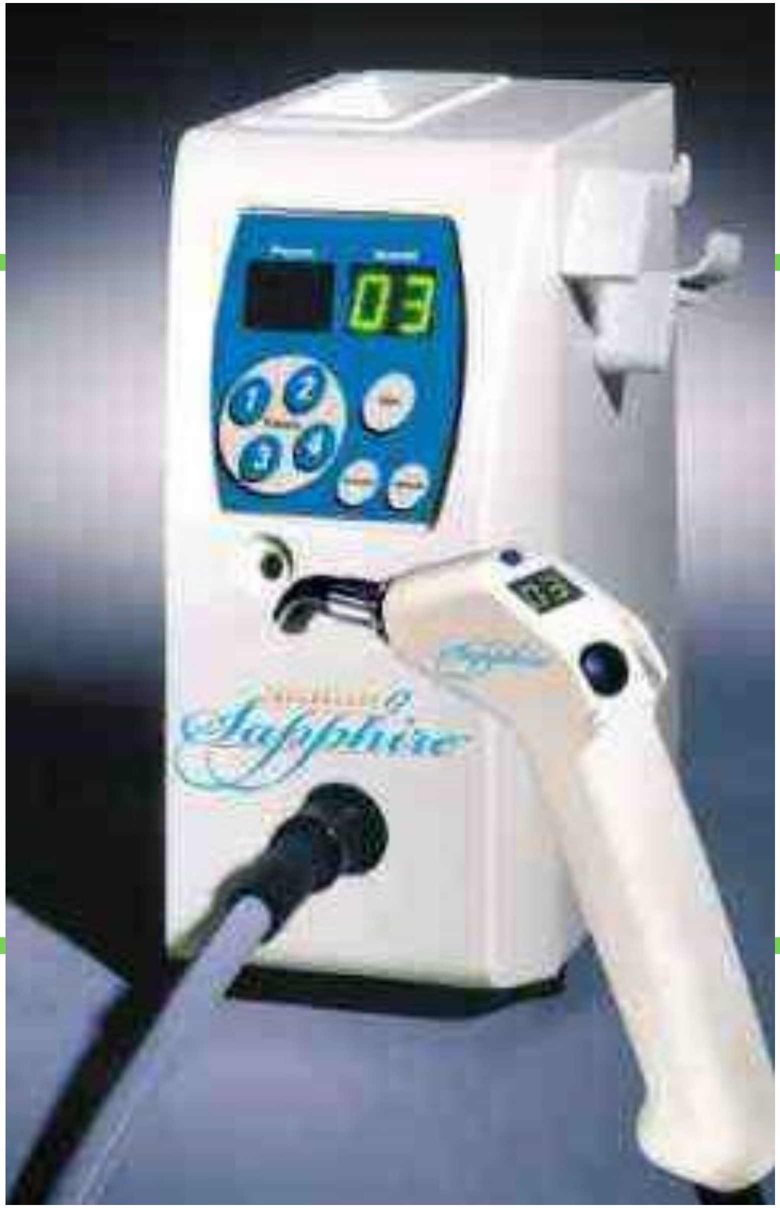
QTH

-mains powered
-noisy
-relatively low radiant power and low irradiance.
-Consequently, they required an exposure duration between 30 and
60 seconds to adequately polymerize a 2-mm-thick increment of
resin composite

Plasma-Arc (PAC)

- Two tungsten electrodes
  - small gap
- Pressurized chamber
  - xenon gas
- High-voltage spark
  - ionizes gas
- plasma
- High voltage is generated between two tungsten electrodes
creating a spark that ionizes Xenon creating a conductive gas known as Plasma.

PRESENTATION



Plasma-Arc (PAC)

•tremendous amount of electromagnetic radiation over a wide spectral range (High levels of IR and UV)
– extensive filtering

• Blue light 390-510 nm.

• Heat generated.

• approximately 10 seconds is needed to adequately photocure a 2-mm thick increment of most composites

PAC

Advantages:

– High irradiance up to 2400 mW/cm2

– claim fast cure.

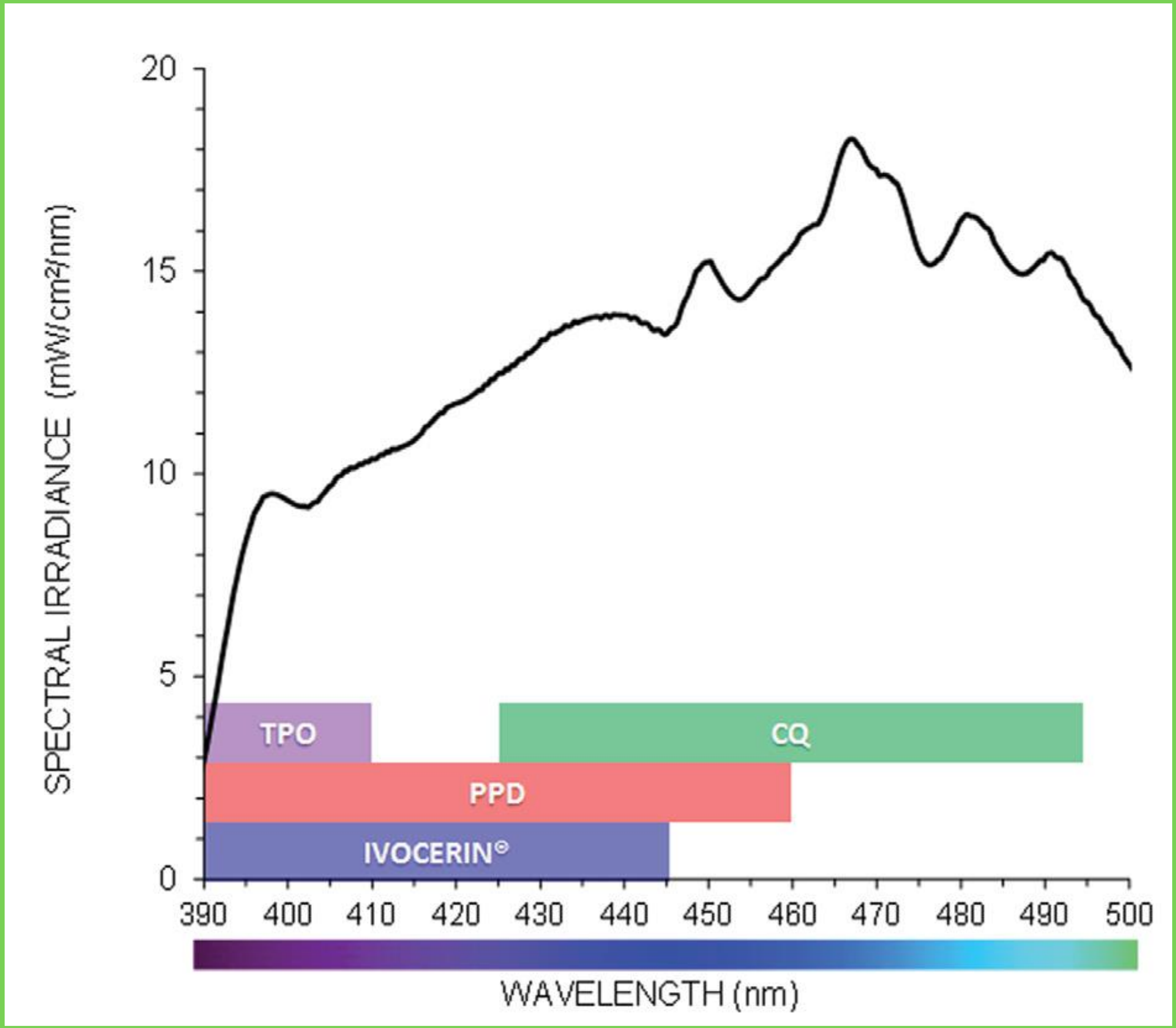
Disadvantages:

– Expensive.

– High temperature development.

– Heavy so not portable.

– Requires an in built filter to produce narrow continuous spectrum.



•Spectral emission profile of a typical PAC light with absorption wavelength ranges for typical photoinitiators.
•a contemporary PAC light is considered as broadbanded,

Argon Laser

• High radiant power and iiradiance

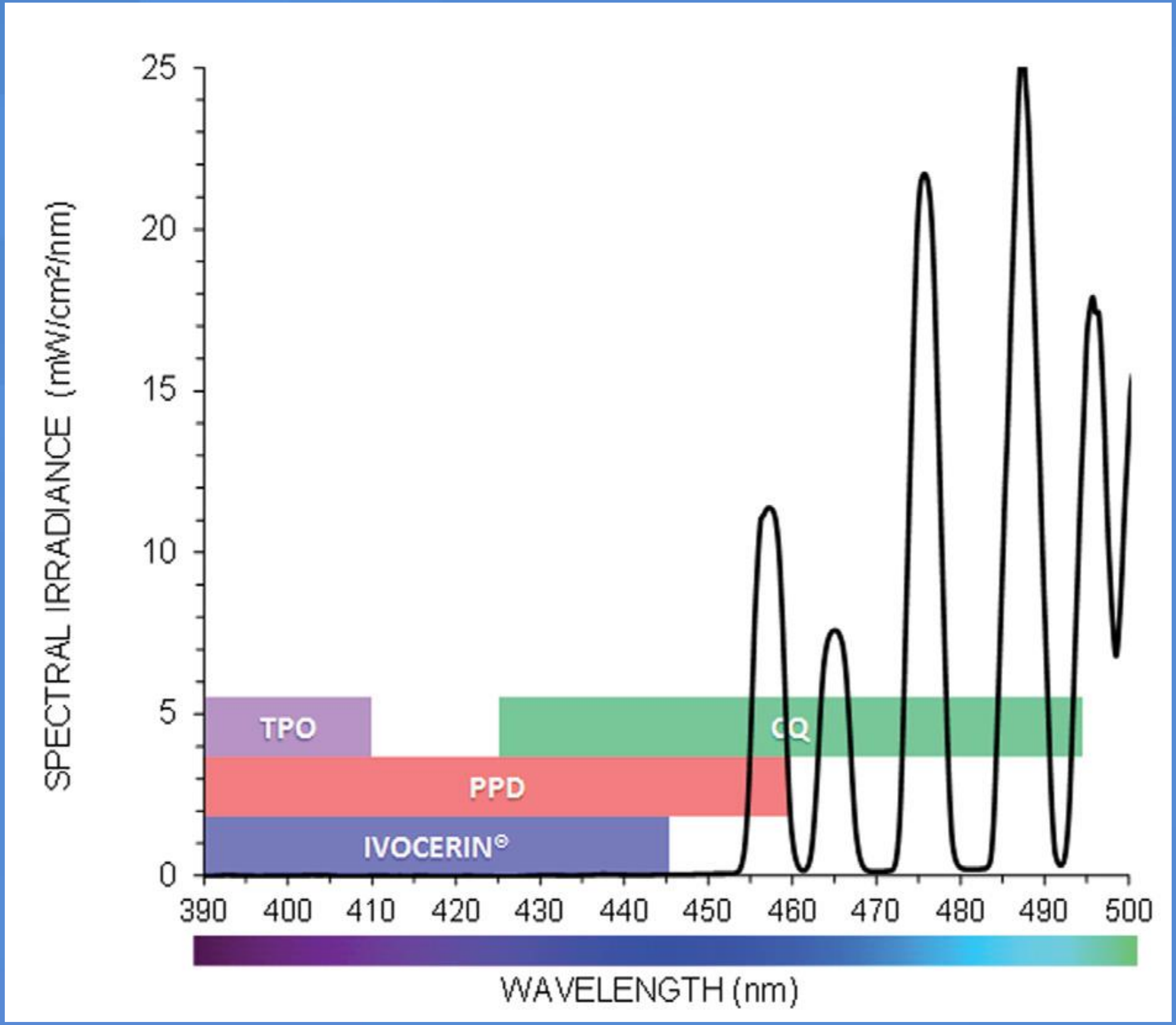
•short exposure times of 10 seconds or less

•does not produce a broad spectrum of light.

