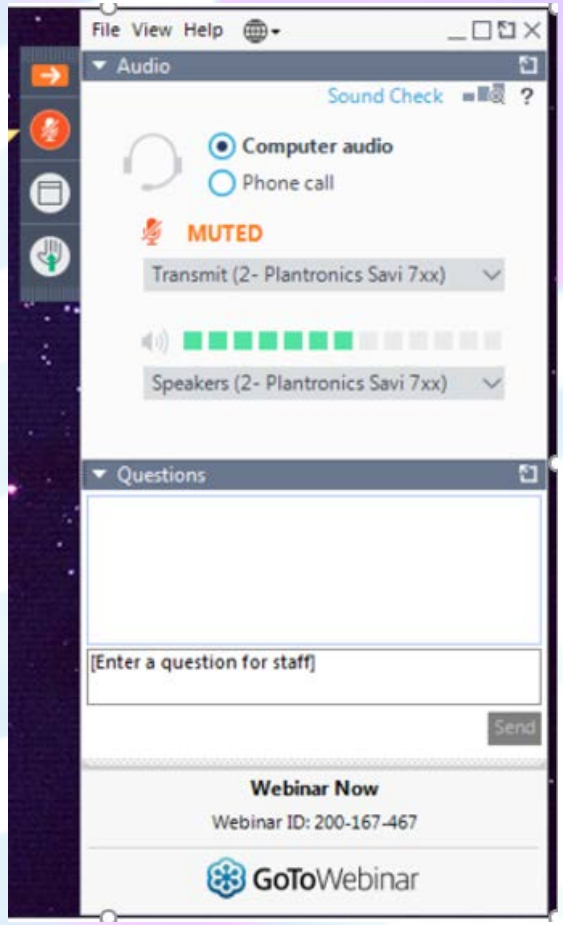
UV CURING BASICS

Broadband & LED Technology and
Applications by **Heraeus Noblelight**

HOUSEKEEPING

- Webinar duration: presentation: 30-40 min with additional 20 min for Q&A
- This webinar will be recorded and every registrant will receive a link to the recording and handouts
- All attendees are muted by default
- Questions can be submitted ONLY via Go To Webinar Question's box at any time, we will address them at the end of the presentation
- If you are joining via "Computer audio", we recommend using a headset
- If there is an issue with your internet connection, you can always dial in via phone



AGENDA

- Introduction to Heraeus and Heraeus Noblelight
- Principles of UV curing: chemistry, process, UV lamp systems
- Benefits of UV LEDs: explore customer cases
- Q&A session

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HERAEUS – A GLOBALLY SUCCESSFUL PORTFOLIO COMPANY

TOTAL REVENUE
€ 20.3 bn

7% R&D EXPENDITURES[1]

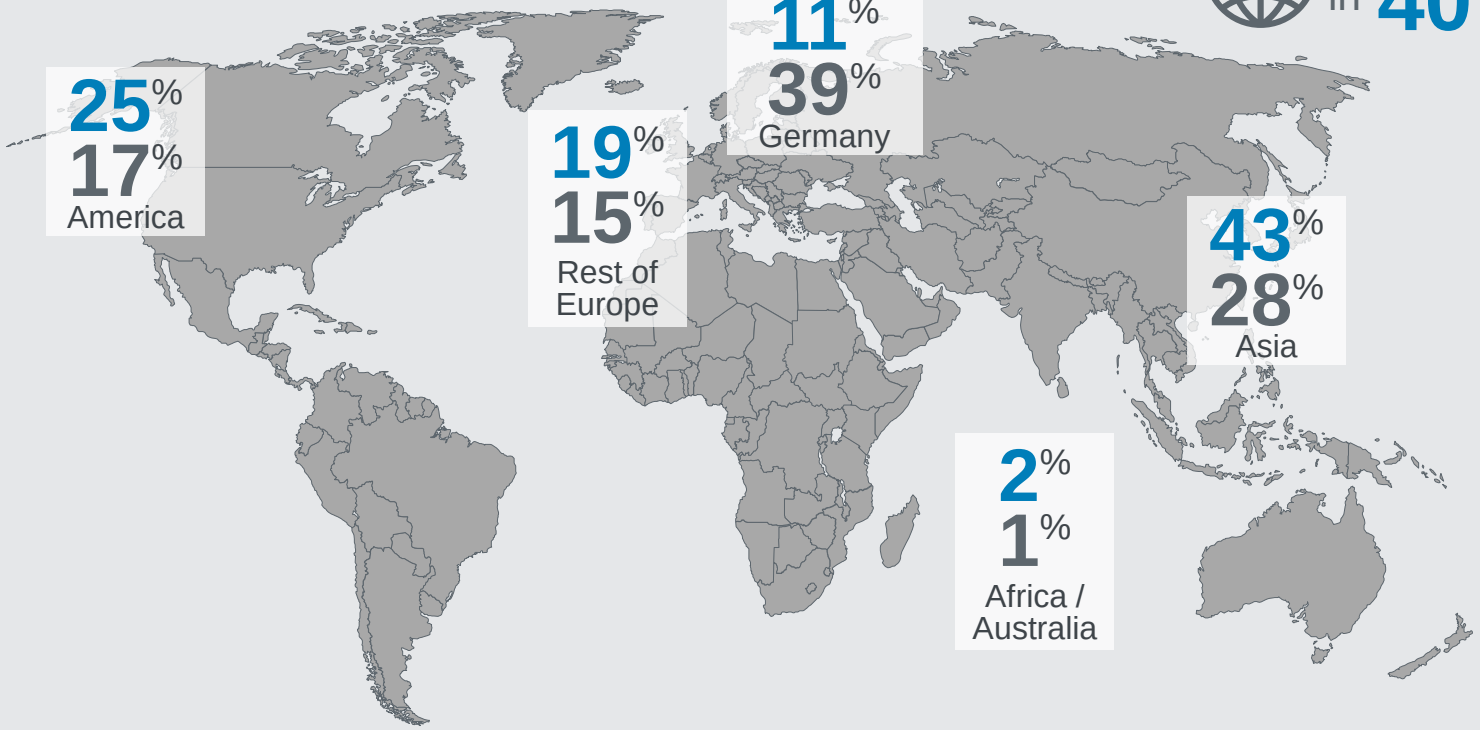
Market-oriented distribution in **11** GLOBAL BUSINESS UNITS

Listed in **FORTUNE GLOBAL 500**

TOP 10 FAMILY-OWNED COMPANIES in Germany

REVENUE EXCL. PRECIOUS METALS
2018 BY REGION

EMPLOYEES
2018 BY REGION



EMPLOYEES[2]
14,900

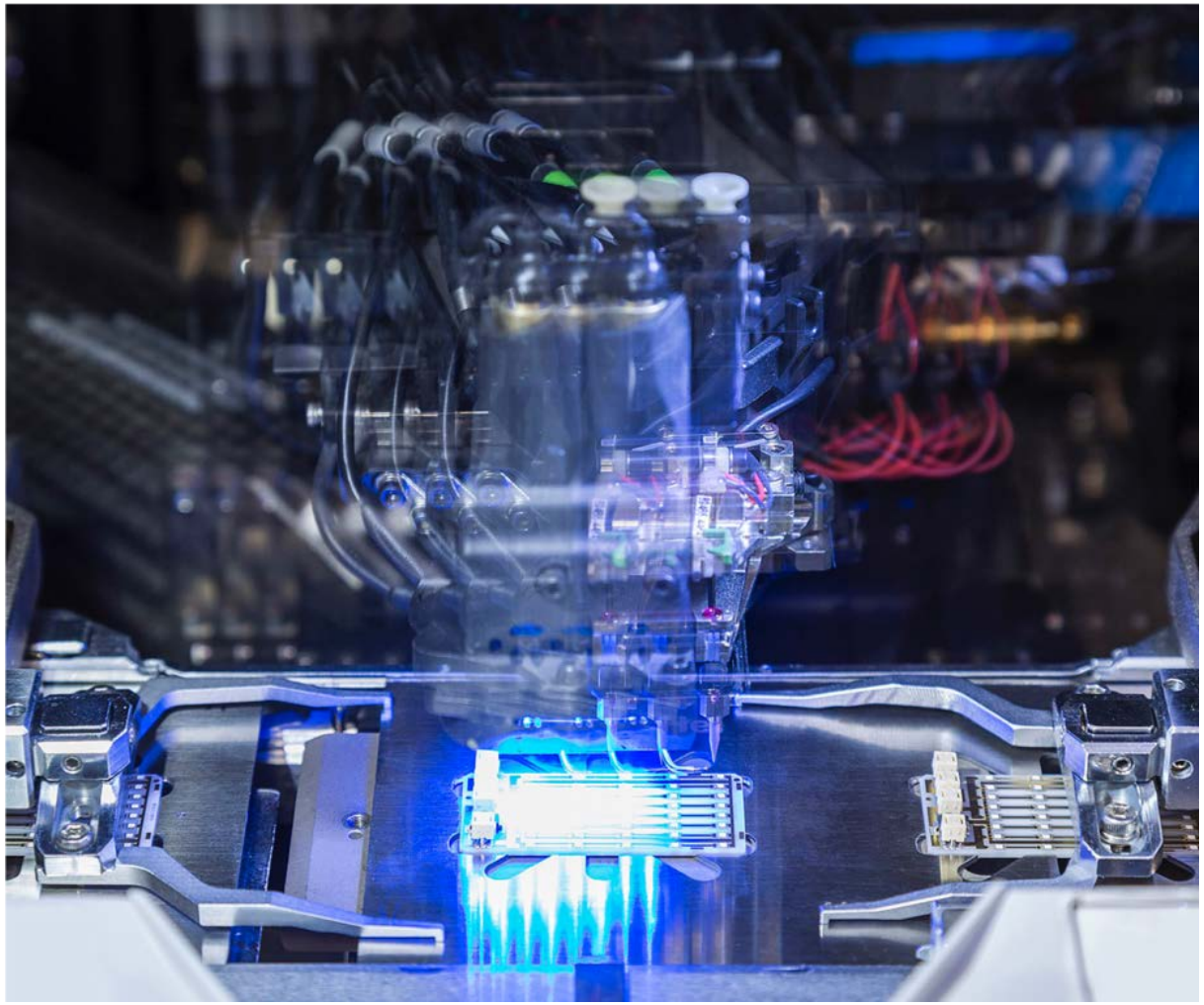
More than **100** SITES in **40** COUNTRIES

