



CRYSTAL IS

High Performance UVC LEDs

AlN based 235nm and 255nm UV-C LEDs as light sources for environmental water analysis

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Crystal IS™

Importance of nitrate ion (NO_3^-) monitoring



Runoff of nitrate into lakes and streams fertilizes them, cause:

- Eutrophication (overly enriched with nutrients)
- Algal bloom and Cyanobacteria (blue-green algae) that contain microcystins (toxins)
- Anoxia (loss of available oxygen)
- Excessive nitrate in drinking water could cause methemoglobinemia or “blue baby syndrome”

Monitoring nitrate concentration in aquatic systems is essential for better control of environment

Comparison of nitrate measurement methods

	Grab sampling	ISE (ion selective electrode)	Optical w/ Xenon flash lamp or deuterium lamp	Optical w/ UV-C LED
Measurement range	+++	++	+	++
Lifetime	N/A	-	++	++
Cost	-	++	-	++
Real time monitoring	-	-	++	+++
Accuracy	+++	+	++	++
Calibration frequency	++	-	++	++
Multi parameter monitoring	+++	+	++	+

Comparison of ultraviolet light sources

	LED	Deuterium Lamp	Xenon Flash Lamp	Mercury Lamp
Spectrum	Single Peak	Broad Spectrum	Broad Spectrum	Broad Spectrum
Stability of Light Output	Excellent temporal and spatial stability	Good	Relatively Poor	Relatively Poor
Warm Up Time	Instantaneous	20–30 Minutes	Instantaneous	1–15 Minutes
Thermal Effect on Samples	None*	Heat-sensitive samples can be affected	None	Heat-sensitive samples can be affected
Cost of Ownership	Low**	High	High	Low
Drive Electronics	Simple	Complex	Complex	Complex
Safety	Low voltage and cold light source	Hot bulb surface; High voltage power supply	High voltage supply; Ignition and sparking risk	High voltage supply and contains mercury in fragile quartz envelope

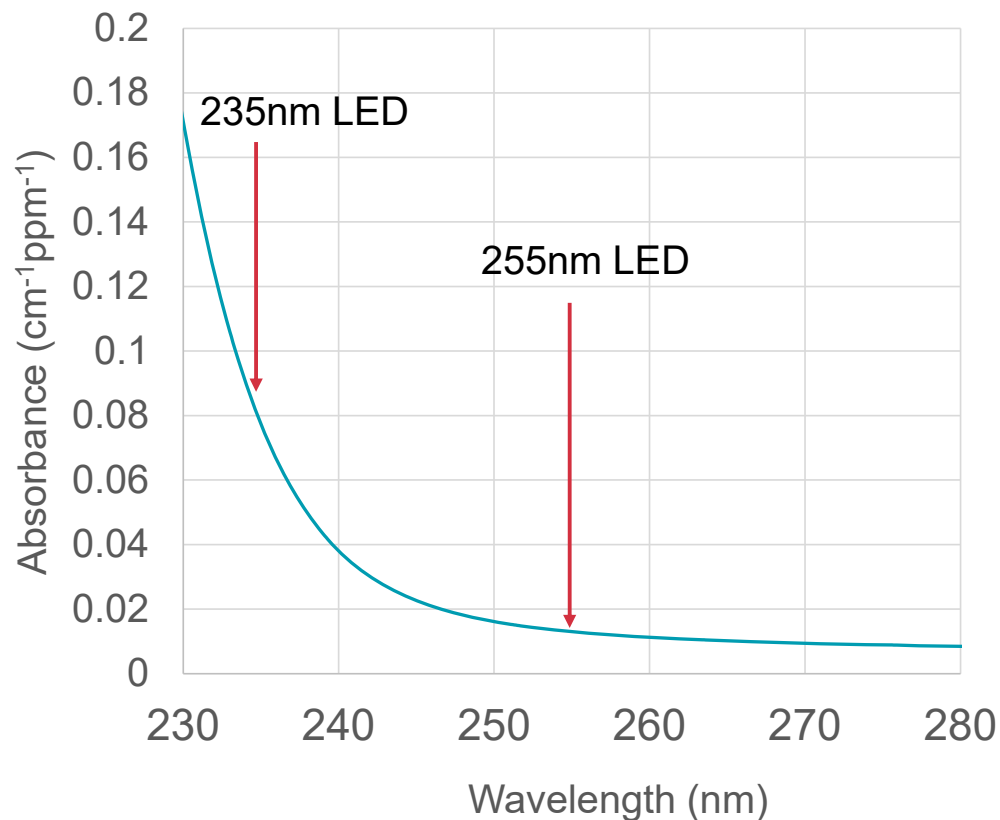
* LEDs do not emit forward heat

** Lower cost of ownership due to cost savings on power supply, housing and filters

Nitrate absorbance

- Absorbance measurement of nitrate is a long standing technique
- Emission peaks of UVC LEDs are in a sensitive range for KNO₃
- A background measurement is still needed at 255nm