• several intense and well-defined emission peaks in the blue spectral region

•In addition, the argon laser beam is **collimated**, focused on a specific target, resulting in a more consistent power density over distance

•**coherent**, meaning that photons travel in phase and do not collide



Spectral emission profile of an argon-ion laser curing light with absorption wavelength ranges for typical dental photoinitiators.

Advantages

– Produces narrow focused non divergent
– Less power utilized.
– Thoroughness and depth of cure is greater.
– Laser curing bond strength did not decrease with increasing distance.

Disadvantages

– Risk of other tissues being irradiated.
– Ophthalmic damage of operator and patient.
– Large in size and heavy.
– expensive

Blue Light-Emitting Diodes(LED)

- LEDs are solid state , lightweight, battery driven, and more efficient;
- the LED emitters are do not require any band pass filters

1976 — 1990

- extremely long working life
- luminous efficacy are now 10 times more than QTH

Light-Emitting Diode Technology

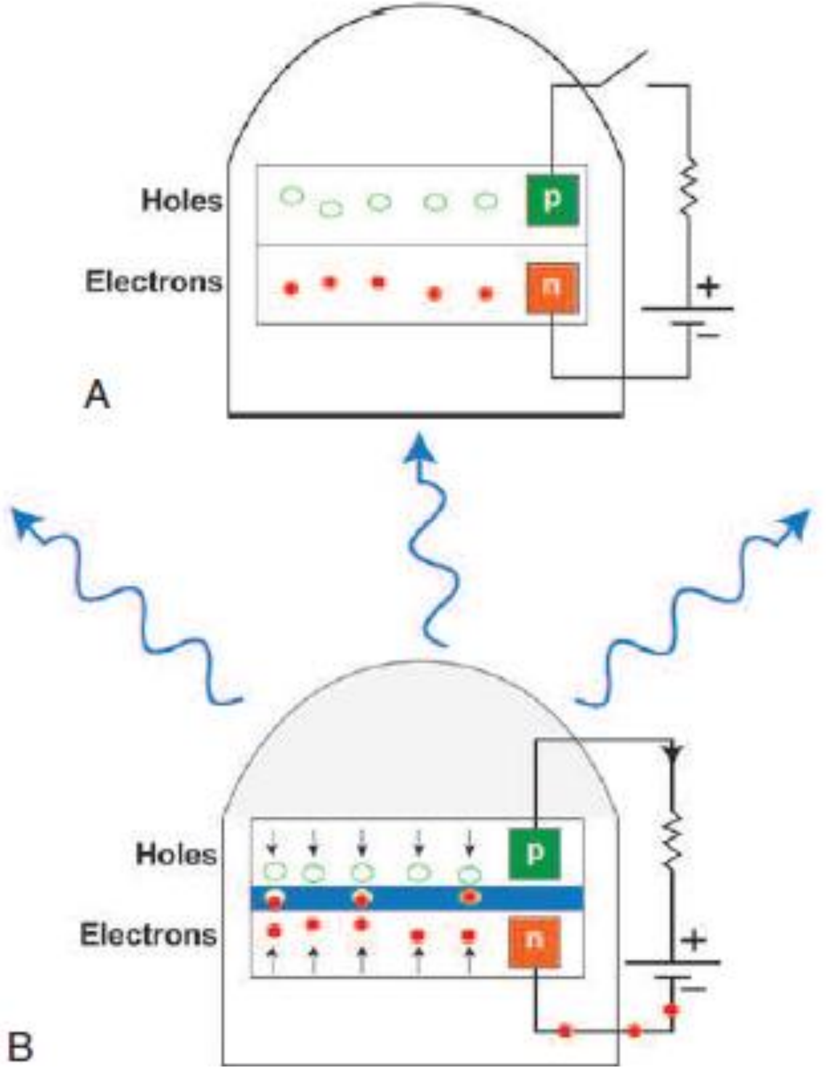
LEDs are **semiconductor** light sources that have been doped with impurities to create a p-n junction.

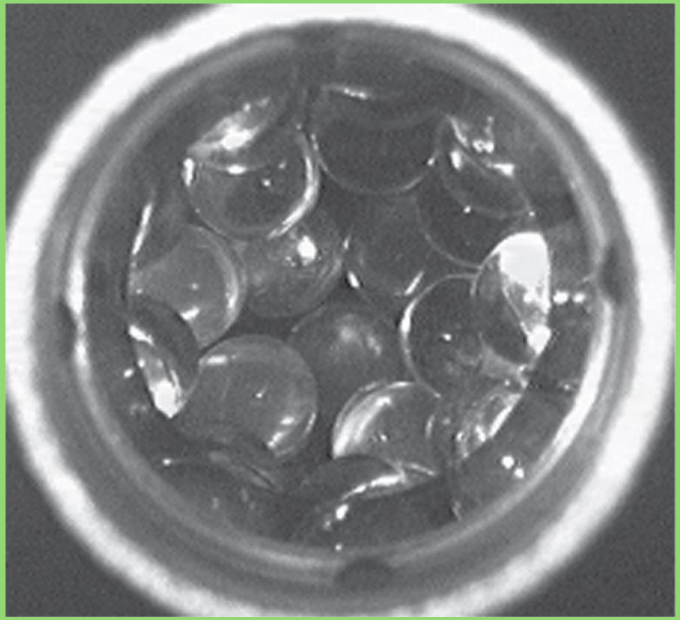
When a current is applied, this p-n junction emits light by a process called **electroluminescence**.

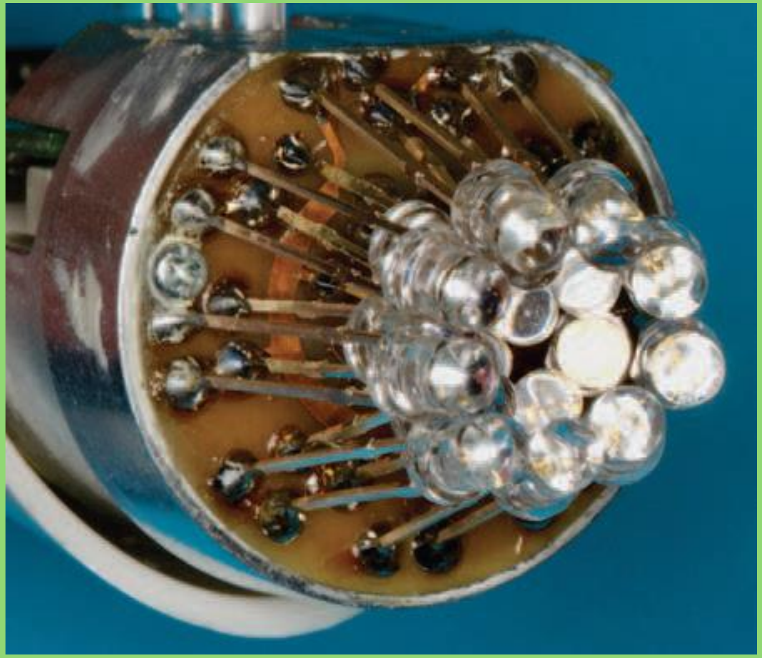
Electrons from the **n** substrate (**cathode**) then pass through and “fall” into “holes” in the electron-deficient **p** side, or **anode**.

When an electron meets a hole, it “falls” into a lower energy level and releases energy in the form of a photon of light

semiconductor material used in blue LEDs is composed of a mix of **gallium nitride** (GaN) and indium nitride (InN).