[1] based on revenues excl. Precious Metals

[2] incl. contract employees

HERAEUS UV LED

- 10+ years of experience in UV LED mechanical & electrical engineering, optical & thermal simulations, photon management and production.
- Manufactured in Germany in fully automated state-of-the-art production lines. In-house qualification of chips delivers better and more consistent quality. Tests include electrical and thermal connections on the chips.
- Value Chain control with own production of patented primary optics, of silver paste and gold wire. Full traceability of assembled material, inline process parameters, final inspection measurement data
- Independent measurement laboratory accredited as a test laboratory and local Application Competence Centers (ACCs) for in-house trials with the support of experienced chemists.



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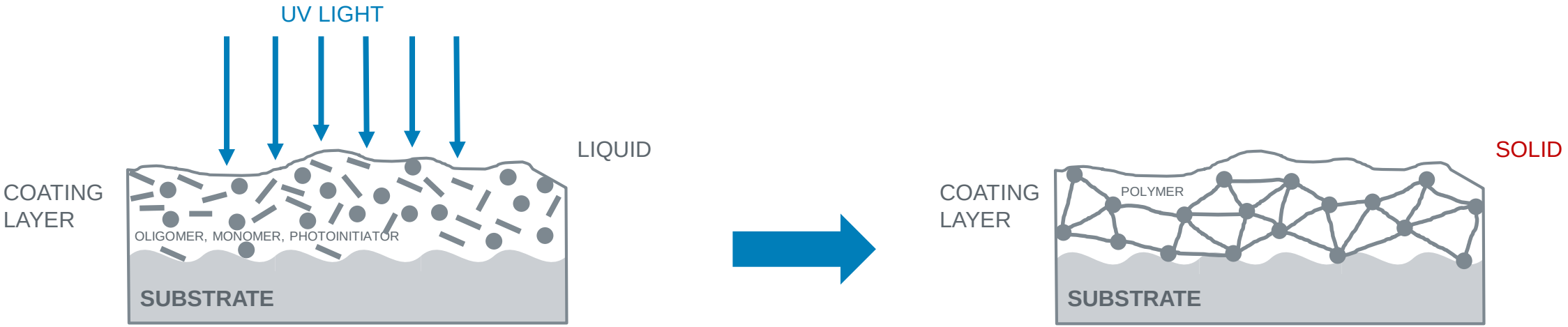
UV CURING PROCESS

- UV curing is based on a photochemical reaction
- Fast, immediate process due to UV irradiation
- No outgassing and no loss of coating thickness
- Solvent-free
- Free radical polymerization process is typical (shown)

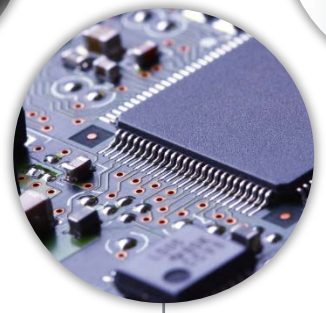
Polymer chains are built up and crosslinked into a 3-dimensional network using a photoinitiated polymerization process.
Within a split second, the cross-linked system is dry and abrasion-proof and can **immediately be processed in the next production step**.



APPLICATION AND INDUSTRIES FOR UV CURING

COATING OF SURFACES

ELECTRONICS COATINGS & ASSEMBLY



GLASS DECORATING

METAL DECORATING & BOTTOM RIM COATING

FIBER OPTICS

ADHESIVE AND PAINT CURING

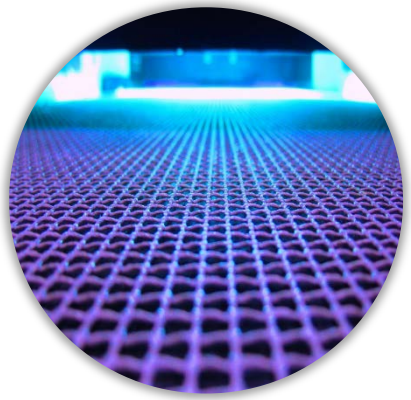
AUTOMOTIVE INDUSTRY

PRINTING INDUSTRY
(DIGITAL, FLEXO, SCREEN PRINTING)

FACTORS THAT INFLUENCE THE UV PROCESS

UV lamp system

- Spectral distribution
- Irradiance and energy
- Energy distribution
- IR-radiation



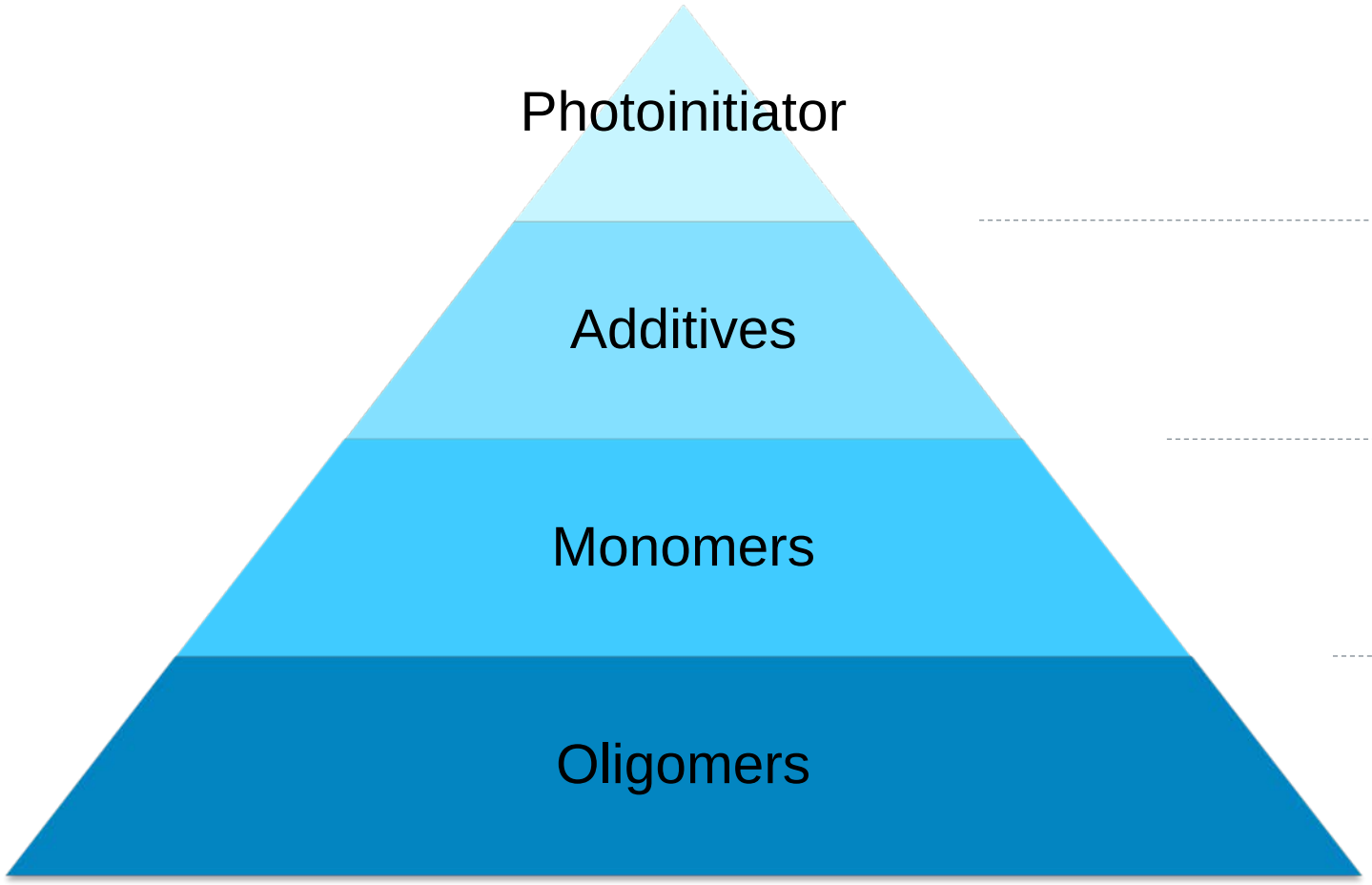
Product

- Dispensing method
- Layer thickness
- Process speed
- Substrate

Formulation

- Chemical components
- Spectral absorption
- Spectral reaction
- Optical thickness

