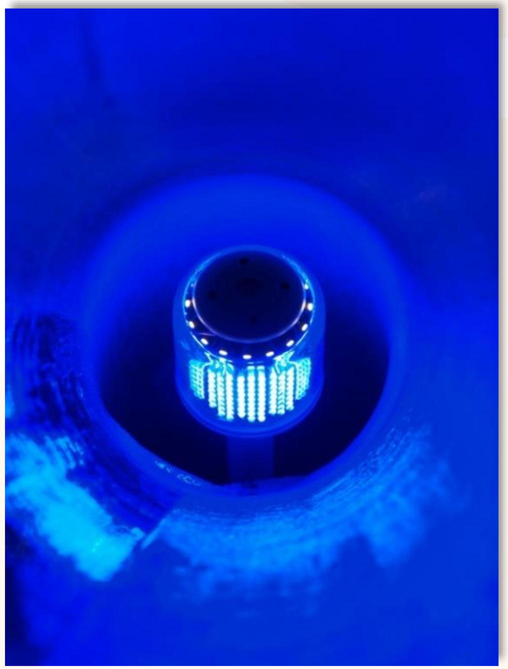
37TH INTERNATIONAL NO-DIG FLORENCE 2019

Fortezza da Basso • FLORENCE (Italy)

30th September • 2nd October 2019



CIPP | Advantages, risks and potentials of LED curing

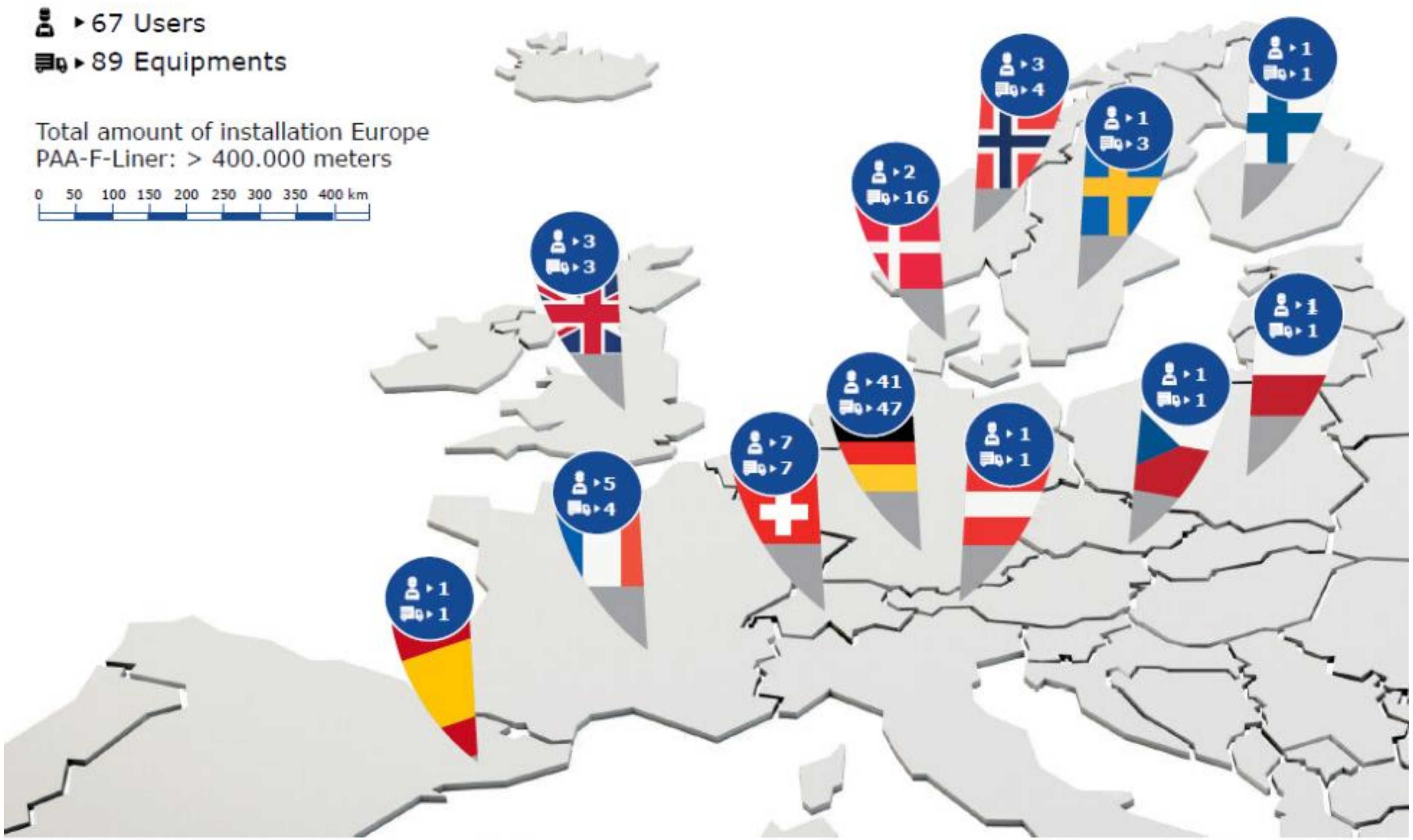
Dipl. Ing. Niklas Ernst, CEO, Bluelight GmbH, Stuttgart, Germany

History of LED curing

- In 2008: Per Aarsleff A / S carries out initial trials with styrene-free vinyl ester resin and first LED prototypes for curing. Subsequently, Per Aarsleff initially introduces the system exclusively in Denmark on own construction sites and thus develops it to practical maturity.
- In 2015: 8 systems are operating in Denmark, 2 in Norway and 1 in Sweden exclusively in own Aarsleff companies.
- In December 2015: Bluelight GmbH is founded in Germany to distribute the technology via a B2B concept to third parties.