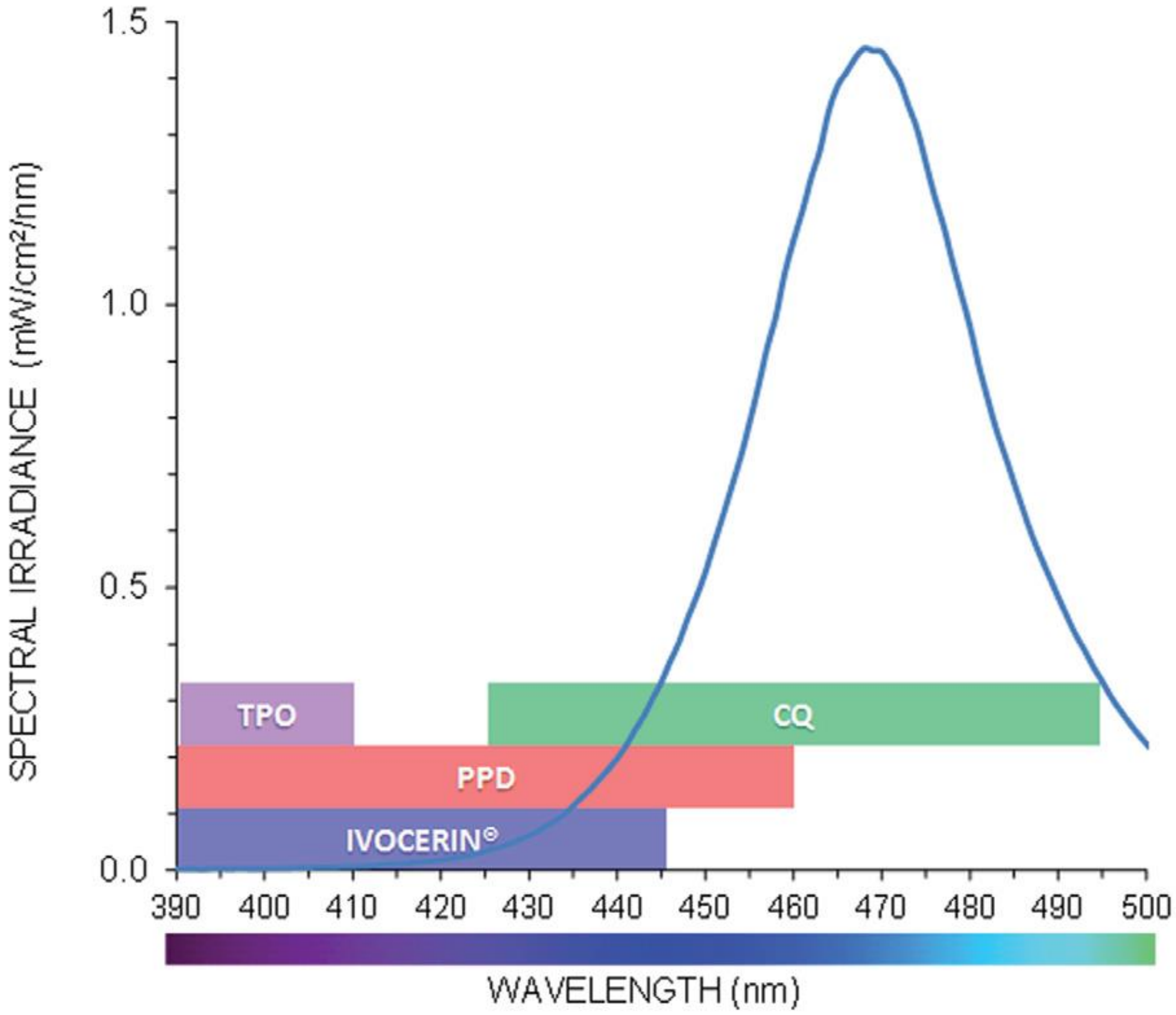


First Generation LED

–blue light emitted from individual ,similar, low power cans (typically from 8 to 64 in number)

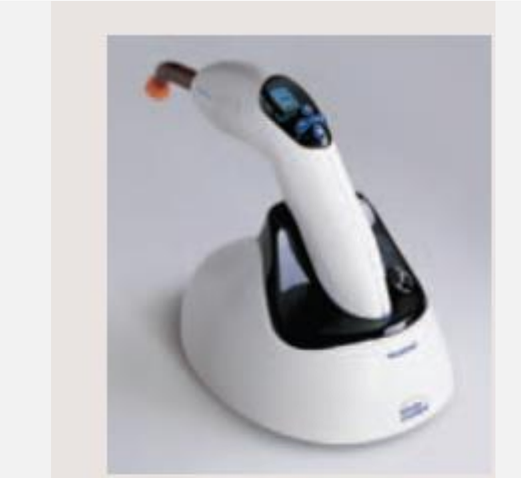
– low radiant power output

Portable
Light weight
Battery operated
Output in the range of CQ (470nm)
Cool lights
•nickel cadmium Battery (NiCAD).

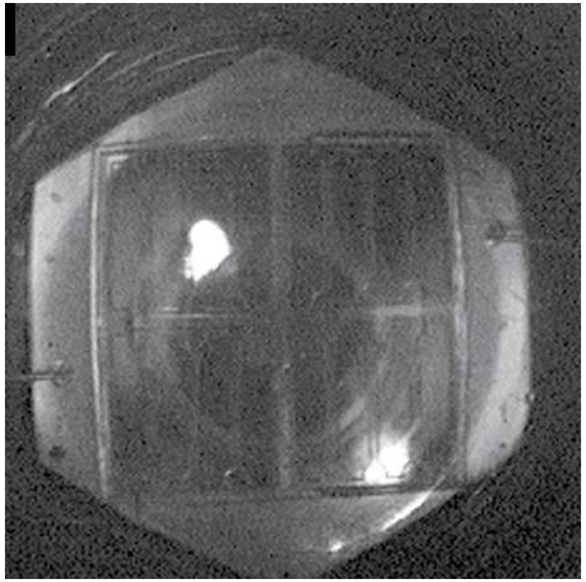


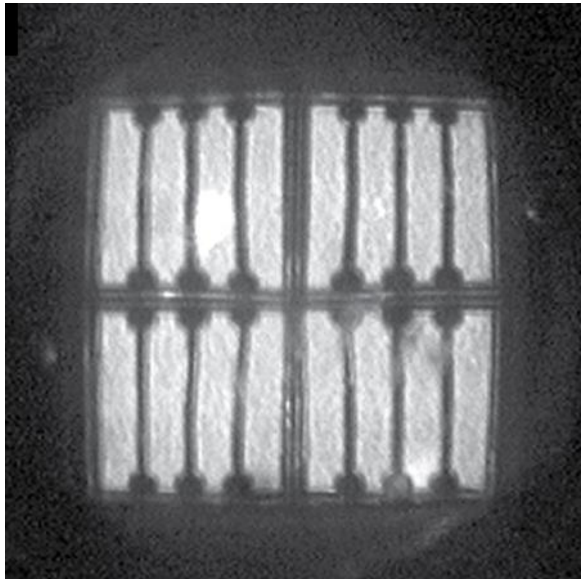
Spectral emission profile of an early, 1st generation blue LED dental curing light.

Second Generation **LED**



bluephase
(Ivoclar Vivadent)





- One-Watt chips consisting of 4 main areas of illumination each consisting of 4, bar-shaped emitting surfaces

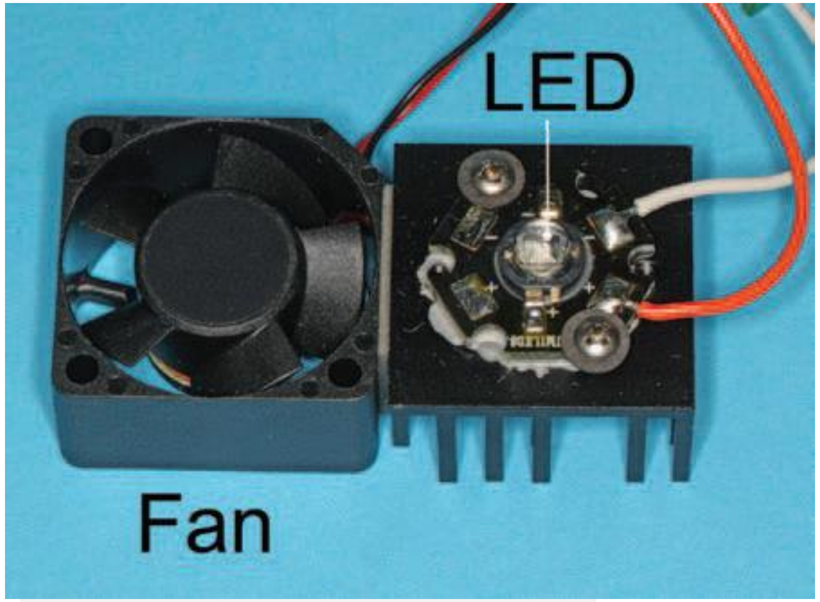
- LEDs consuming 10 and 15 Watts become incorporated, further increasing irradiance values
- lower exposure values