COMPONENTS OF A UV CURABLE FORMULATION



Molecules that absorb UV light and initiate polymerisation process

Pigments, flow control agents, matting agents, fillers etc

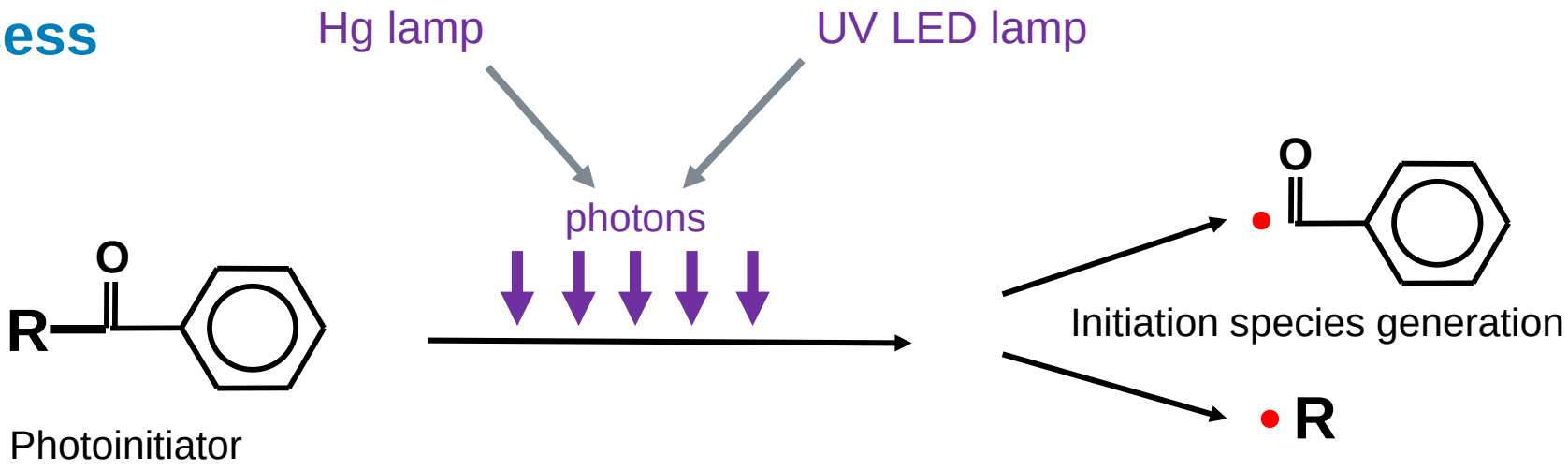
Molecules crosslink with each other & with oligomers.Viscosity reduction. Contribute to coating performance characteristics

High molecular weight molecules with reactive sites. Key coating performance characteristics.

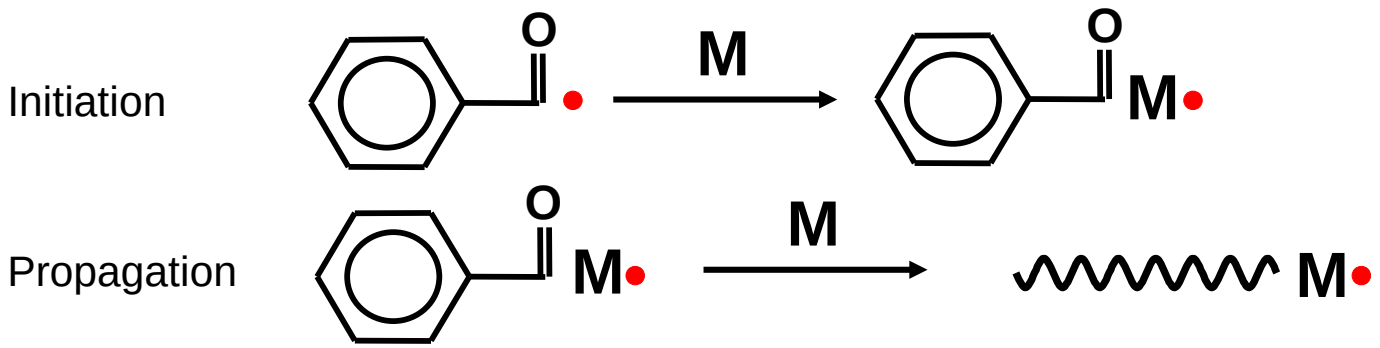
PHOTOINITIATORS

Photochemical process

Initiation reaction



Polymerization process



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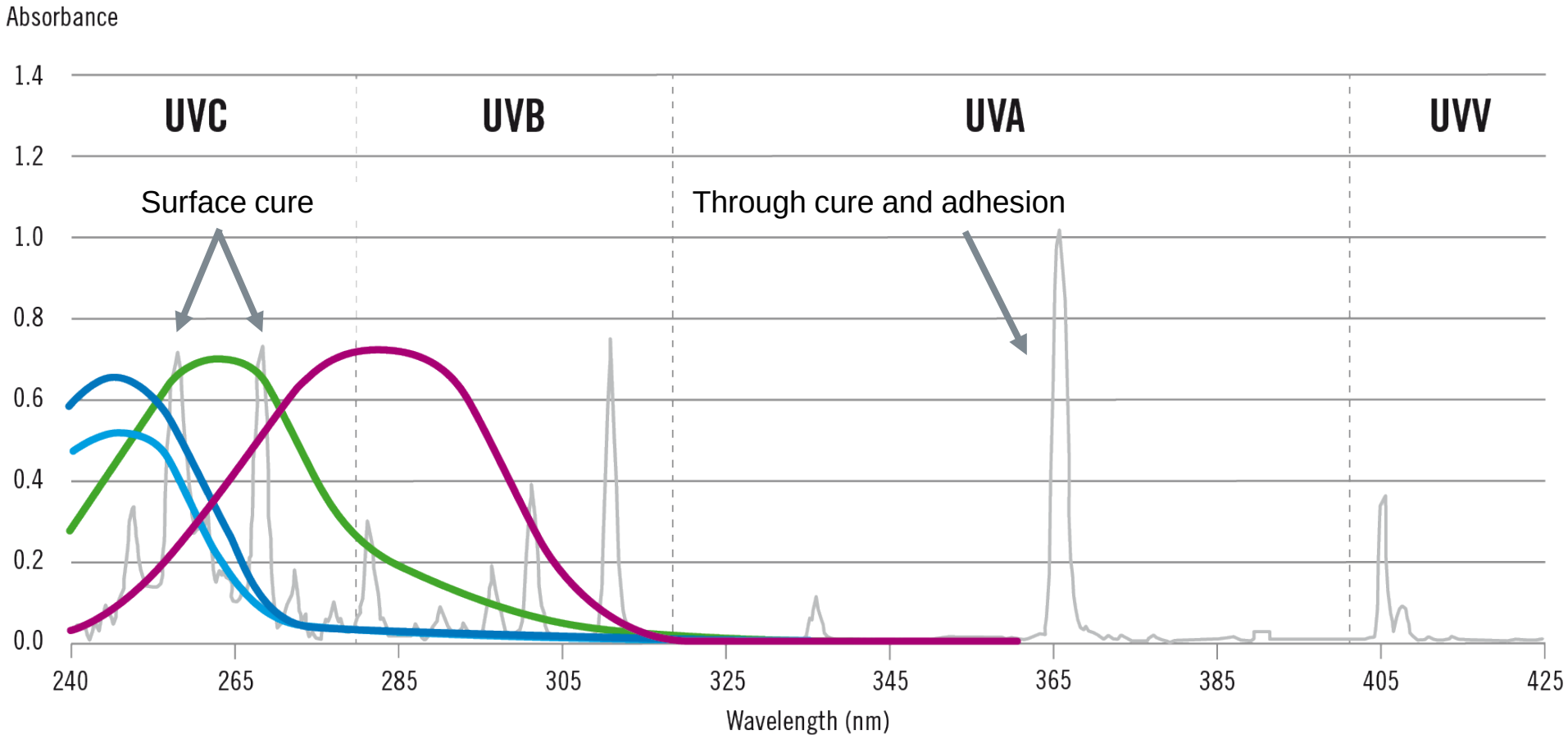
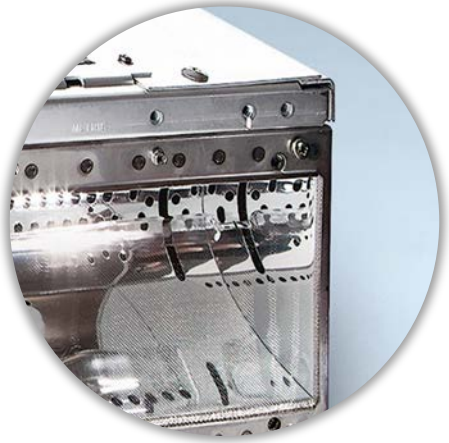
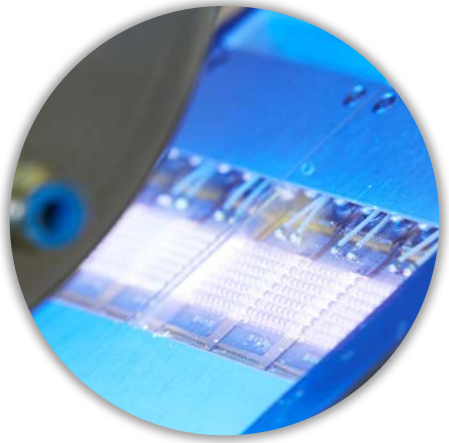