Dipl. Ing. Niklas Ernst, CEO, Bluelight GmbH, Stuttgart, Germany

Bluelight Status quo in Europe today



Bluelight worldwide

- Worldwide distribution of Bluelight hardware and PAA F-Liners outside of Europe and Russia is performed by US-based company “Hammerhead Trenchless” since February 2019.
- Per Aarsleff A / S focuses on Scandinavia and Russia and Bluelight GmbH focuses on central and southern Europe.

Dipl. Ing. Niklas Ernst, CEO, Bluelight GmbH, Stuttgart, Germany

Why is Bluelight unique?

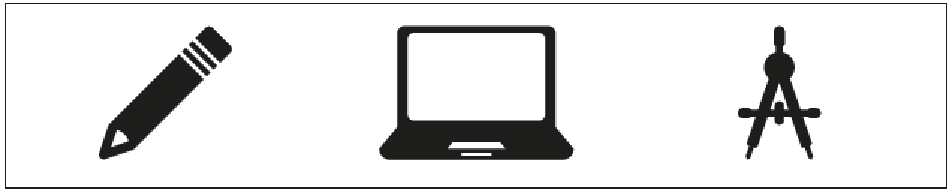
- Proven and documented process safety
- More than 400,000 m (984,250 ft.) laid throughout Europe

  More than 60,000 single installations
- Environmentally friendly resin, odorless and low-emission technology
- Process technology approved by the DIBt (German Civil Engineering Institute)
- Harmonized LED equipment and liners from a single source
- Minimum installation time, quick recommissioning of the renovated sections
- Between 90% and 99% CO_2 savings compared to heat-curing systems
- More than 11 years practical development and site experience
- High-quality result: top end product with at least 50 years lifetime

ADVANTAGES FOR CONTRACTORS

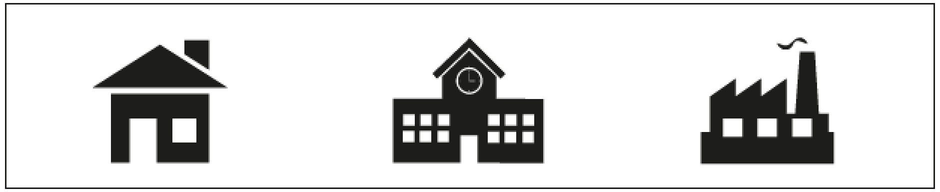
- Maximum flexibility thanks to choice of impregnating on site or using already impregnated liners
- User support by a global player in trenchless renovation of drainage sys-tems; remote maintenance and remote sessions are possible
- Less waste (reusable silicone supporting hoses, excess resin from impregnation can be filled back)
- Liner installation is two to five times more efficient
- Possibility to check the liner before curing using the integrated camera on the LED head
- Storage stability of the impregnated liners
- Fully automated quality assurance and documentation of all relevant parameters
- Instruction manual including definitions of all procedure steps
- Low space requirement for the installation equipment with maximum equipment mobility
- Fully software controlled system technology
- Reduction of error potential compared with 2-component systems

Dipl. Ing. Niklas Ernst, CEO, Bluelight GmbH, Stuttgart, Germany



ADVANTAGES FOR ENGINEERS, PLANNERS AND ARCHITECTS

- Quick and reliable project management
- Fully automated quality assurance and documentation of all relevant parameters
- Reduction of error potential compared with 2-component systems
- Installation lengths of up to 95 m (311 ft)
- Proven process safety



ADVANTAGES FOR PRIVATE, PUBLIC AND INDUSTRIAL BUILDING OWNERS AS WELL AS PROPERTY MANAGERS

- Appreciation of real estate and property through sustainable investment
- Long-term compliance with official and general drainage requirements
- Restoration of tightness and static carrying capacity of the pipeline, with an improved outflow hydraulic system
- Maximum efficiency and minimum impairment thanks to speed
- No chemical odors during work

Approvals and Certificates

Whole system as combination of curing method and CIPP liner

Deutsches Institut für Bautechnik DIBt

wrc approved

Suitability at users

GÜTEZEICHEN RAL KANALBAU

Verband Schweizer Abwasser- und Gewässerschutz-fachleute
Association suisse des professionnels de la protection des eaux
Associazione svizzera dei professionisti della protezione delle acque
Swiss Water Association

VSA

Europastrasse 3
Postfach, 8152 Glattbrugg
sekretariat@vsa.ch
www.vsa.ch
T: 043 343 70 70
F: 043 343 70 71

Eignungsattest

Nr. 2018-05-8444-04

IKT Liner-report 2018

- As the first system provider with main application area in lateral CIPP lining Bluelight joins the IKT liner report.
- Samples were obtained at various construction sites with installations by own demonstration and rental equipment. Installation was performed exclusively by Bluelight application technicians.