- chips greatly increased the radiant power output of curing lights

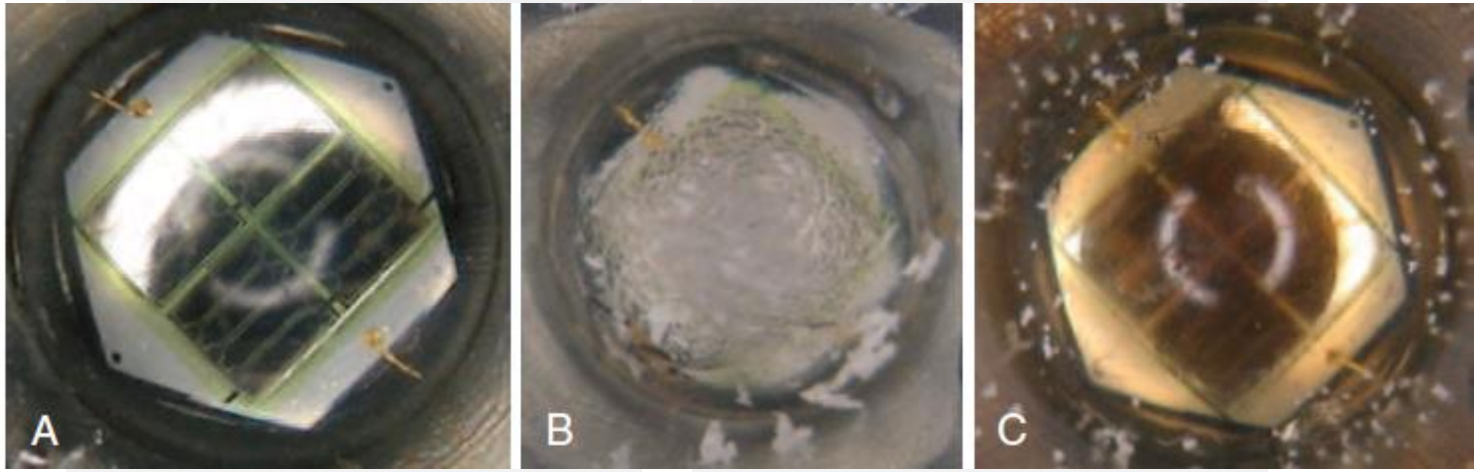
- Output power exceeding QTH and PAC

- longer-lasting nickel metal hydride (NiMH) battery

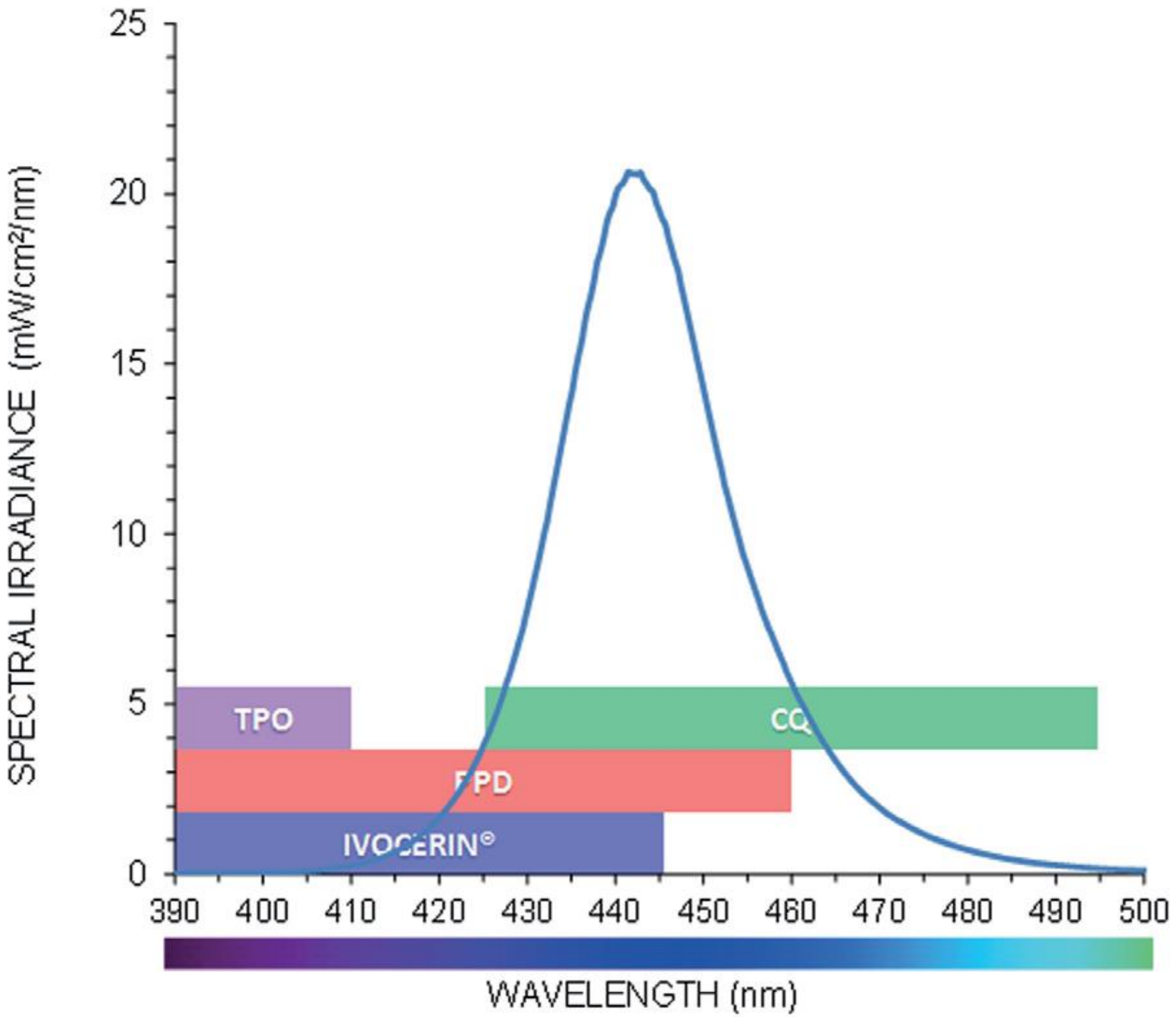
Second Generation **LED**



With the increase in radiant power output, the need to cool the LED chip became critical



internal fans and large metal heat sinks were used to remove the heat from the LED arrays



Spectral emission from a typical second generation, blue LED curing light.

Product	Company	Cordless	Built-in Radiometer	Weight	Extra Battery	Spectra Wavelength Range, nm*
bluephase	Ivoclar Vivadent	Yes**	Yes	9.5 oz.	Yes	430-490
Coltolux LED	Coltene Whaledent	Yes	No	2.2 oz.	No	450-470
Elipar Freelight 2	3M ESPE	Yes	Yes	7.8 oz.	No	430-480
Flashlite 1001	Discus Dental	Yes	Yes	3.6 oz.	No	465-475
Smartlite iQ	DENTSPLY/Caulk	Yes	Yes	8 oz.	No	430-475
L.E.Demetron 1	SDS/Kerr	Yes	Yes	12.9 oz.	Yes	450-470
radii	Southern Dental Industries, Inc.	Yes	Yes	5.4 oz.	No	440-480
Allegro #033959000	Den-Mat	Yes	Numeric value	12 oz.	Yes	415-490
Allegro #033960000	Den-Mat	Yes	No	12 oz.	No	415-490
the CURE	Spring Health	No	No	1.5 oz.	n/a	450-490
TPC Uni-LED	TPC Advanced Technology	No	No	2.7 oz.	No	450-490

Smartlite iQ
(DENTSPLY/Caulk)

Allegro
(Den-Mat)

Third-Generation LED Lights:

Multiwave, Multipeak, Polywave

- Alternative photoinitiators are activated by shorter wavelengths of light closer to violet (<420 nm) light
- additional color chip(s) was added to the blue LED array
- the lights now emitted both the lower wavelengths of violet light, usually from 390 to 430 nm, as well as light from 440 to 500 nm
- G-light Prima, Bluephase G2 and Bluephase 20i, Valo, Smartlite Max, Fusion, Beyond CL- 628 ,

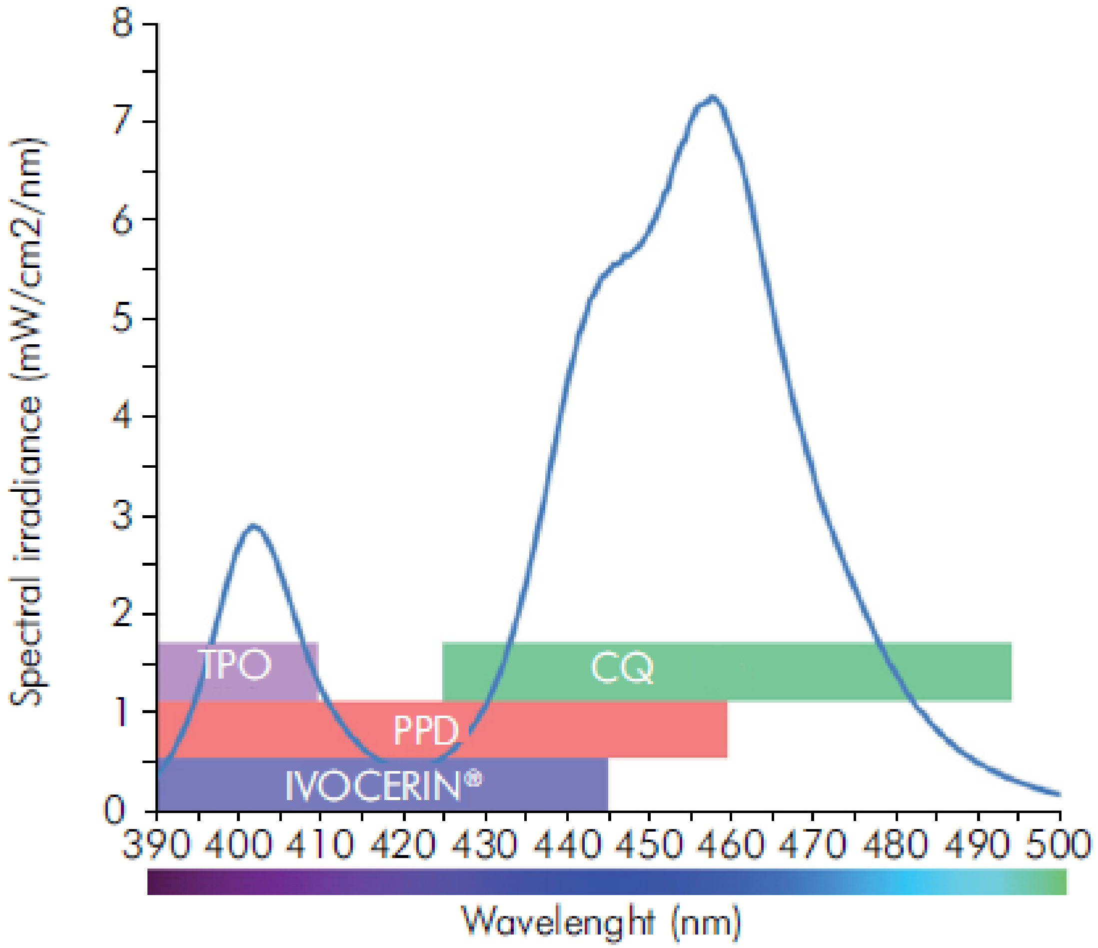
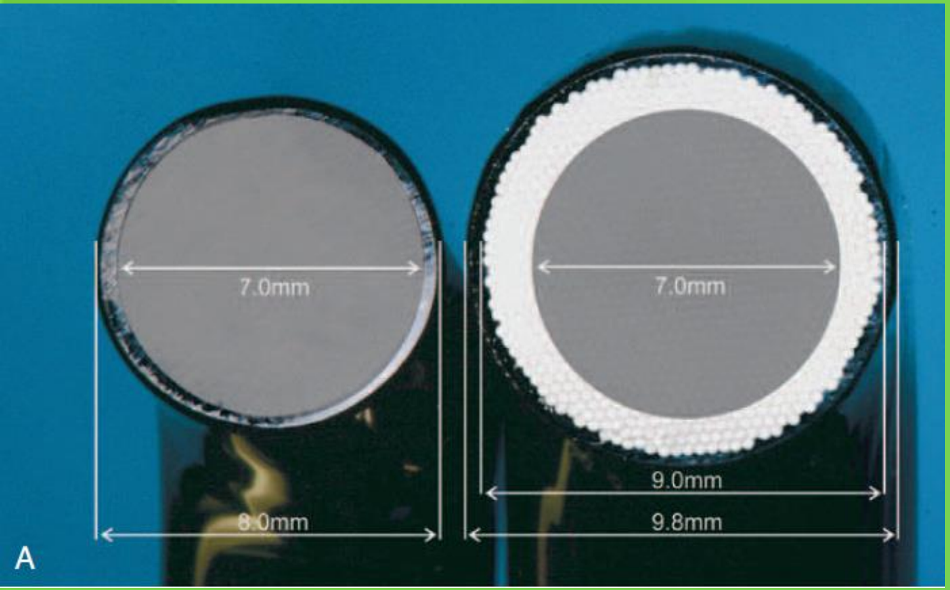


Figure 32. Spectral emission profile of the VALO curing light.