Absorbance of 4 different photo initiators

KEY FEATURES OF A UV LAMP SYSTEM





Irradiance, W/cm²

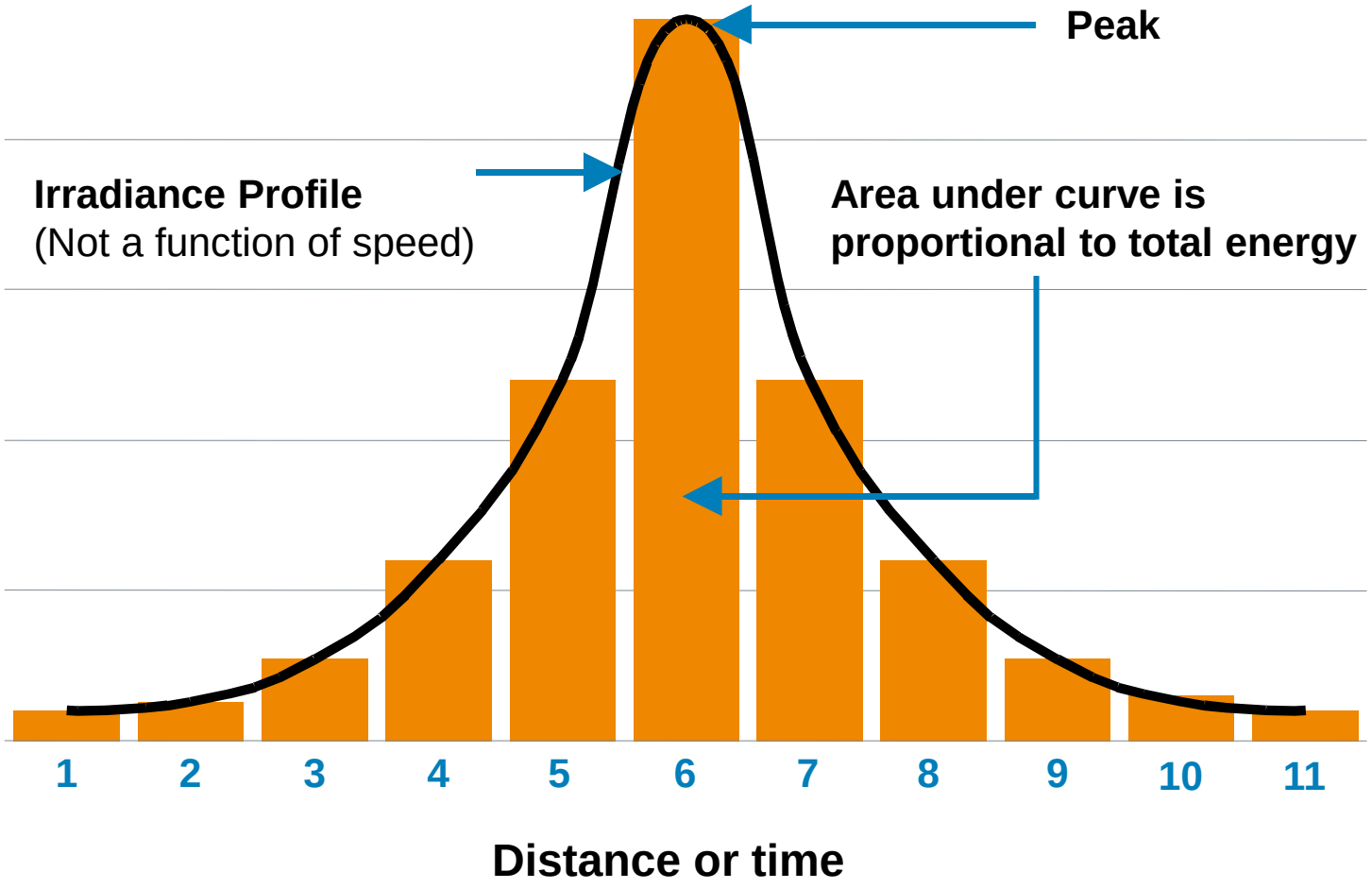
Profile of radiant power arriving at a surface, in a specific waveband

Usually peak irradiance is reported

Energy, J/cm²

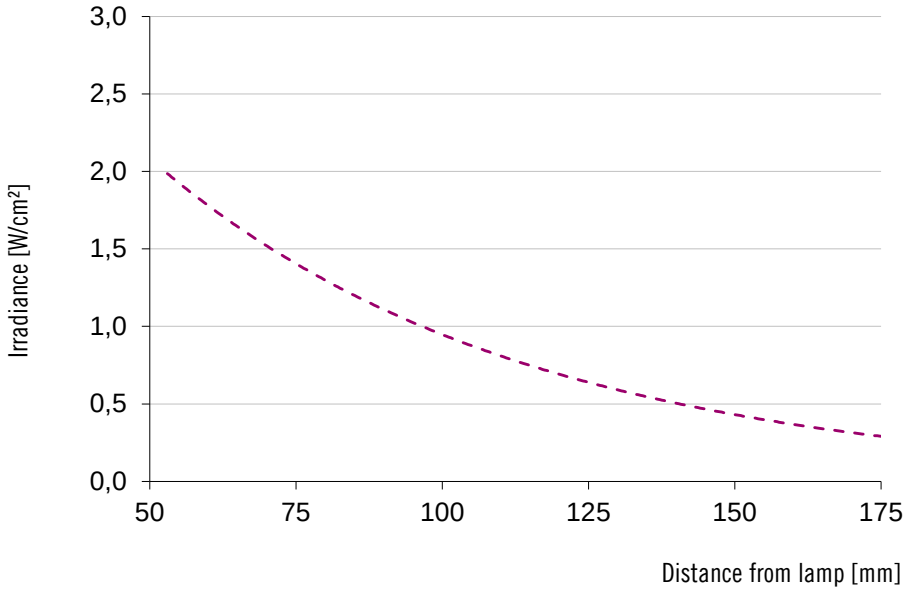
Spectral output

PEAK IRRADIANCE & TOTAL ENERGY

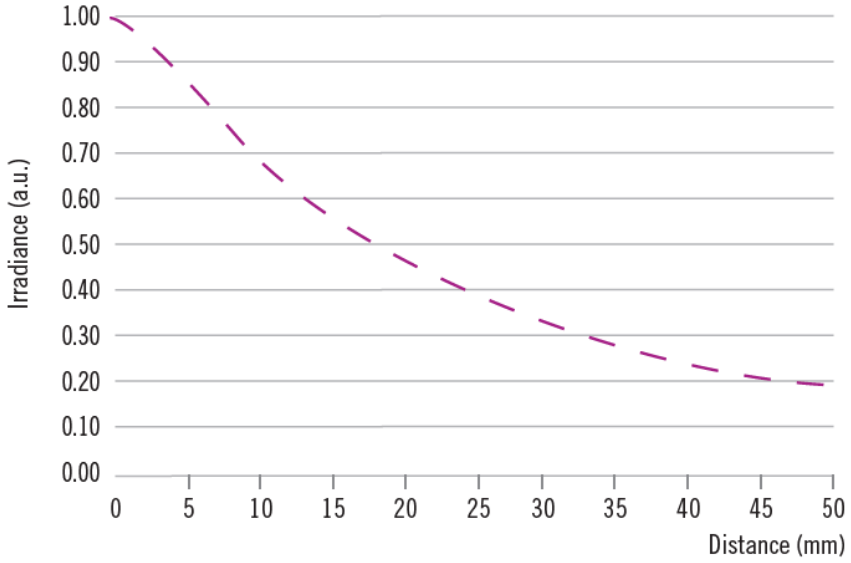


IRRADIANCE & DISTANCE TO THE SURFACE

Microwave powered UV lamp, 240W/cm H bulb



Semray® UV4000 UV LED lamp



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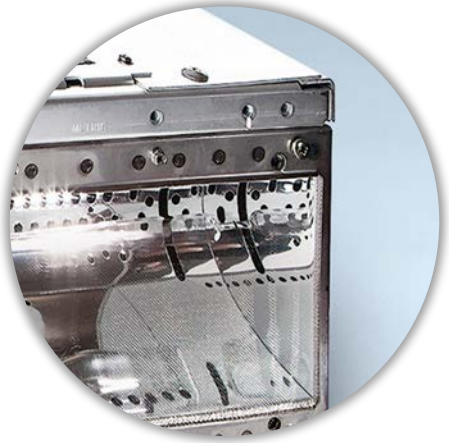