Figure 7: The Star Table for lining companies achieving 100% passes against all four test criteria in recent years.

Dipl. Ing. Niklas Ernst, CEO, Bluelight GmbH, Stuttgart, Germany

LED curing-hardware

(European patent: EP 2 129 956 B1)

Product data	Unit	Bluelight LED mini head	Bluelight LED spherical head	Bluelight LED cylinder head
Input power	watt	292.3	705.6	1,461.6
Output power	watt	200.4	470.4	974.4
Efficiency at 50 degrees Celsius	%	69	66.7	
Length of the light source	cm	5.2	6.5	13.2
Width / Diameter of the light source	cm	4.1	5.2	
Weight of the light source	gram	79	165	375
Output power / weight	watt / gram	2.5	2.9	2.6
Number of diodes per light source	pcs	144	336	696
Manufacturer diodes		Osram		
Operating temperature diode	centigrade	-40 ... 120		
Junction temperature absolute diode	centigrade	150		
Wavelength	nm	444 ... 457		
Viewing angle	degree	120		

Fields of Usage

Lateral CIPP lining: PAA-F-Liner LED Standard und 3D

-> Diameters 100*) – 250mm, inversion-process, flexible liners based on synthetic fibers, one or two diameter changes are possible, styrene-free Vinylester resin, ready to use pre-impregnated or to be impregnated by the user.

*) future application planned: 70mm

Fields of Usage

Small main-lines, PAA-G-Liner LED

-> Diameters 200 – 300mm*), pull-in-process, non-flexible CIPP liner based on glass-fibre, styrene-free Vinylester resin, only pre-impregnated

*) in Sweden @ Volvo up to 600mm successfully realized

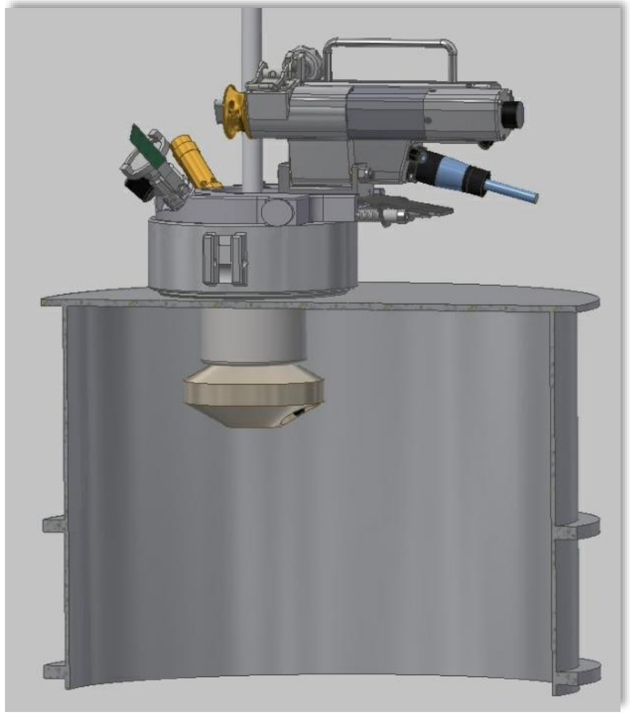
Installation Procedure

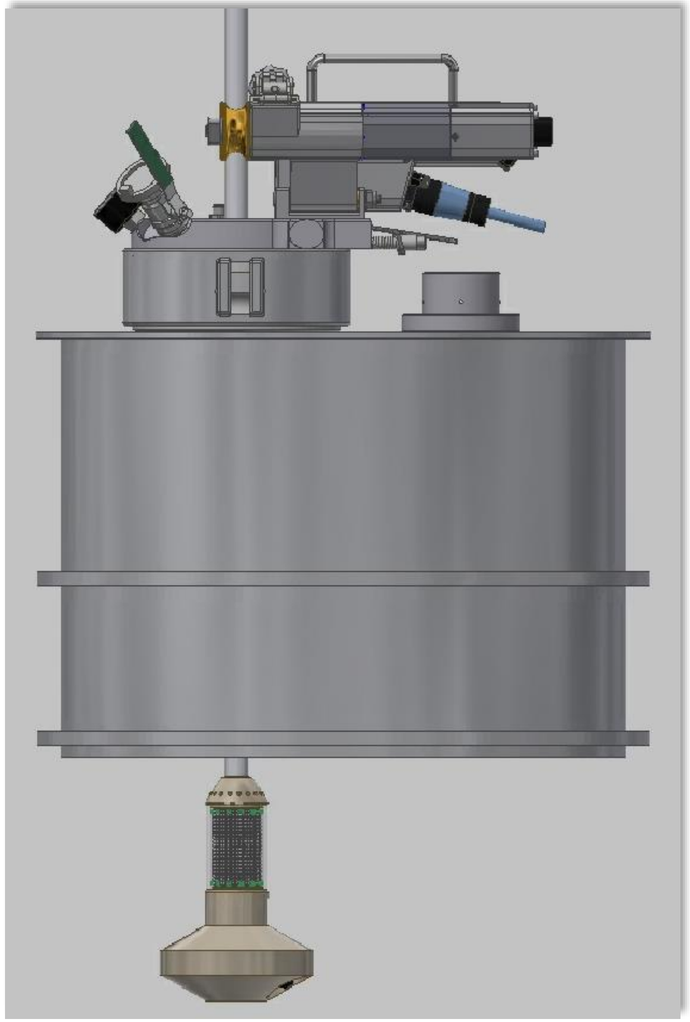
- Pneumatic inversion of flexible CIPP liner with open or closed end out of inversion drum.
- With open end: Inversion of a translucent special inner-hose made from silicone.
- If necessary, alternatively also insertion of the GRP hose liner from manhole to manhole.
- Connection of the installation unit to the CIPP liner or support-hose.
- Manual push-in or pull-in of the LED light source up to the head / end of the liner.
- Automatic software-controlled curing by motor-driven retraction of the LED light source.