Budget Curing Light

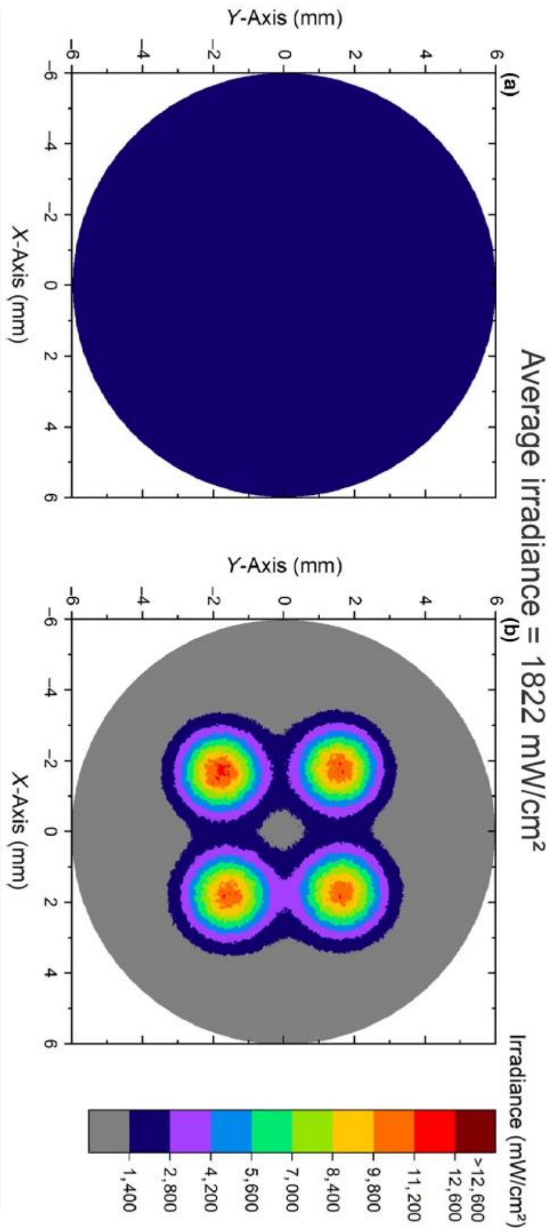


often use small diameter (6 to 7 mm) light guides

light beam profiles from these budget lights can also be inferior compared with those of the higher priced lights from major manufacturers

without any warning to the user, the light output from battery-operated budget curing lights may not be stable during operation

Light beam irradiance uniformity

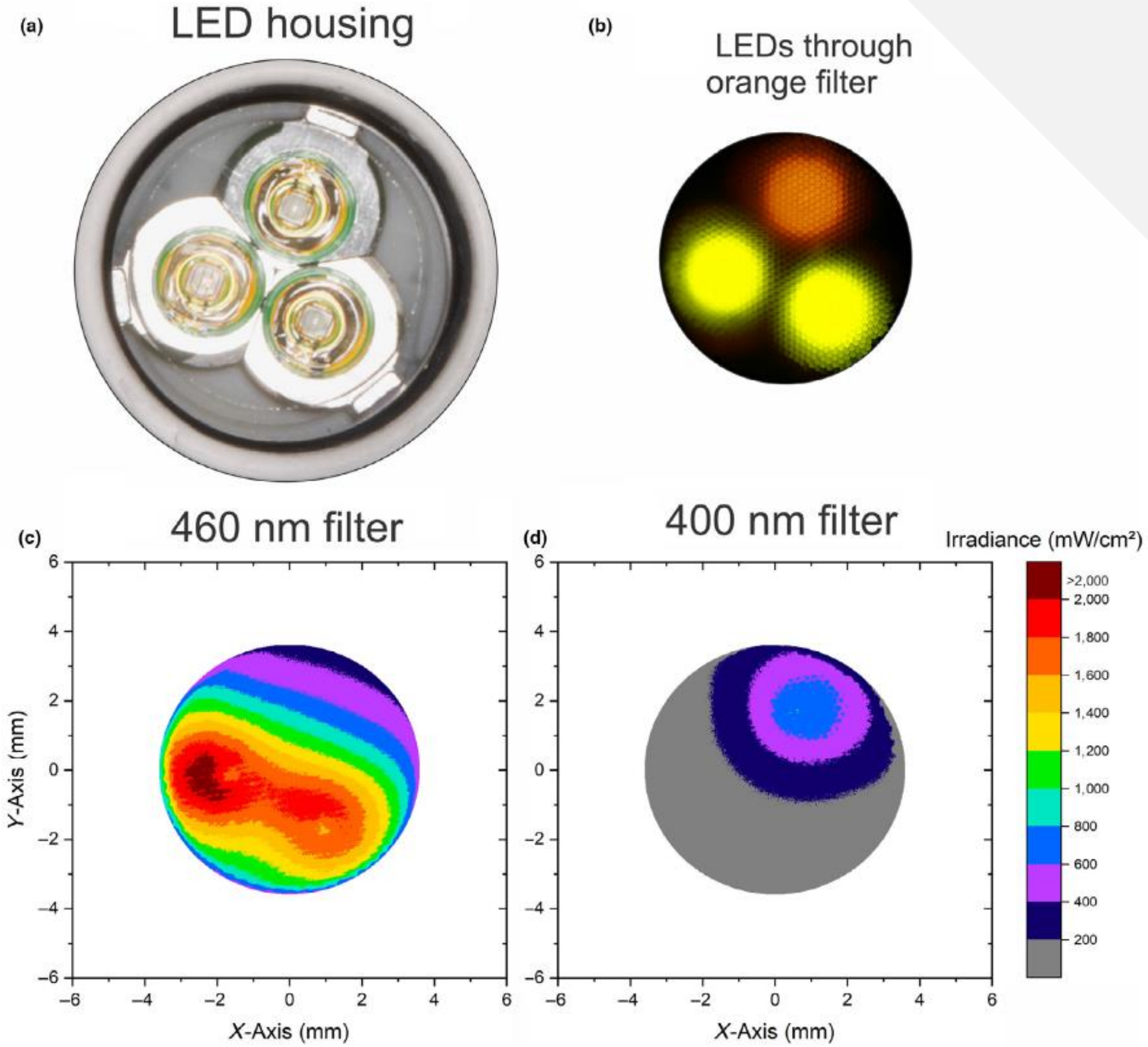


the radiant power was divided by the optical tip area to produce an averaged radiant exitance of 1,822 mW/cm2.

The four ‘hot spots of high radiant exitance that are above 12,600 mW/cm2, and

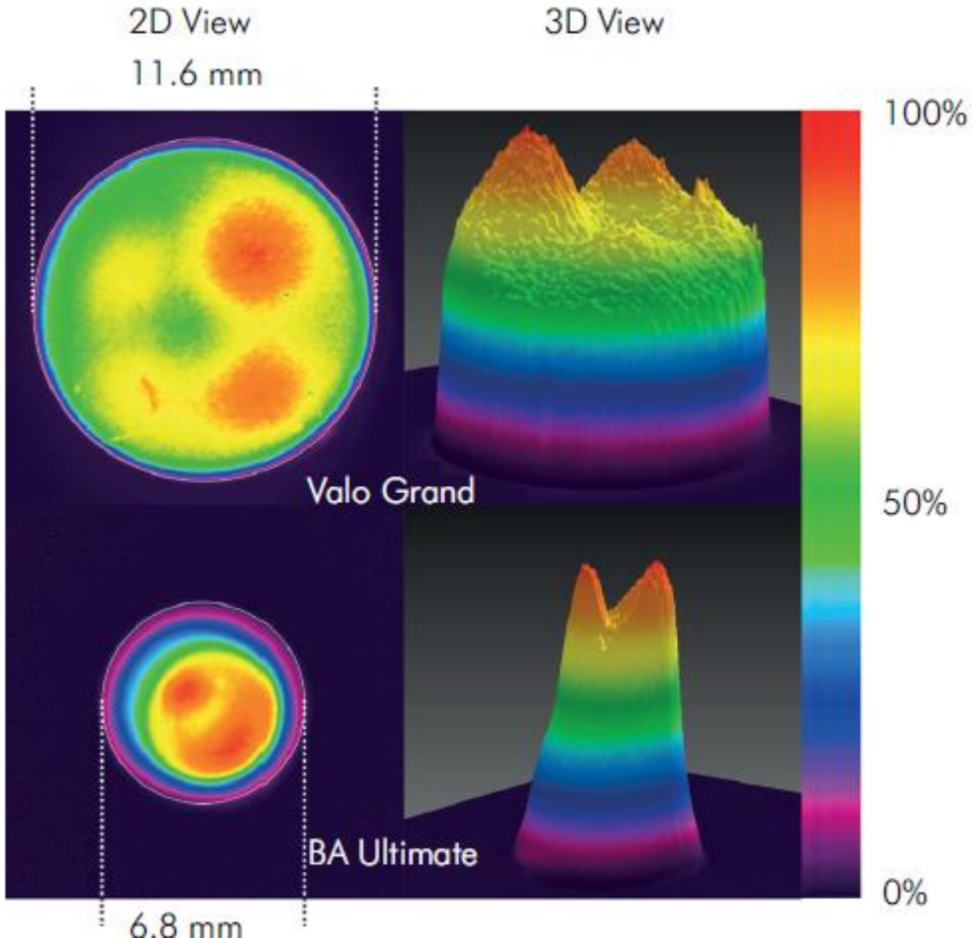
other regions where the light output is lower.

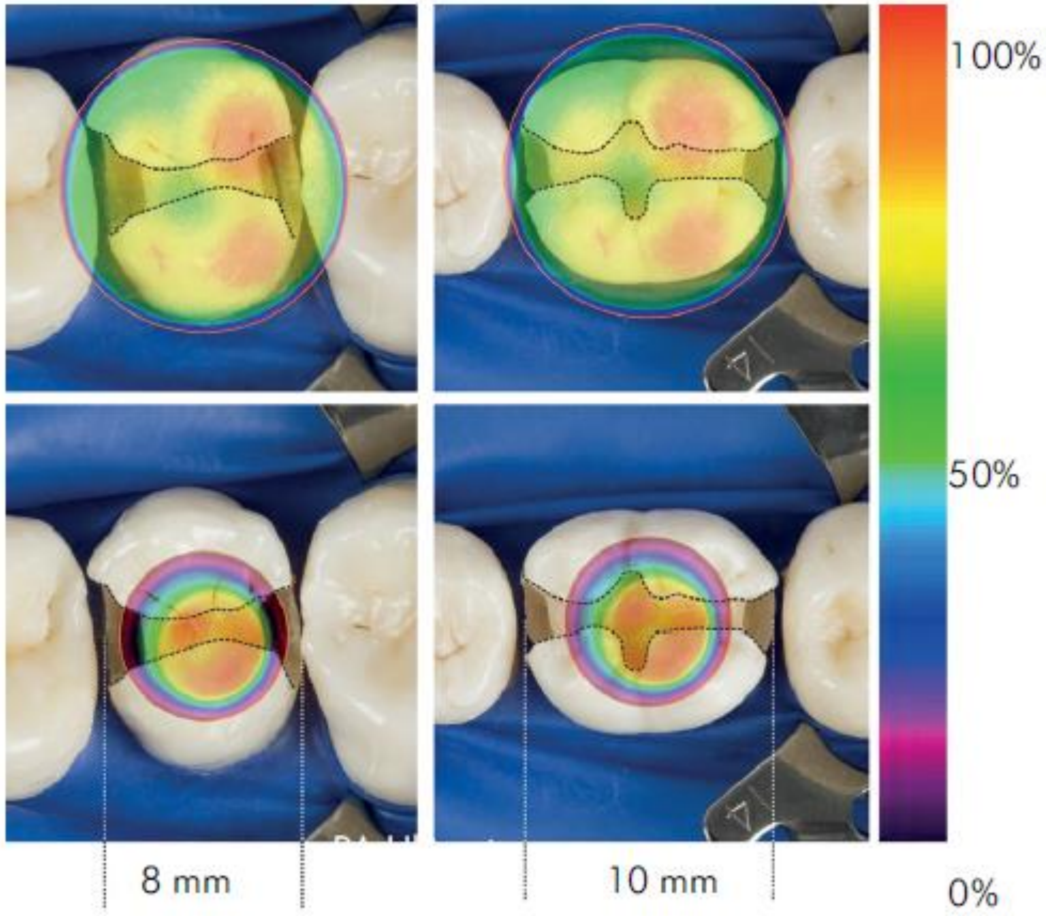
Light beam spectral uniformity



Light Beam Uniformity

the irradiance from many dental curing lights is not evenly distributed across the emitting end of the light tip
the localized inhomogeneity in the irradiance results in “**hot spots**” of high-intensity light and“**cold spots**” of lower values
the irradiance across the light tip is a range of values and the irradiance homogeneity depends on the design of the curing light