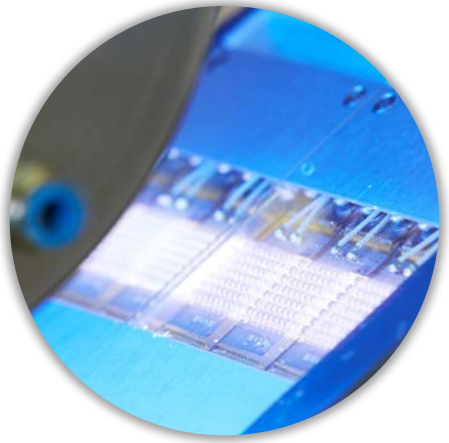

Irradiance, W/cm²

Profile of radiant power arriving at a surface, in a specific waveband

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Energy, J/cm²

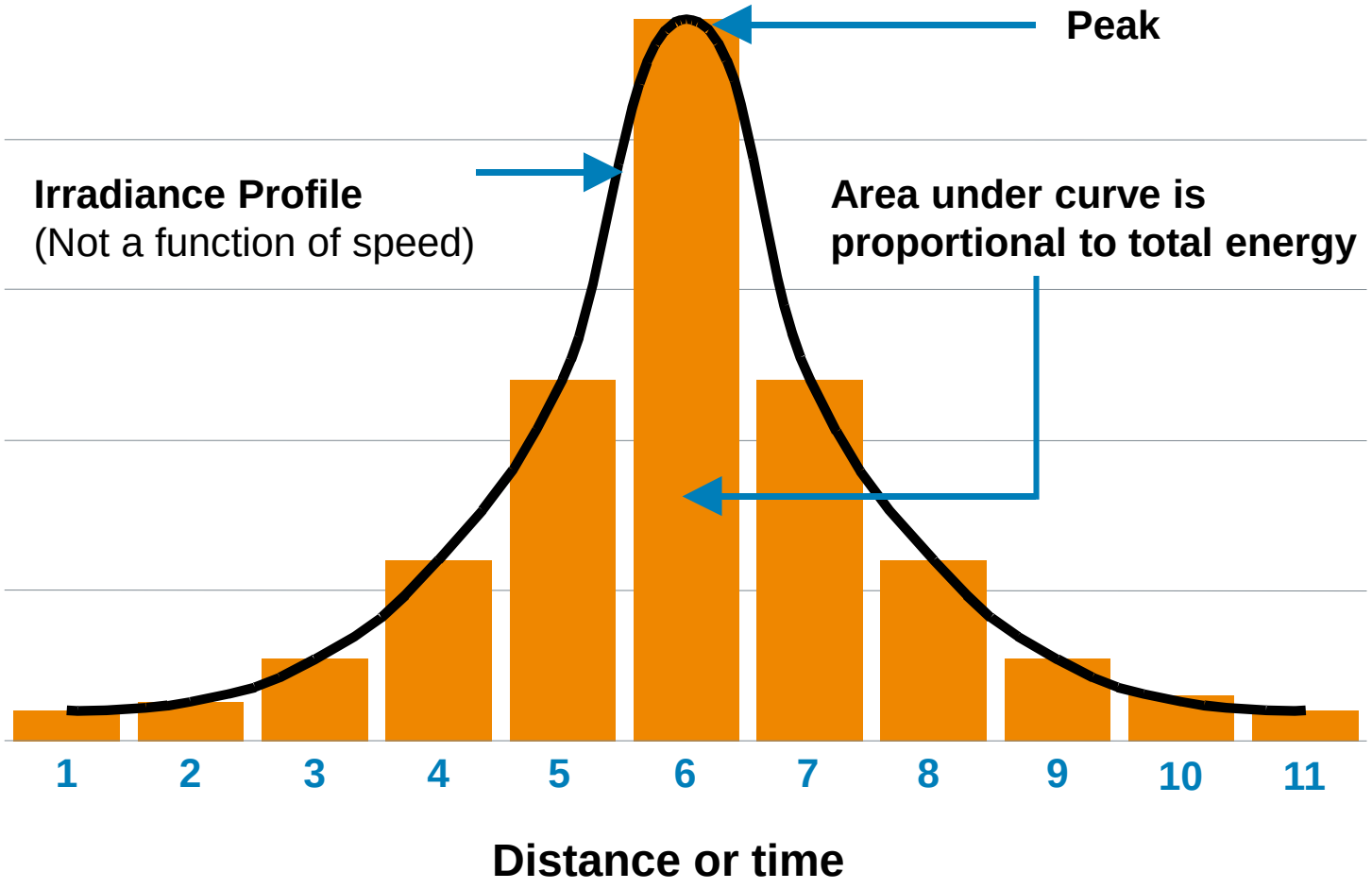
Total energy arriving at a surface in a given time

Time integral of the irradiance profile

Inverse of speed

Spectral output

PEAK IRRADIANCE & TOTAL ENERGY



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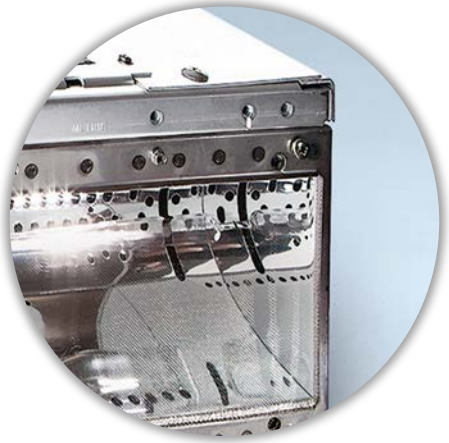

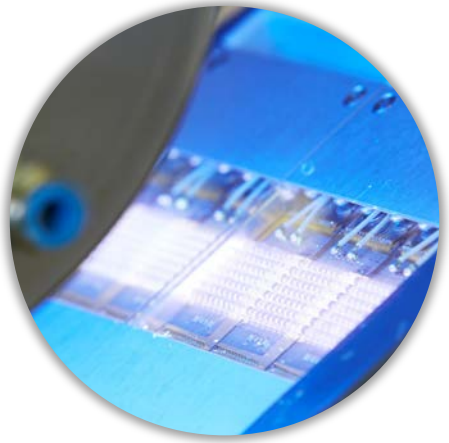

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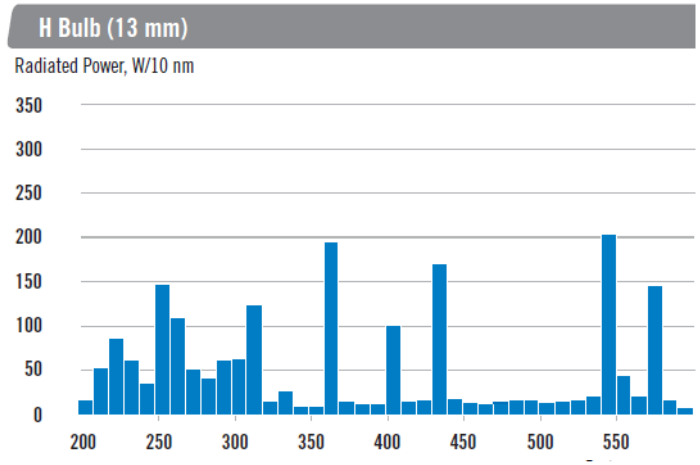
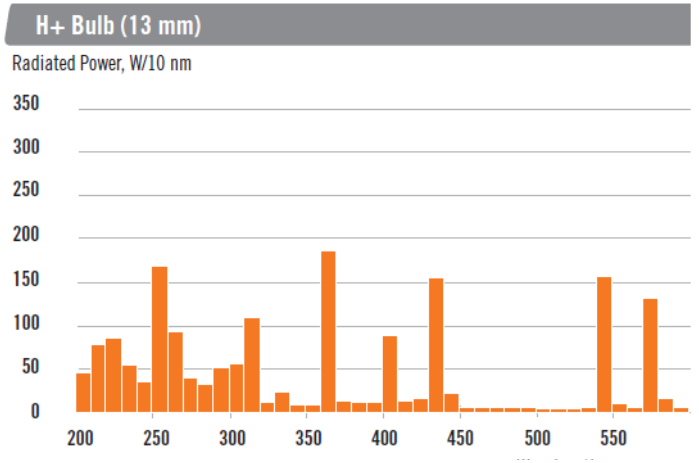
Spectral output