Installation Situations

Future Applications

CIPP for man-holes with diameters from 800mm until 1200mm





Future Applications

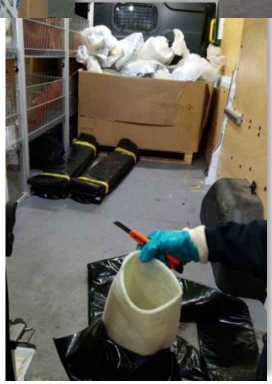
Aarsleff Side Shooter (ASS)

CIPP liner inversion with integrated hat profile in DN100-150mm from main pipe DN200-600mm with open end against the flow direction up to 15 meters in length.

Up to 7 pieces per working day. One system already works daily in Denmark, others are under construction.






Do liners with VE-resin shrink …

… and may they produce a non leak tide circular gap between host pipe and liner?

Who raised this question and why? Per definition and standardization a CIPP liner is close fit, but not force fit.

Anyway due to loss of market share, CIPP liner resellers who prefer to stick to Epoxy believe they have identified a non leak tide circular gap between liner and host pipe as a potential weak point of light cured liners using VE resin. Even there are no practical problems experienced by Bluelight users so far, this was repeatedly addressed.
In real insitu use 100% force fit CIPP could never enter any approvals or standards because of missing insitu proof. Common jet cleaning fails to safely remove all grease from existing host pipes. Standard implemented static design and load calculations only work with non force fit CIPP.

Anyway two German producers have tested Epoxy Liners and could establish leak tide circular gaps with Epoxy resin under certain lab conditions over ground in a selection of fabric new host pipes limited to certain materials.

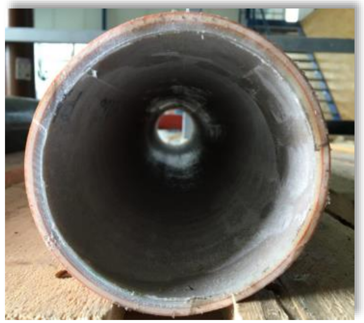
Dipl. Ing. Niklas Ernst, CEO, Bluelight GmbH, Stuttgart, Germany

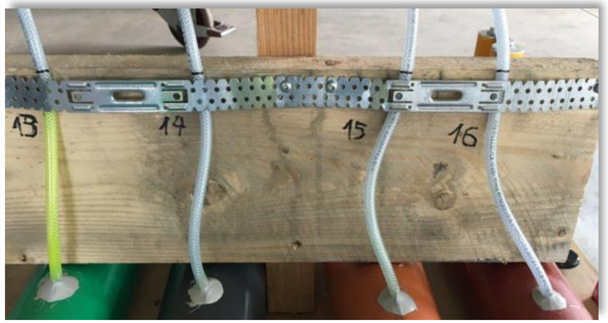
Do liners with VE-resin shrink …

… and may they produce a non leak tide circular gap between host pipe and liner?

Reaction:

Bluelight has done the same test under same scheme and has found results for the standard Bluelight curing of styrene-free VE resin (AP450). It behaves almost identically to Epoxy.



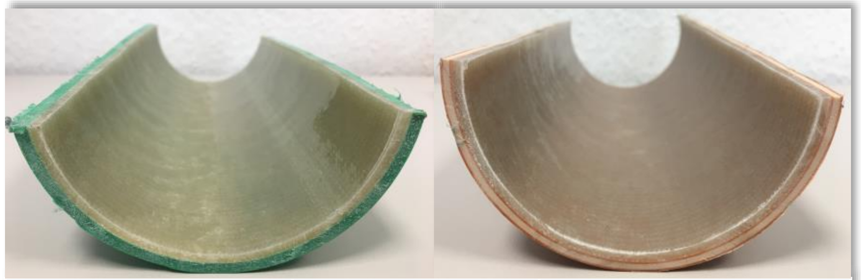
Dipl. Ing. Niklas Ernst, CEO, Bluelight GmbH, Stuttgart, Germany

Do liners with VE-resin shrink …

… and may they produce a non leak tide circular gap between host pipe and liner?

Results: *Chemical shrinkage takes place during curing under pressure only at the inside of the CIPP liner and therefore does not impact circular gap. Outside radial or longitudinal shrinkage of any CIPP liner is mainly a result of thermal shrinkage and therefore might affect both Epoxy- and VE-based CIPP depending on how fast materials cool down.*
Leaktide circular gaps are possible under similar conditions with similar results when using Bluelight cured VE resin compared to Epoxy.