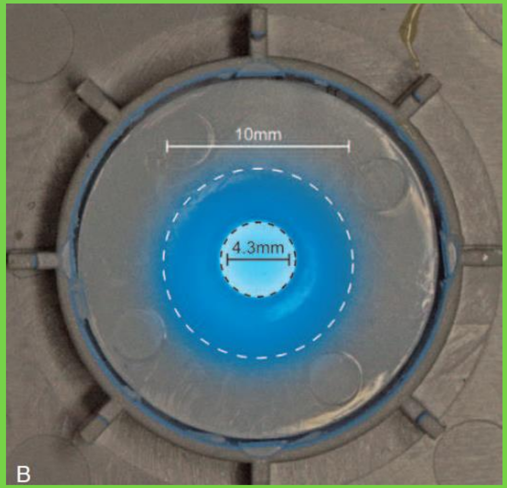


Monitoring

CURE RITE
DENTMATE

500 mW/cm²<
>2,000 mW/cm²

0
200
400
600
800
1000
mw/cm²
OPTILUX RADIOMETER



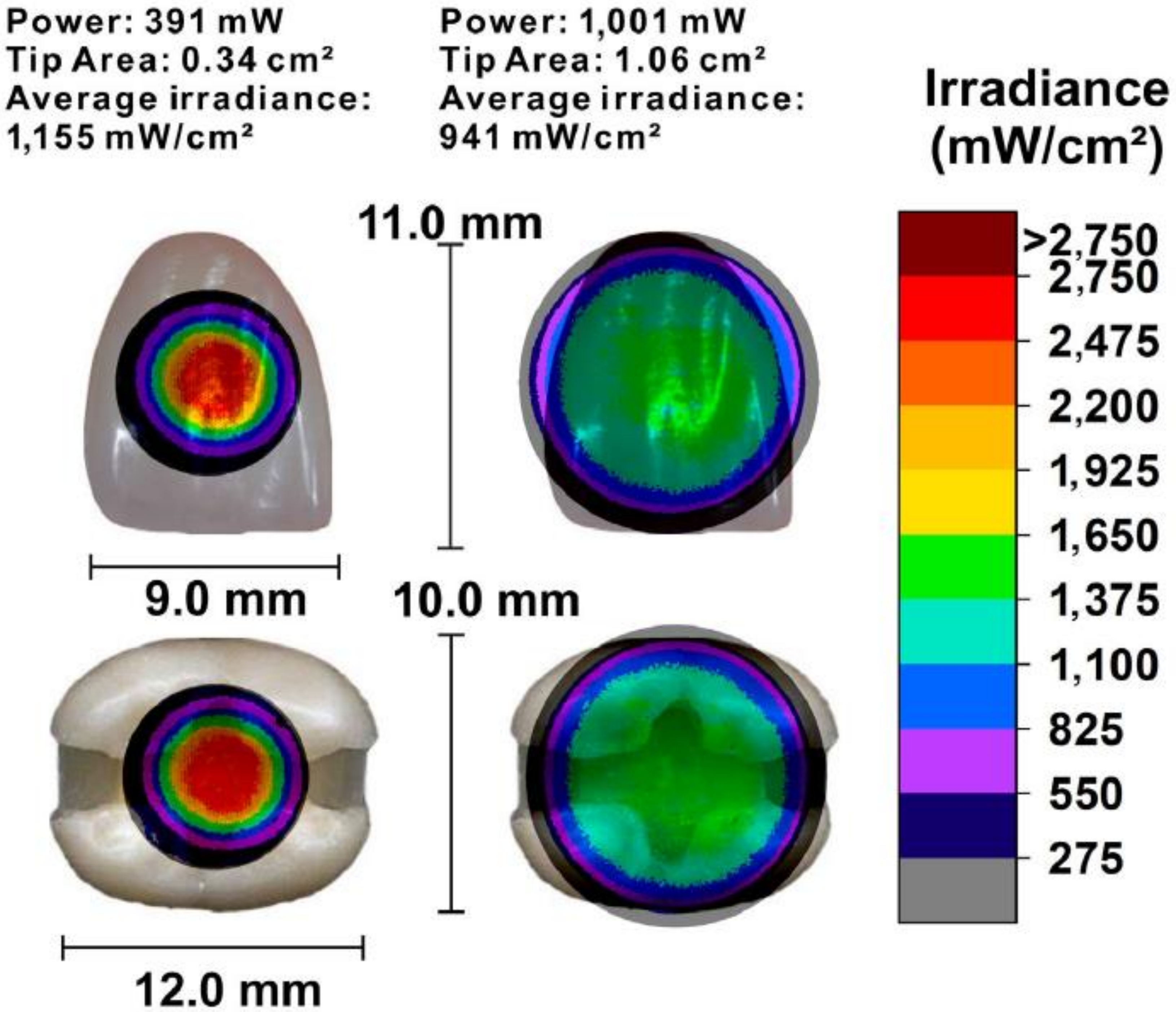
10mm
4.3mm
B

Exposure Time

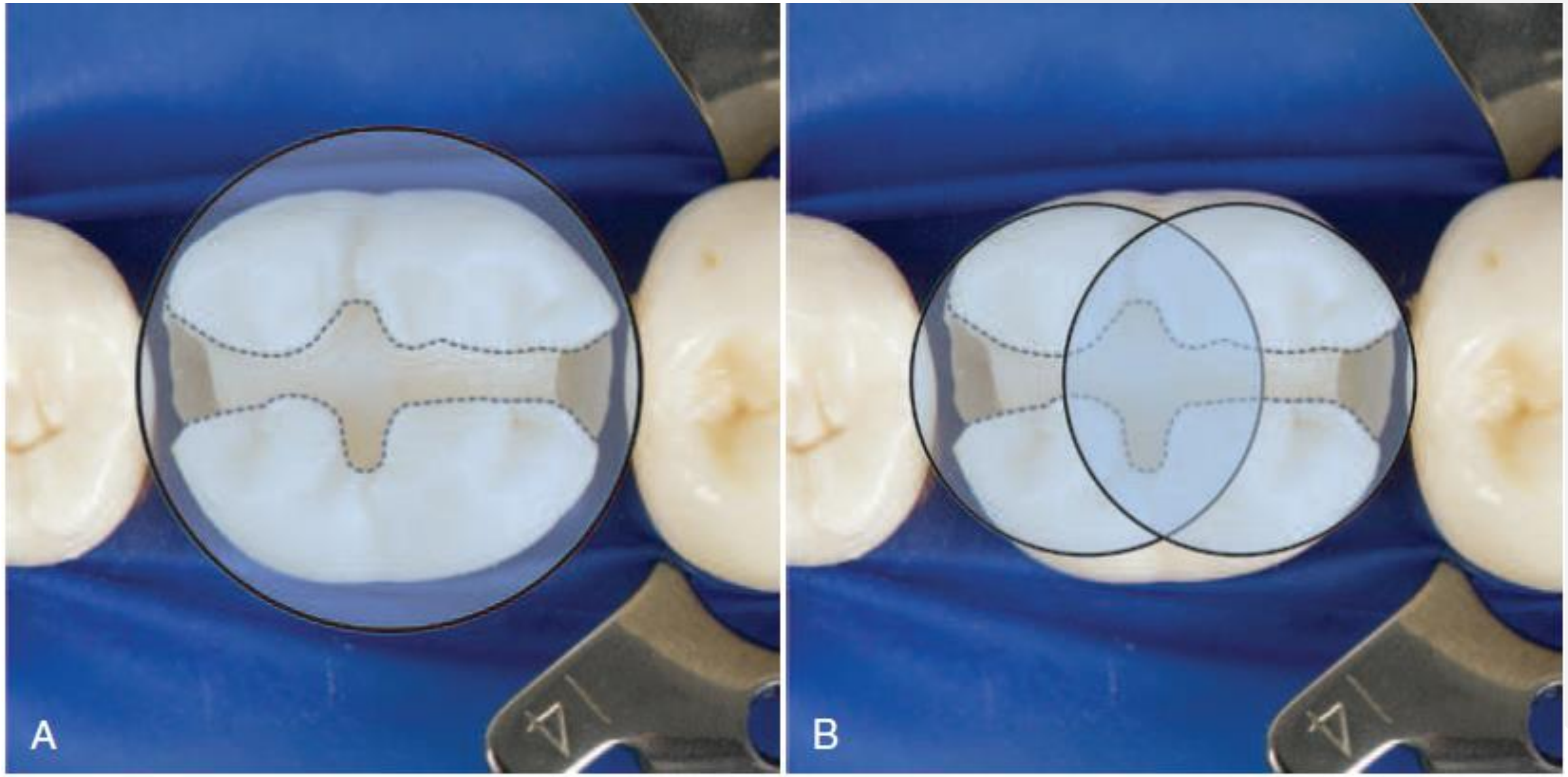
the irradiance delivered is multiplied by the exposure time, the product describes the **radiant exposure** (in J/cm2) delivered to the exposed surface of the resin.

most dental resins require a radiant exposure of approximately 20 J/cm2 to adequately cure to a depth of 2 mm.