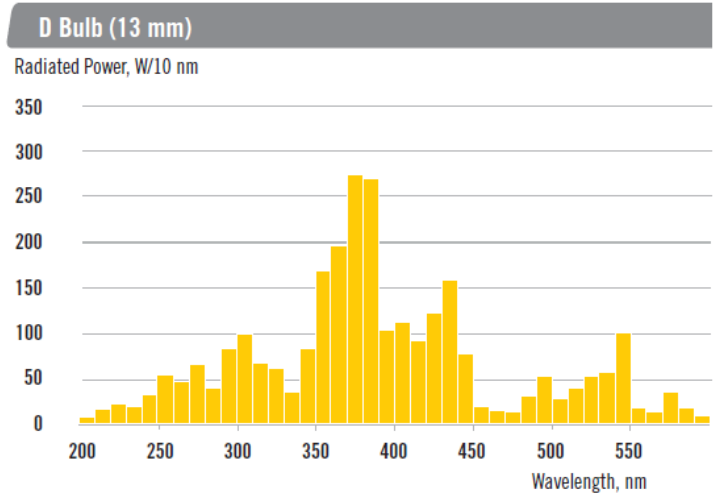
Relative radiant output versus wavelength (nm)

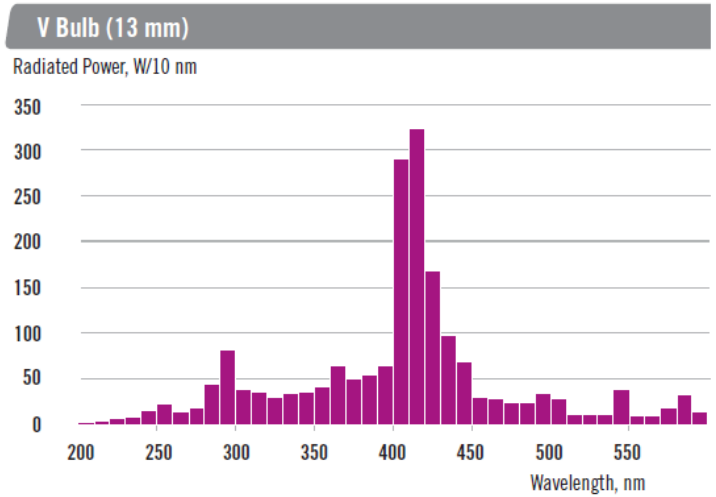
UV SPECTRAL OUTPUT

Spectra of different microwave-powered bulbs



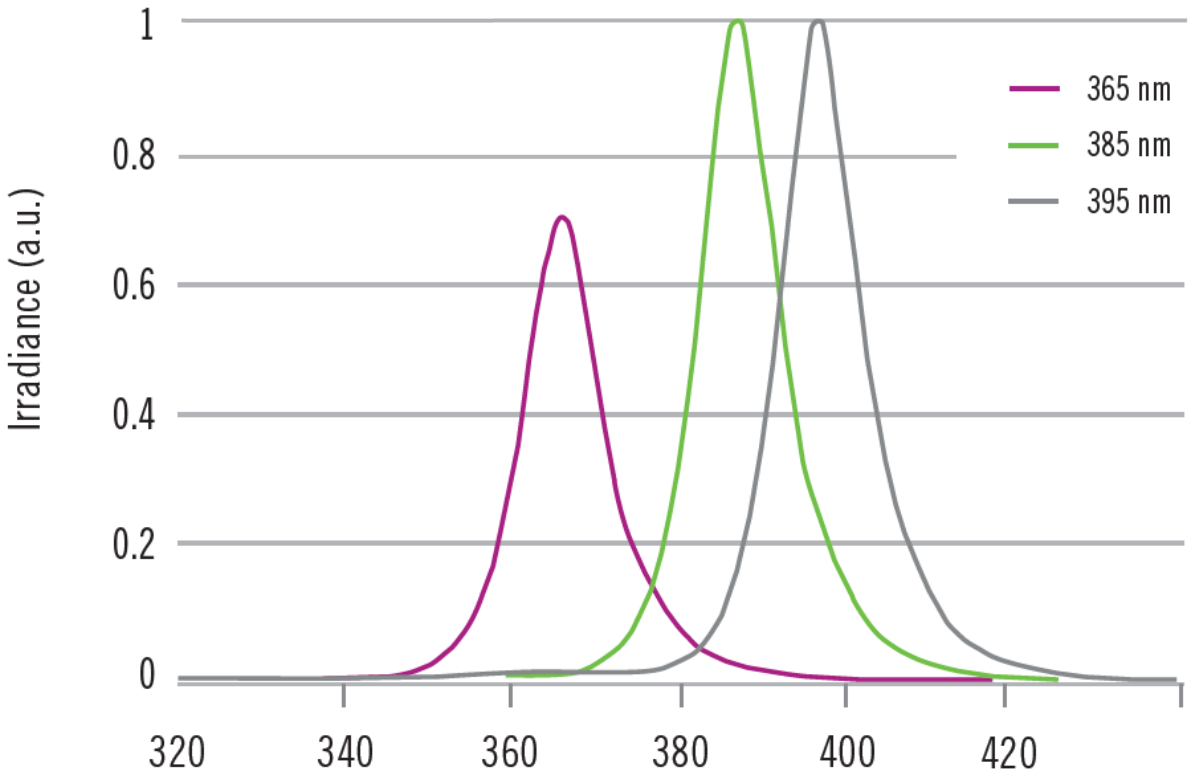




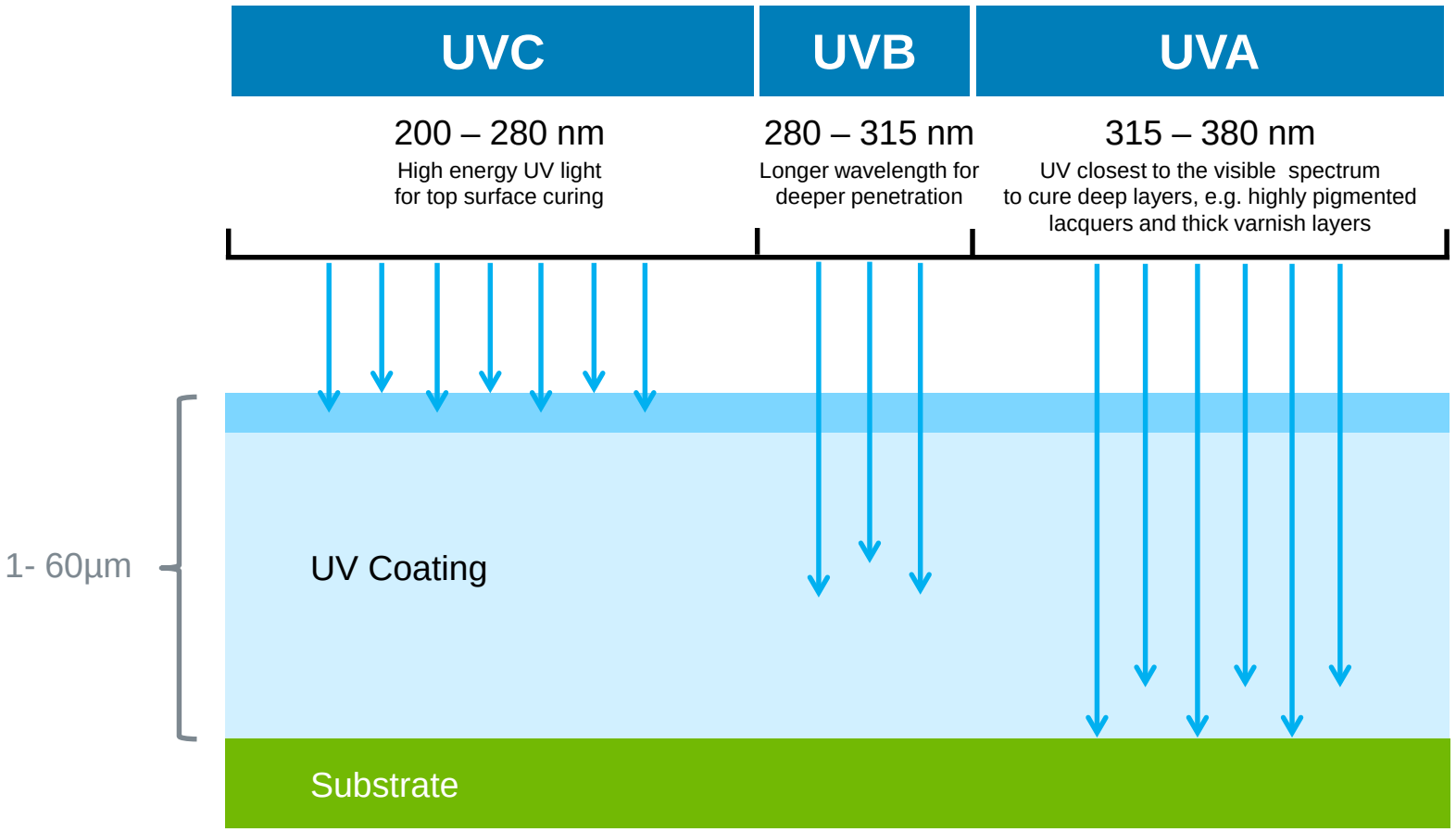


SPECTRAL OUTPUT

Semray® UV4000 series output wavelength



PENETRATION OF MATERIAL BY UV RADIATION

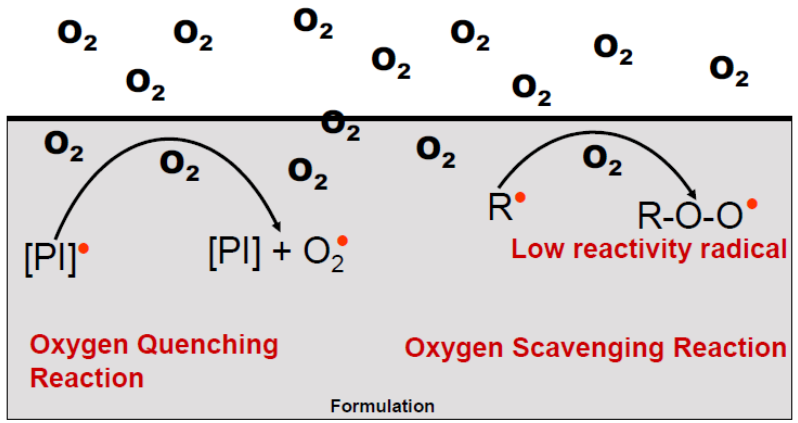


Optical thickness of a curable film determines to what extent irradiance will affect depth of cure and adhesion.

Spectral absorbance of coatings will affect which wavelengths will more effectively penetrate and how the irradiance level will achieve depth of cure.

Absorption spectrum of the photoinitiator will determine the wavelength responsivity.

OXYGEN INHIBITION - CHALLENGE FOR SURFACE CURE WITH UV LED



- Oxygen is present on the surface & dissolved in the bulk of the formulation
- Reduces the efficiency of photoinitiators
- Formation of peroxy radicals reduces polymerization process
- Variation in double bond conversion through the depth of coating

Challenge – lack of short wavelength output

- Absorbed in top layers of coatings
- Overcome problems caused by oxygen inhibition
  - Tacky surface

Challenge – lack of short wavelength output

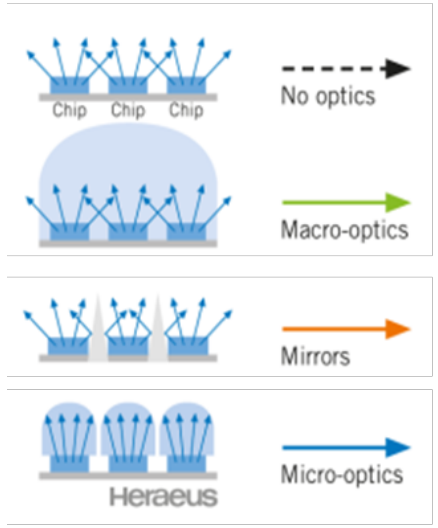
- Optimise formulation