But: *it is in doubt if this effect can work safely insitu on site for any CIPP system, because it is dependent on specific material of host-pipe and a well cleaned and prepared host pipe surface. Force fit CIPP is not expected to enter any standards or approvals and might rather stay a marketing tale.*



material	connection leak tide	max. water pressure (m)
PVC-U	Y	5,00
PP-HT	Y	5,00
PE-HD	N	1,50
Fibre cement	N	1,50
PP	N	1,50
Stoneware	Y	0,20

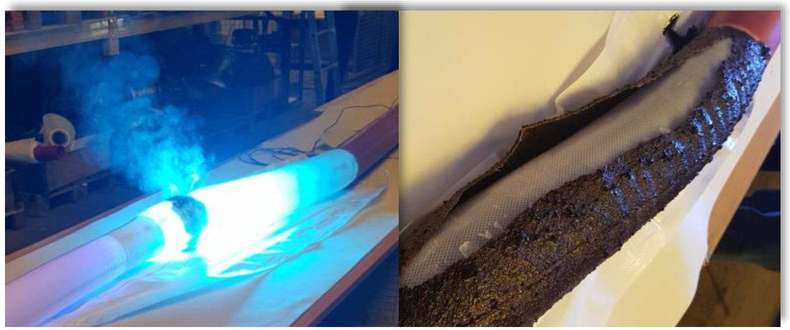
Is light curing Epoxy the future?

At Per Aarsleff and Bluelight trials are ongoing for some time …

Some of the problems have been:

- Too high reaction temperatures for liners and host pipes (up to 200 degrees Celsius)
- Shrinkage-, crack- and tension effects due to temperatures

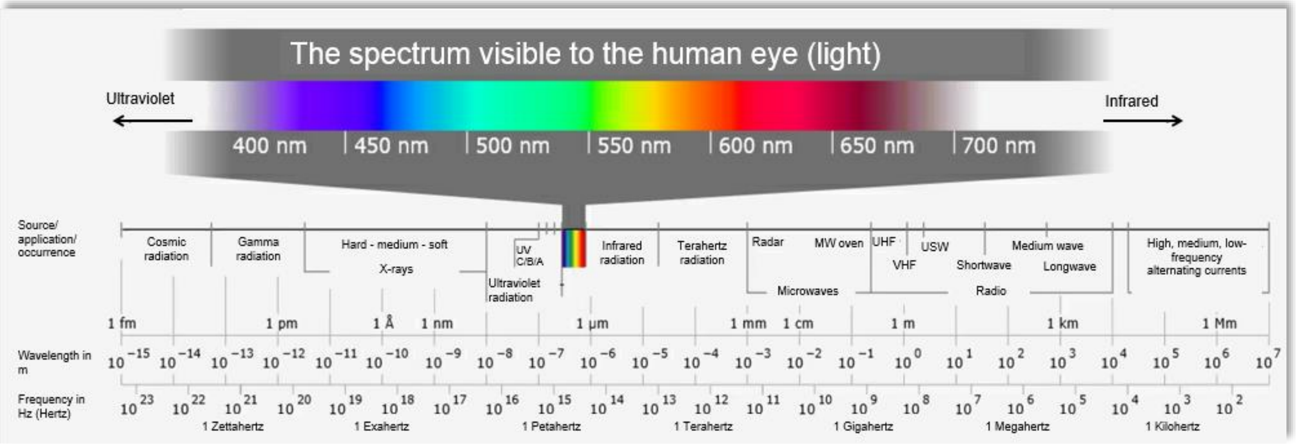
Newer reformulations tend to deliver better results
… but where are the benefits to styrene free VE?
Price? Quality? Reactivity? Skrinkage?



Dipl. Ing. Niklas Ernst, CEO, Bluelight GmbH, Stuttgart, Germany

Why visible light in the wavelenght of 450 nano-meters and not UV-LED light?

Source: wikipedia



The driving force behind the development of LED diodes, in addition to the lighting industry, has been the automobile industry in recent years.

In those fields only visible light is needed. Therefore, the highest efficiencies are found in these wavelengths.

UV LEDs have only a relatively small scope e. g. in medical applications, in which no high performance is required.

Bluelight uses high-performance diodes from Osram.

Is LED technology superior to UV gas lamps?

Bluelight LED Cylinder Head

100% of the output power is in the wavelength range required by the photoinitiator of the resin between 440nm and 460nm.

A GFRP liner DN300mm / 4mm is cured at 100m / h (1.65m / min) with approx. 1.5KW input power.

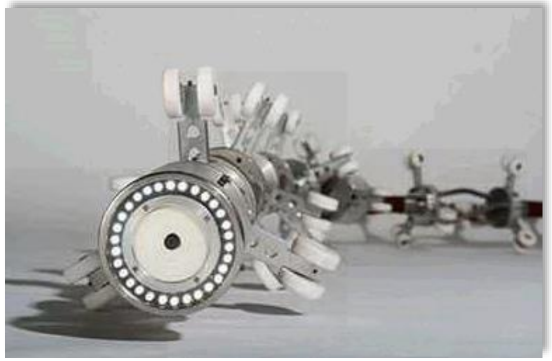
Efficiency: 67%. Output power: 1.0KW.

UV gas discharge lamp

The output power has numerous peaks over the entire spectrum. A large part of the energy is not used by the photoinitiator of the resin.