However, diferent brands of resin require diferent exposure times, and the minimum radiant exposure may range from 6 to at least 24 J/cm2

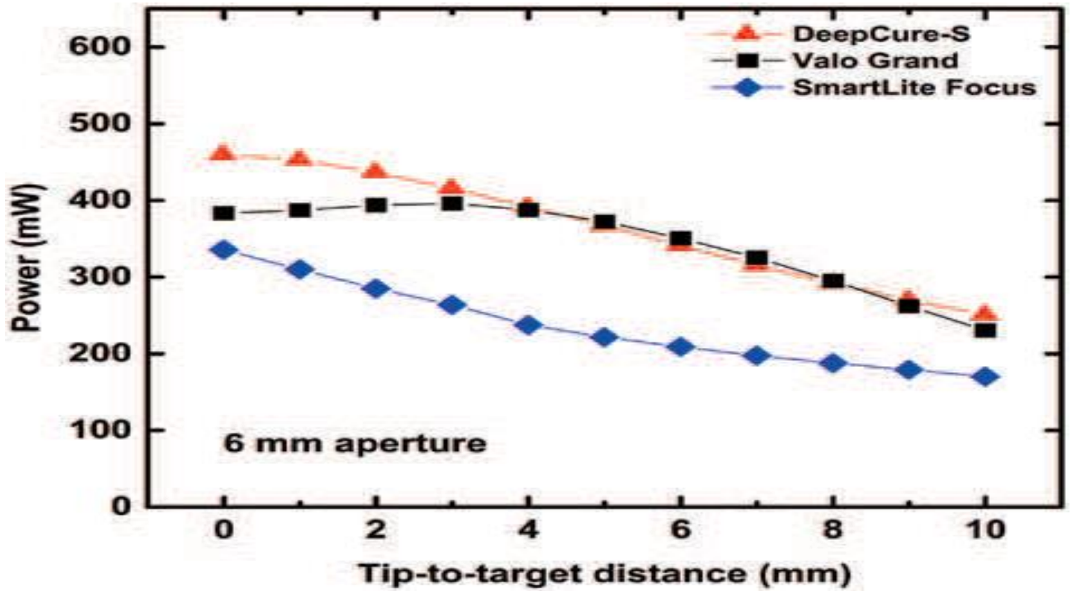

Power: 391 mW
Tip Area: 0.34 cm²
Average irradiance:
1,155 mW/cm²
Power: 1,001 mW
Tip Area: 1.06 cm²
Average irradiance:
941 mW/cm²
Irradiance
(mW/cm²)
>2,750
2,750
2,475
2,200
1,925
1,650
1,375
1,100
825
550
275
11.0 mm
9.0 mm
10.0 mm
12.0 mm

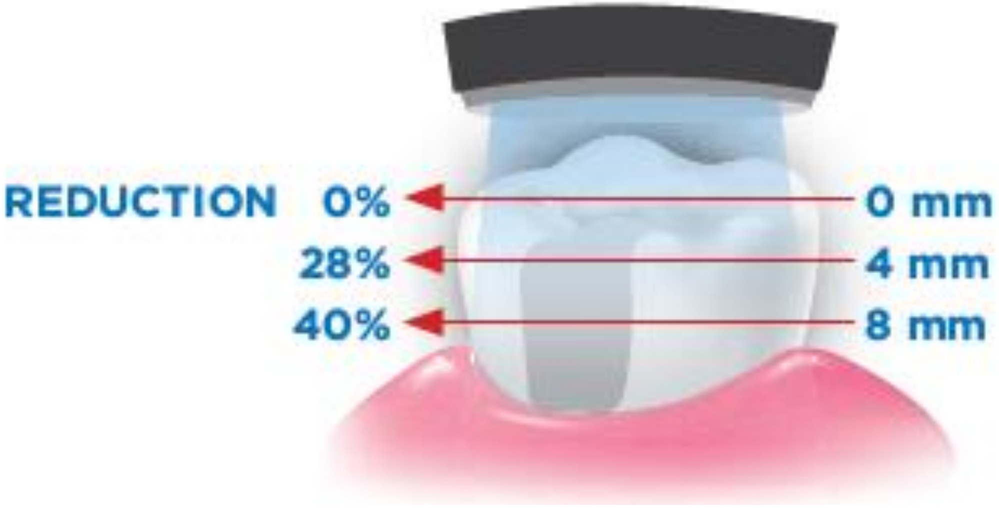
Light Guide Tip Design



multiple, sequential, overlapping exposures will be required to ensure that all areas of the restorative material have received an adequate amount of light

Ditance to Target

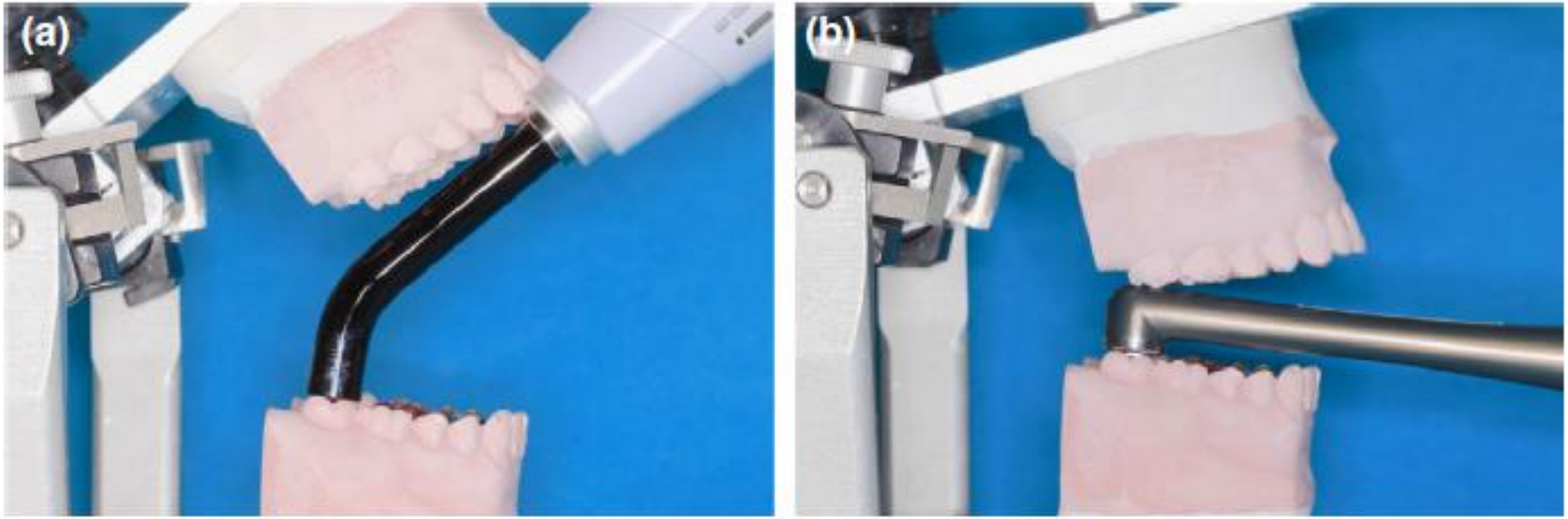




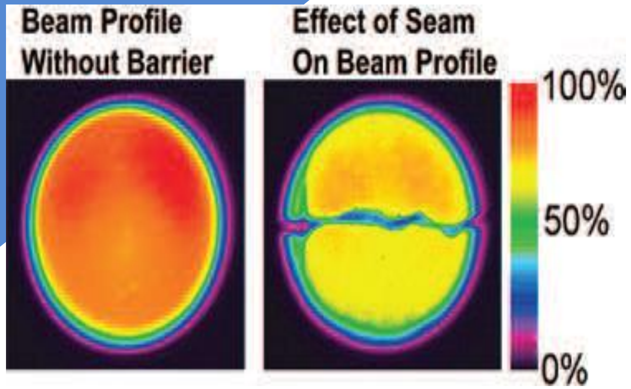
Because the resin is usually
2 to 8 mm away from the light tip,
this value does not relect the
irradiance values that are received
by the restoration.

radiant exitance not only at the
light tip, (tipirradiance),
but also the irradiance
delivered at clinically
relevant distances up to 10
mm away

when curing adhesives in deep
proximal boxes
with a curing light of 600
mW/cm2, the curing time
should be increased to 40 to
60



low-profile head (b) is preferred as it will allow better access to the posterior teeth



Infection control

•some fiberoptic light guides can be autoclaved,

• the body of the curing light itself cannot

•Some barriers can reduce the radiant existance by up to 40%

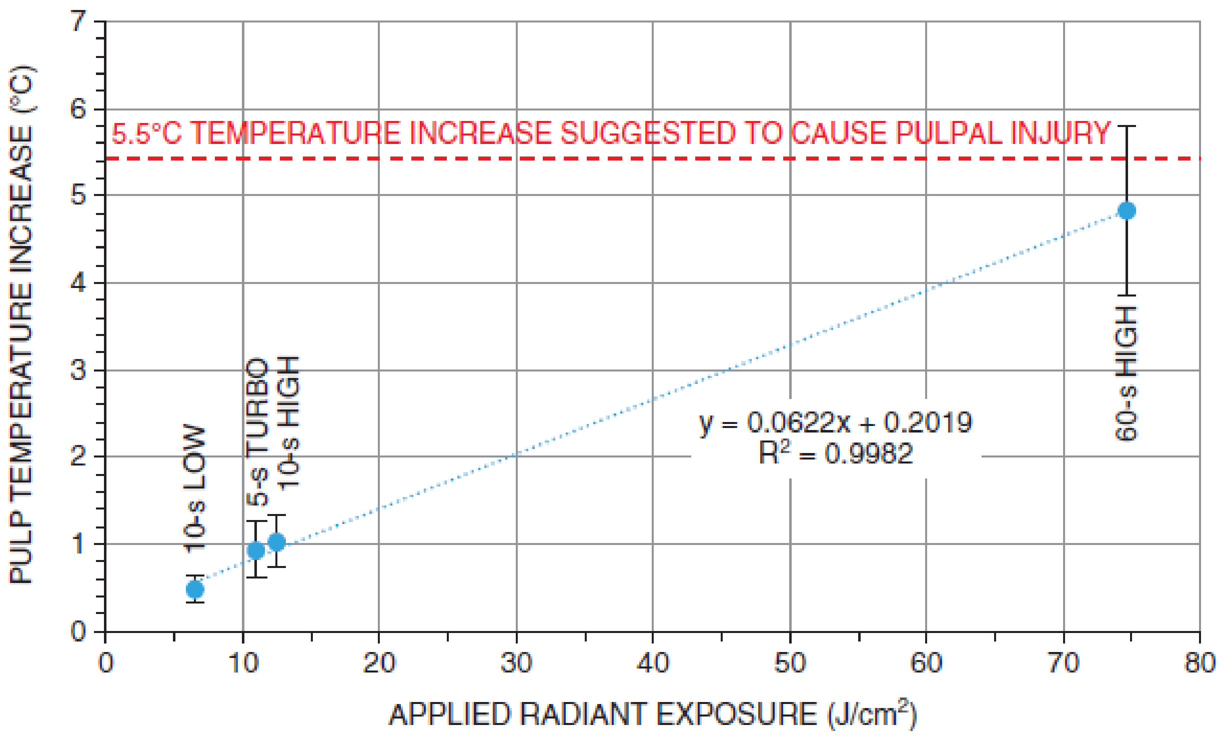
• latex-based barriers negatively affect resin polymerization

•the output should be tested on the radiometer with the barrier over the light tip.