- Cure in inert atmosphere
- Combine with other UV lamps, e.g. med. pressure Hg
- Ensure high UV irradiance reaches the coating surface
- Higher power UV LED lamp
  - Increase concentration of initiating & propagating radicals

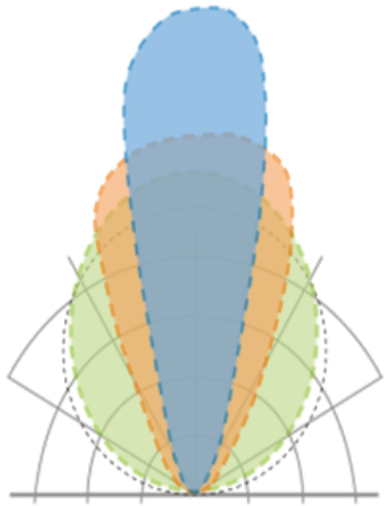
UV LED CHALLENGES – WORKING DISTANCE

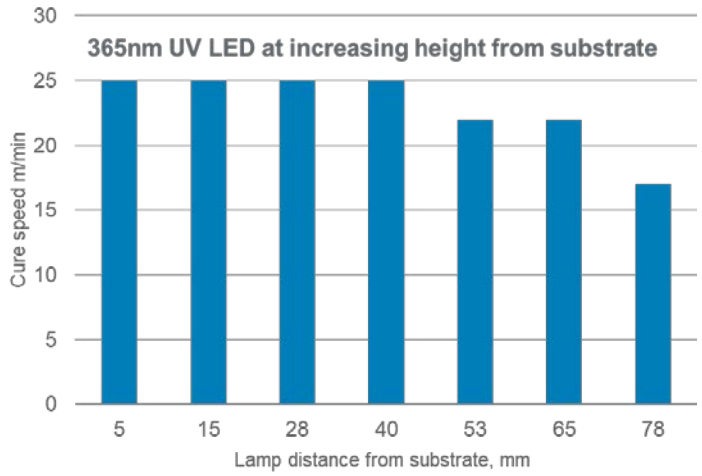
Working distance

- As distance increases, intensity of UV decreases
- Reduces cure speed of the coating
- Some applications may not be possible:
  - Intensity/energy reaching coating is too low
  - Physically need lamps to be further away

- **Optimise micro-optics within the UV LED lamp**
- **Ensure minimum stray light**







- Micro-optics reduce exit angle from 120° to 60°
- 30% higher UV energy reaches the substrate
- Possibility to cure coatings at larger or variable working distances

PHOTOPOLYMERISATION WITH UV BROAD BAND LAMP & UV LED LAMP

Similarities

- Principle of UV curing
- Photopolymerization process
- Used for both free radical & cationic curing
- Components UV formulation
- UV curing system design considerations
- Process & application development process

Differences

- Reduced heat delivered to coating during curing
- No ozone generation
- Lack of short wavelength UV impacts surface cure
- Restricted photoinitiator choice matching narrow band LED emission