A UV light chain with 9x500W = 4.5KW input power cures a GFRP liner DN300mm / 4mm with about 80m / h (about 1.33m / min).

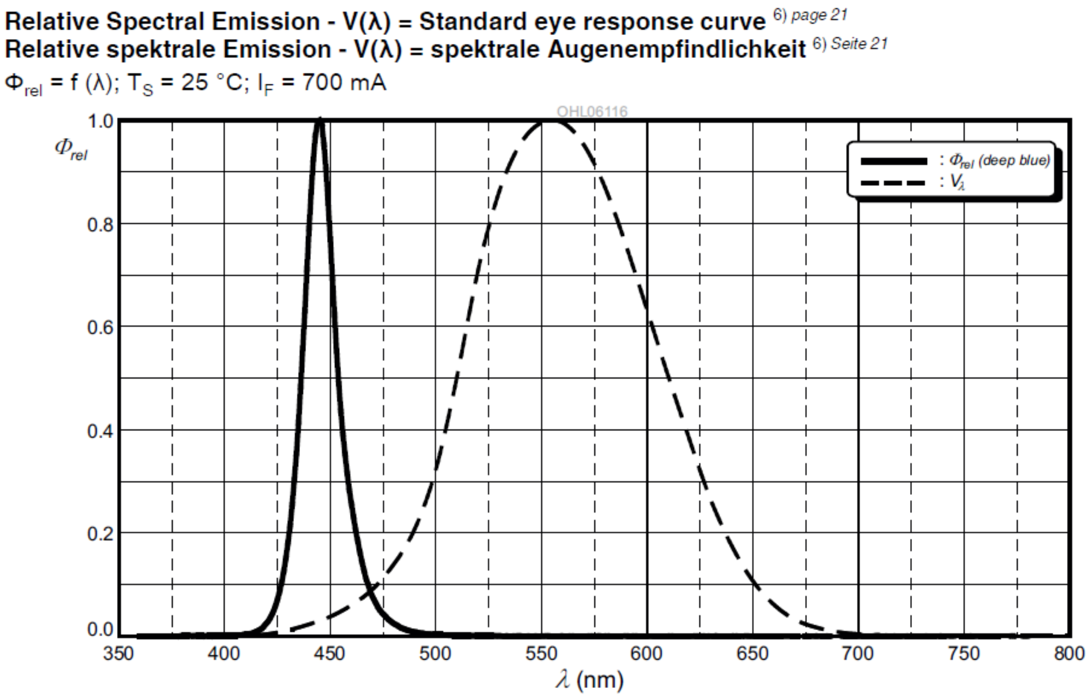
Efficiency in the UV range approx. 15% to 20%. Output power: 0.68KW to 0.9KW.



Dipl. Ing. Niklas Ernst, CEO, Bluelight GmbH, Stuttgart, Germany

Is LED technology superior to UV gas lamps?

Spectrum of Bluelight diode



This most compact high-power LED (2 W class) allows dense clustering and simple circuit designs. Its extremely low thermal resistance helps to keep the efficiency remarkably high even when driven at high currents. High reliability. Long lifetime.

Features:

- **Package:** SMT ceramic package with silicone resin and silicone lens
- **Viewing angle at 50 % I_V:** 120°
- **Color:** 445 nm (deep blue)
- **Radiant Flux:** typ. 1350 mW
- **Radiant Efficiency:** typ. 65 %
- **Corrosion Robustness:** Superior Corrosion Robustness

Applications

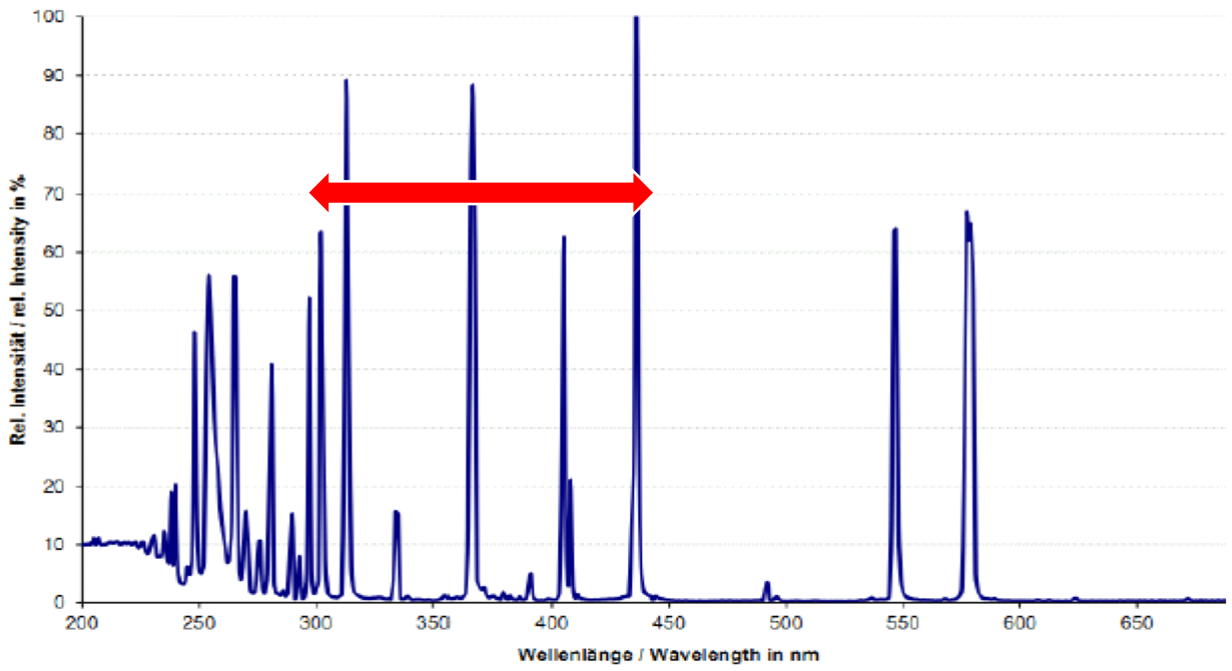
- Architectural lighting
- Stage lighting
- Shop lighting
- Color changing fixtures
- Remote-phosphor fixtures
- Horticultural Lighting