• Clear, plastic food wrap

Effects of curing light on the temperature of tooth pulp and soft tissues

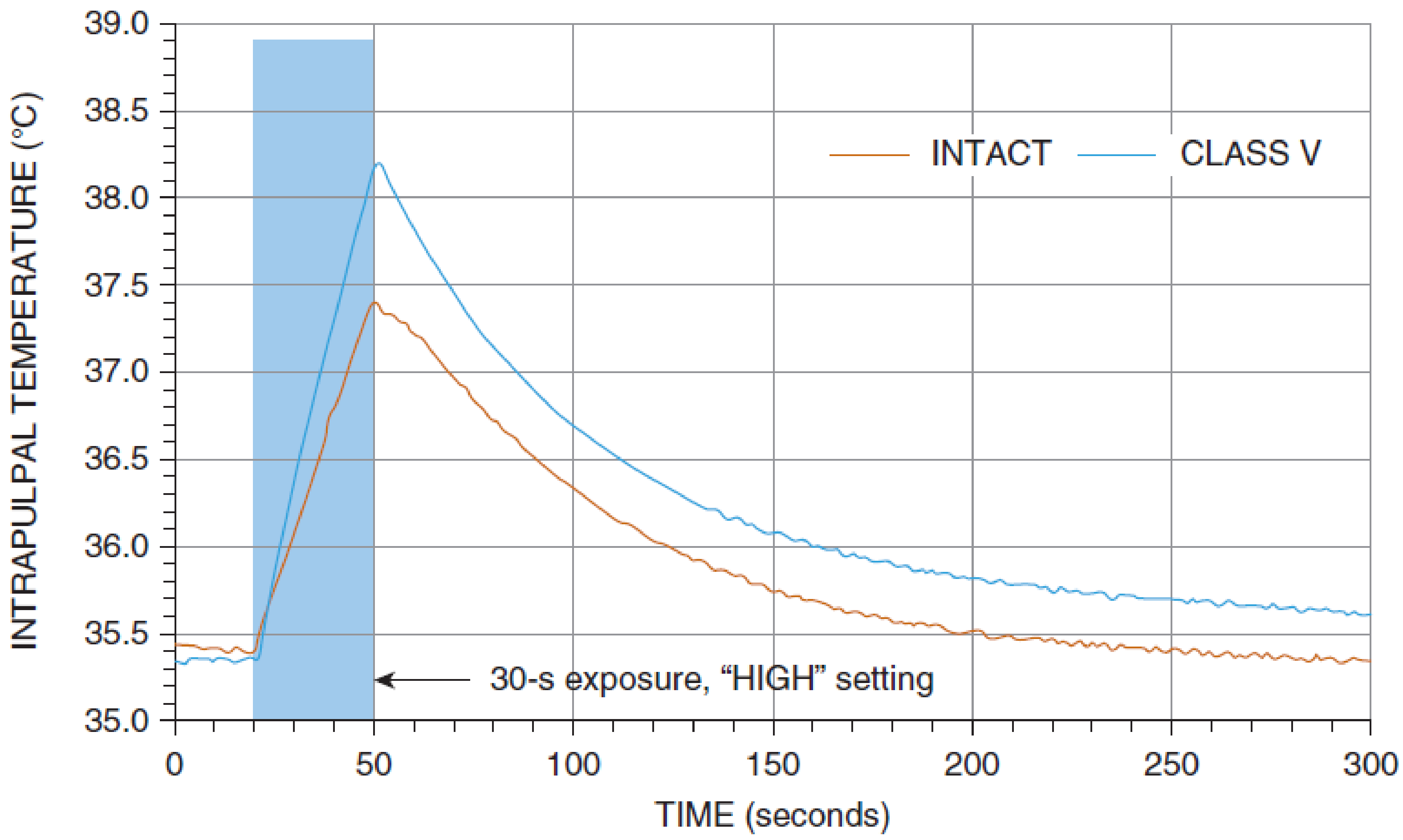
Intrapulpal Temperature Conideration



•increase in intrapulpal temperature of 5.5°C resulted in pulpal necrosis in 15% of the teeth tested

•it is suggested that curing lights that deliver an irradiance greater than 1,200 mW/cm2 should be used for at most 15 seconds

•However, only when the radiant exposure levels approached 72 J/cm2 did some *in vivo temperature* values meet or exceed the 5.5°C increase

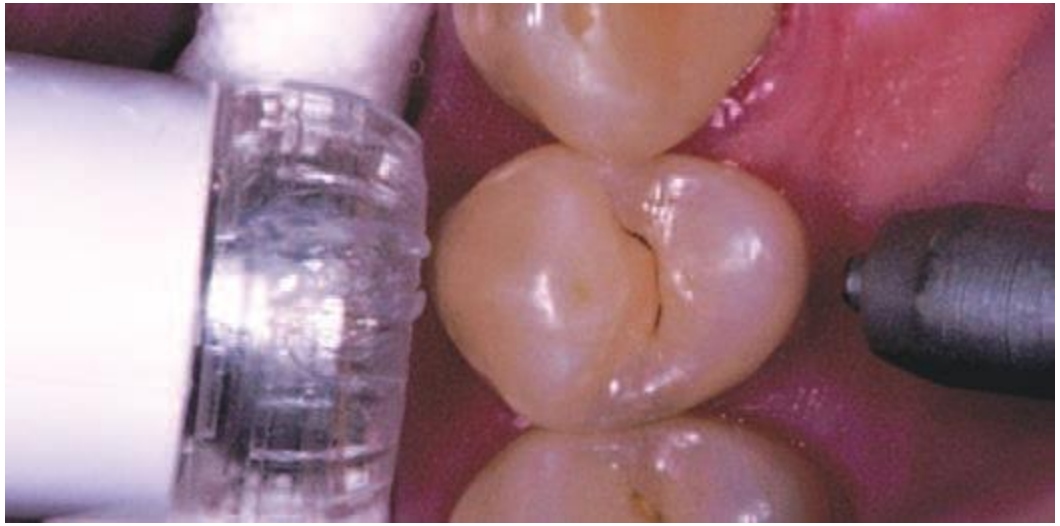


potential for causing temperature increase in pulpal tissue greatly increases as more tooth structure is removed and there is less dentin overlying the pulpal tissues.

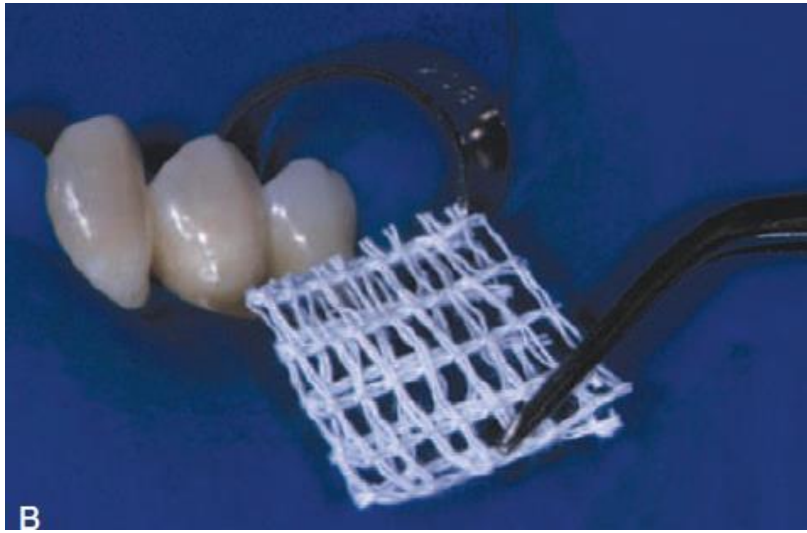
air-cooling during light exposure from the opposite side

high-volume suction to cool the teeth

It may be possible to use irradiance levels greater than 1200 mW/cm2 for longer than 15 seconds if appropriate cooling measures are used



Soft Tissue Damage (IEC 60601)

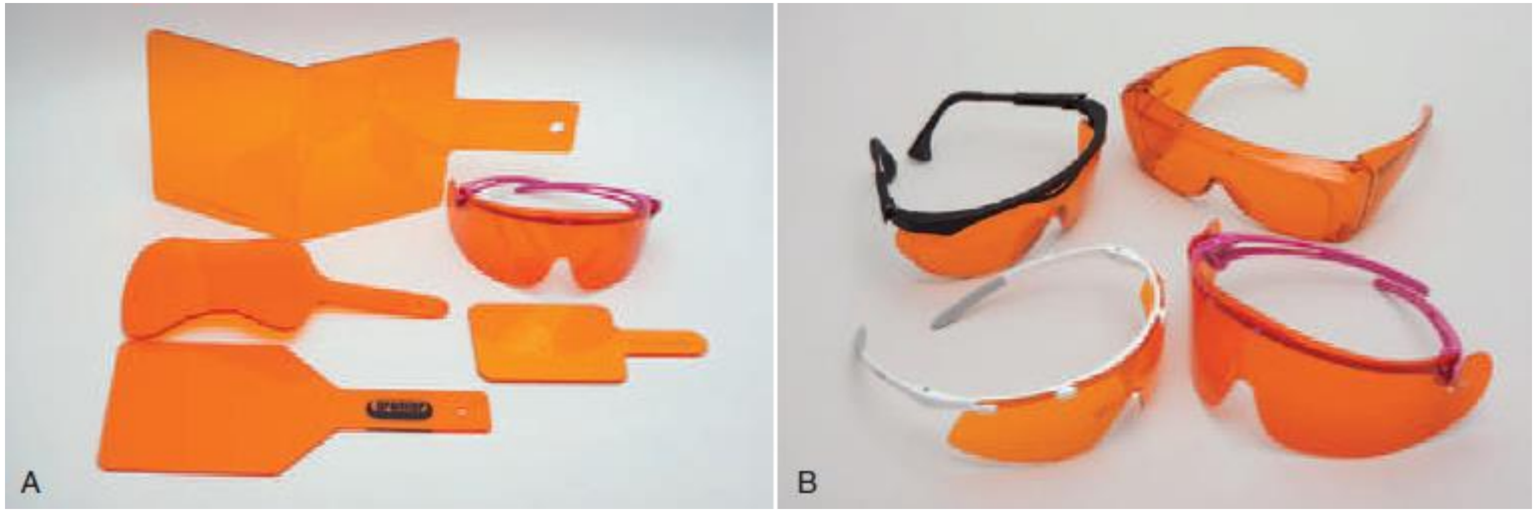


The Optical “Blue Light Hazard”

Immediate and irreversible retinal burning

Accelerated retinal degeneration and chronic photochemical injury to choroid.

the hazard mostly occurs between about 415 nm and 480 nm and is greatest at 440 nm
If the operator looks directly at the curing light, even for just 1 second, it may only take as few as seven curing cycles to exceed the recommended maximum daily exposure to blue light



Thank you for your attention