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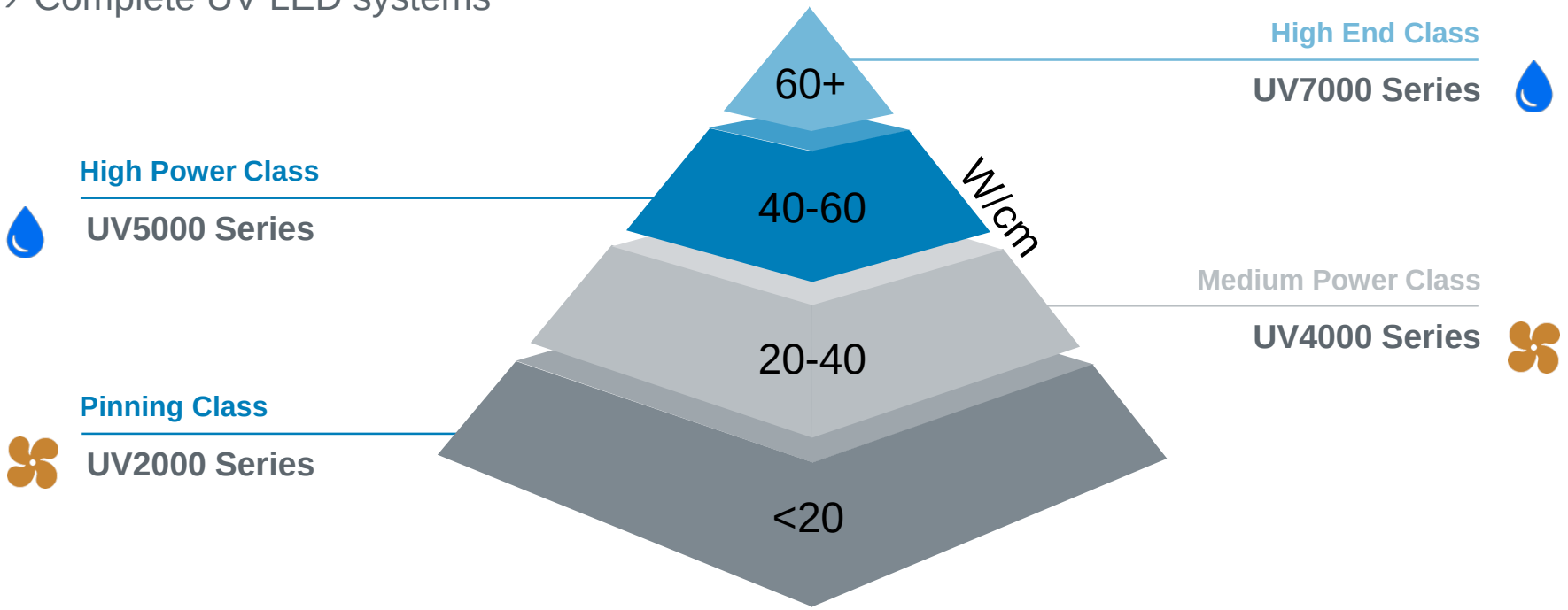
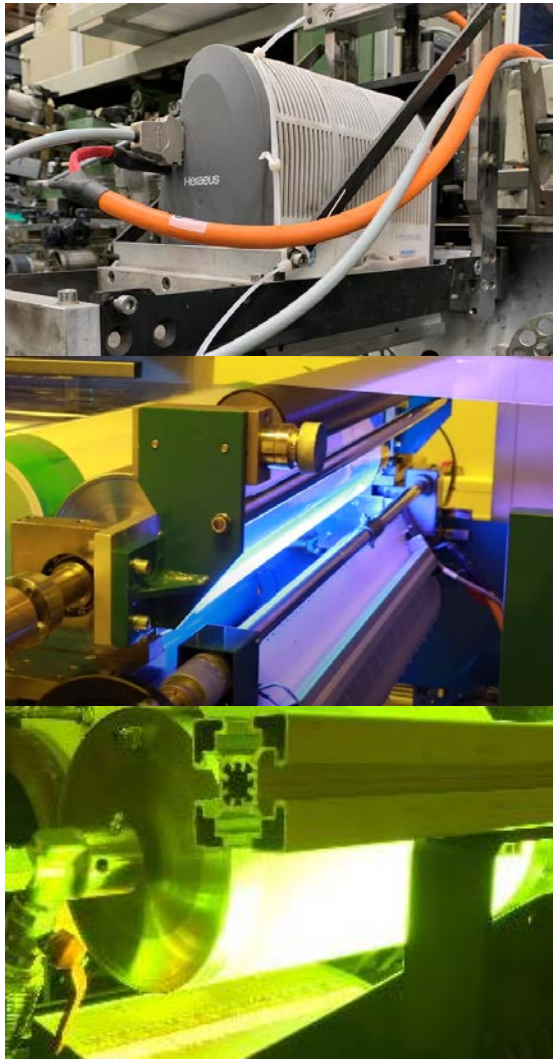
DIFFERENT SOLUTIONS FOR DIFFERENT APPLICATIONS

- Irradiance values & Power class
- Optical concepts
- Different cooling concepts
- Complete UV LED systems





CASE STUDY – NANO IMPRINT

Request

- UV irradiance adjustment for different line speeds / coating compositions
- Homogeneity and flexibility for different substrate widths
- High power at 365 nm
- Oxygen inhibition

Development

- Joint trials at Heraeus ACC (lab and demo center)
- Process validation tests
- Machine integration meetings

Solution

- UV4000 BP-16 with Semray UV4003 365 nm [primary optics]
- Interface control integration for automatic or manual control of irradiation width and UV irradiance
- High power for 365 nm with 13 W/cm^2 at the emission window
- Press the coating on the roll to exclude oxygen

CASE STUDY – BOTTLE PRINTING

Request

- Replace outdated mercury system
- Print speed:
  83 ft/min / 25 m/min
- Curing distance:
  3 inches / 76 mm
- Maintain production speed of
  30 to 60 bottles per min.

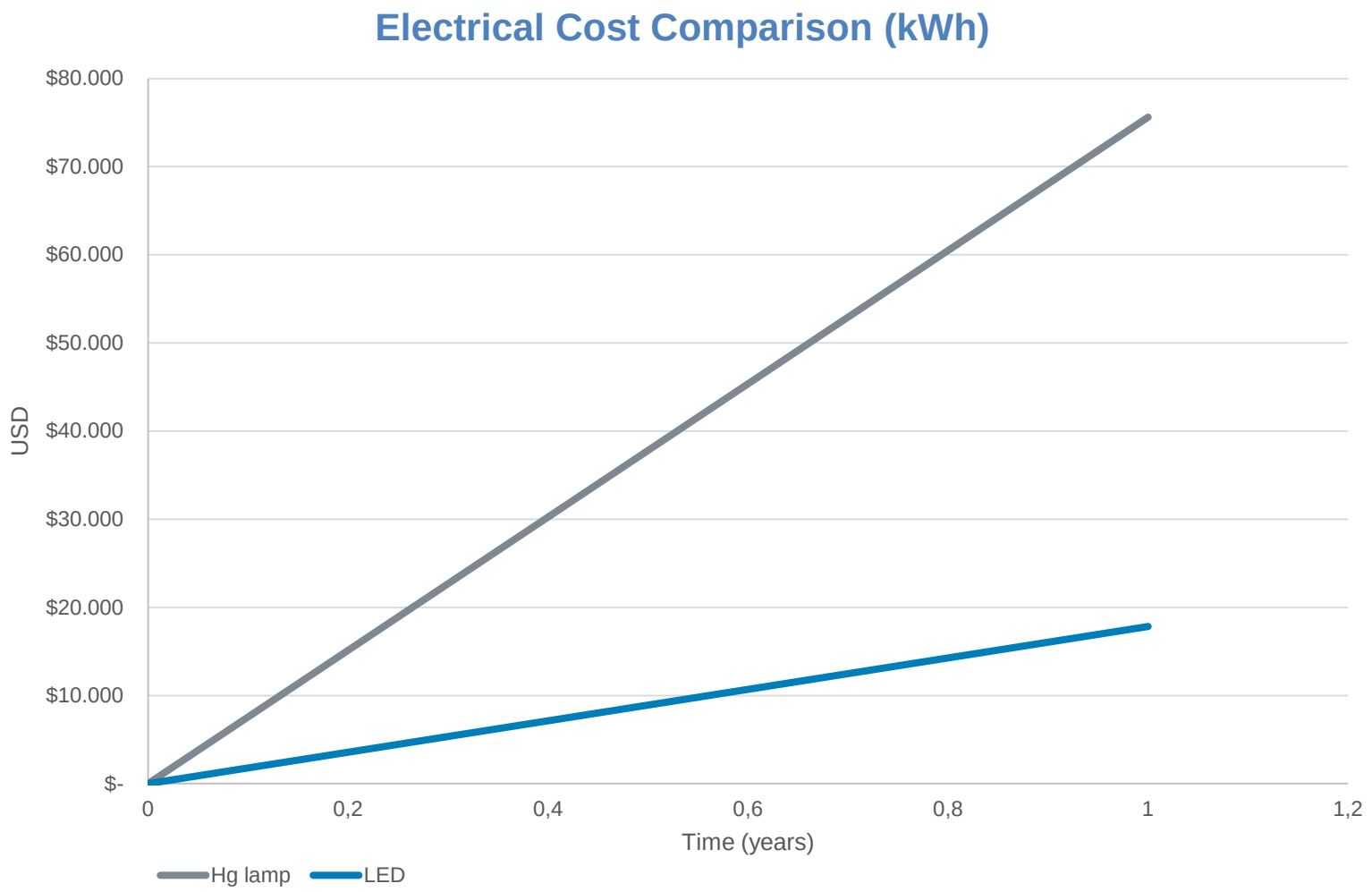
Development

- Trials at Heraeus lab and OEM demo center
- Customer validation tests
- Machine integration meetings

Solution

- Flexible LED installation at demo center
- Exchange of wavelength in seconds
- Flexibility of integration
- 75% Energy savings

ENERGY SAVINGS ESTIMATIONS



CASE STUDY – CABLE MARKING

Request

- Develop a powerful air-cooled small format LED system for curing at marking speeds
- Print speed: 650 ft/min - 200 m/min
- Curing distance: 1 inch – 25 mm
- Support both side curing

Development

- Trials at OEM due to project confidentiality
- First initial tests done with Heraeus LED Altair
- Semray 4003 introduced six months later
- Customer validation tests

Solution

- Compact LED design
- Power modulation adjustable to line speeds
- Cost effective reflective solution
- Semray micro optics allow focus on small footprint

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Many thanks for your participation.

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