100% of the energy is emitted in the area required by the photoinitiator.

Due to the cooling patented by Per Aarsleff A / S hardly any losses due to heat occur.

Is LED technology superior to UV gas lamps?

Spectrum of UV gas-discharge lamp (example)



Approximately 70% loss as thermal heat energy. Of the remainder, approximately 50% are in the range of the wavelength required by the photoinitiator to cure.

Only about 15 to 20% of the energy supplied effectively serves to cure.

Dipl. Ing. Niklas Ernst, CEO, Bluelight GmbH, Stuttgart, Germany

Does LED light-cure replace UV gas discharge lamps in mainline CIPP?

Non-flexible CIPP lining with GRP liners in mains

- LED diodes are superior to UV gas discharge lamps in terms of energy-consumption as well as efficiency, longevity and compactness.
- Currently, the Bluelight technology already covers the nominal widths of 200mm to 300mm safely, efficiently and economically, but only with styrene-free VE resin. For nominal sizes greater than 300mm, there is still no extensive practical site experience available.
- There are no handling advantages of a LED light chain compared to a gas light chain. Advantages in handling arise only through compact single heads.
- Development periods of mature technology are about 5 to 10 years.
- In practice, numerous users in Europe currently operate proven, functioning and already paid UV system technology for curing CIPP liners up to 1800mm. No bottleneck. Low economic motivation to switch.
- In main channels, the LED technology has technical advantages over the traditional gas discharge lamp. However, these benefits are not as significant as they are in laterals compared to heat or ambient curing.
- The existing and proven gas discharge systems will certainly remain the standard for a few years in larger dimensions.

Do any combinations of CIPP liners and light-curing techniques work together safe and well?

Non-flexible CIPP lining with GRP liners in mains

- Structurally and on basis of materials todays GRP liners are very similar: they are all using styrene-containing UP resin + glass fiber + PE / PA inner foils and comparable photo-initiators.
- PE / PA inner foils: almost all come from the same manufacturer, almost all are only used provisionally.
- Curing hardware uses gas lamps with same efficiency and (almost all) from the same manufacturer.
- > 15 years of experience with several CIPP pipe liner manufacturers with polymerization.

Flexible CIPP lining with light curing (LED or gas lamps) in laterals

- Structurally and with regard to materials completely different CIPP liners: carrier made of felt, glassfibre, woven fabric, random fiber, coatings made of TPU or silicone coatings, glued-on PU foils, deviating photo initiators with different wavelengths.
- Inner foils hardly stick with styrene-free VE resins, coatings offer safety, foils do not.
- Curing systems with completely different light sources, output powers and efficiencies as well as different wavelengths.
- Lots of experience with polyaddition, hardly any polymerization experience at most CIPP liner manufacturers.

Minimum standards for lightcuring in laterals

Comparing

Output power

Product:	**Bluelight cylinder-head**	**Bluelight ball-head**	**Other product**
Input power:	1.462 W	706 W	600 W
Efficiency:	66,7 %	66,7 %	28 - 30 % *1)
Output power:	**975 W**	**470 W**	**168 - 180 W**

∗1) Source: http://www.ledwv.com/en/uv-led-395nm-100w-p-637.html

Minimum standards for lightcuring in laterals

Consequences of insufficient polyaddition

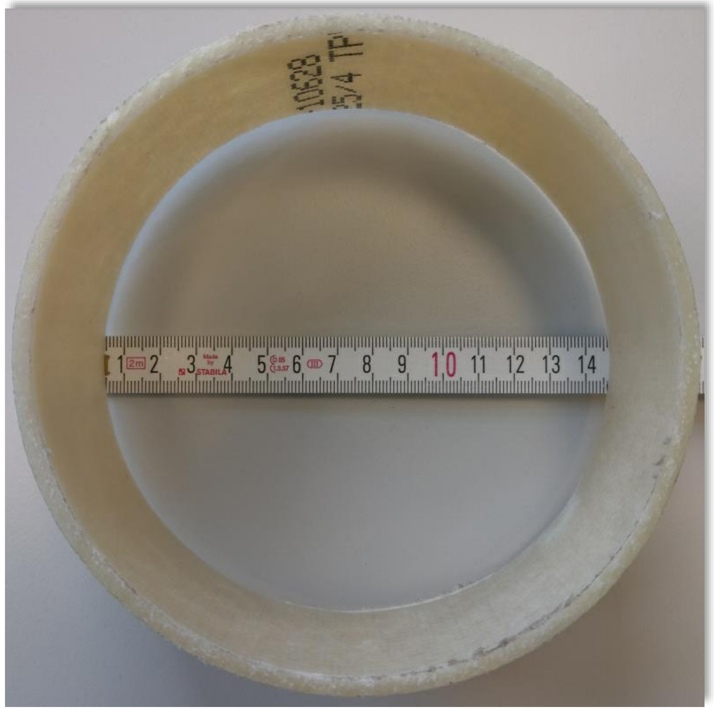
- Heat curing of a CIPP liner also works (conditionally) when the energy "only" initiates the curing process, even if a complete targeted curing would be qualitatively better.
- Manufacturers distribute / users use heaters between 10 and 1.500 KW power.

Consequences of insufficient polymerization

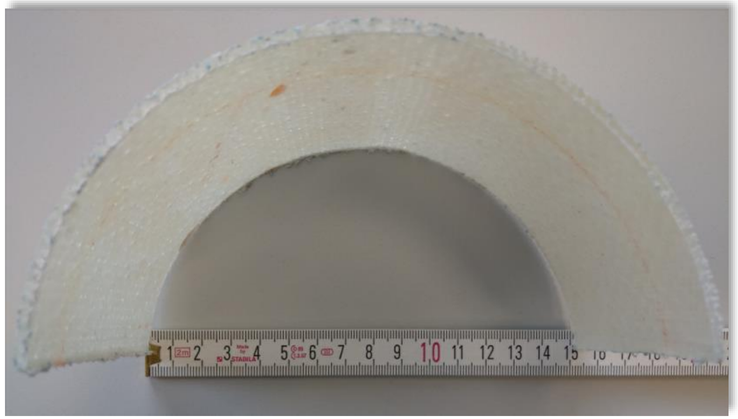
- Stage 1: Resin does not fully cure visibly, but is invisible to TV inspection when an inner layer has cured and only the outer layer is still liquid.
- Stage 2: Resin cures optically and feels completely cured. However, a material test with determination of the E-modulus results in insufficient values. Differentiation to insufficient compression of the sample is important.
- Step 3: Resin cures optically and feels completely cured. The material testing of the E-module gives a "reasonable" value. However, a subsequent 1.000 hour test results in critical reduction factors (above 4.0). The material seems ok at first glance. However, it does not meet the long-term requirements.

Minimum standards for lightcuring in laterals

ISO Standard: ISO 11296-4: minimum wall-thickness of composite $e_C \geq 3{,}0$mm



PAA F-Liner DN150
$e_C \geq 3{,}5$mm



Seamless invertable GRP Liner DN150, $e_C \approx 2{,}4$mm

Dipl. Ing. Niklas Ernst, CEO, Bluelight GmbH, Stuttgart, Germany

Safety when curing in laterals vs. main lines

Speed comparison Bluelight LED cylinder head:

PAA F-liner DN150 / 3,5 -> 63m / h or 1,05m / min

PAA G-Liner DN300 / 4.0-> 99m / h or 1.65m / min

Question: why does DN300 cure faster than DN150?

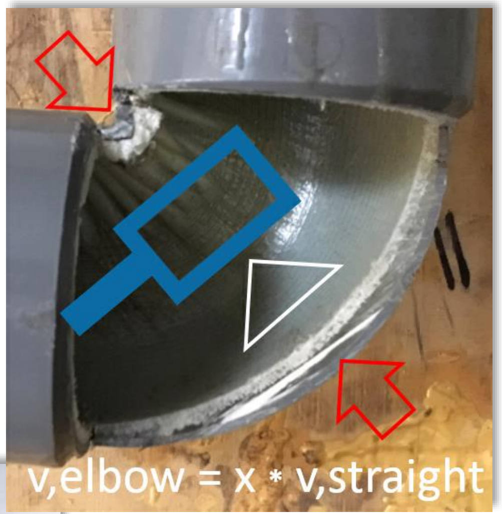
Answer: There are much more difficult conditions in lateral CIPP lining than in the mainline CIPP:

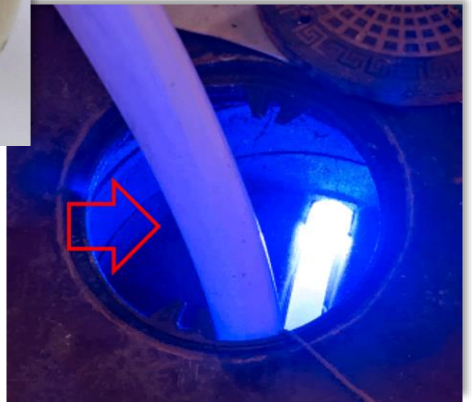
Elbows with folds on elbow inside

Offsets, cuff gaps and relatively high imperfections

open ends with irradiation by translucent silicone hoses, in case of nominal diameter change wrinkles in the silicone tubing.

Therefore at Bluelight, factor 3 safety is used in laterals compared to a straight main-line.





Visit Bluelight at booth no. 11 and join our outside live demos at area „H“

Trenchless technology will only grow long term when all actors have high focus on best possible quality

Thank you for your attention