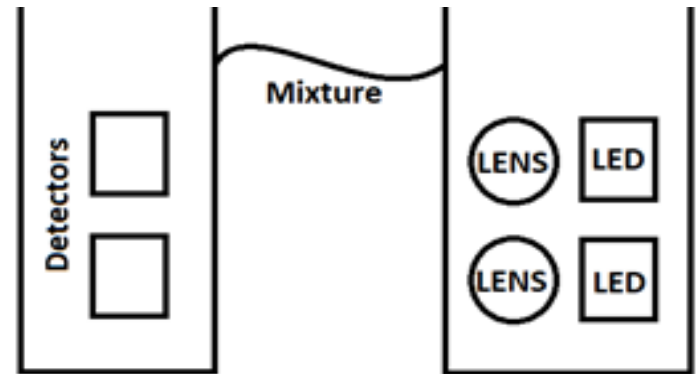
NO₃⁻ Absorption Spectrum



Nitrate concentration probe how it works

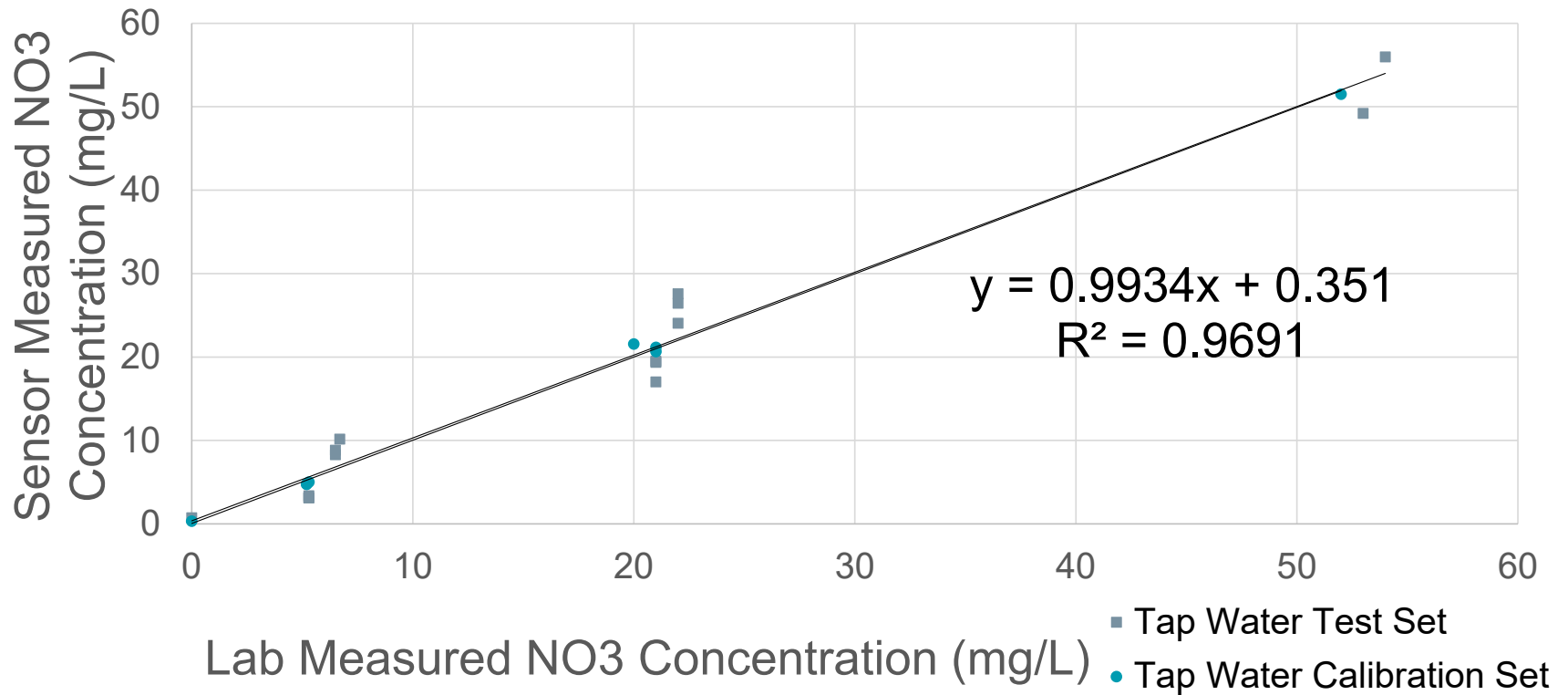
- 2x LEDs – 235 & 255nm shine through solution
- Light detected by 2x photo diodes
- Concentration is proportional to:

$$C_1A_{235} + C_1A_{235}^2 + C_1A_{255}$$
 - Absorbance is the log of the transmission in solution divided by the transmission in DI water



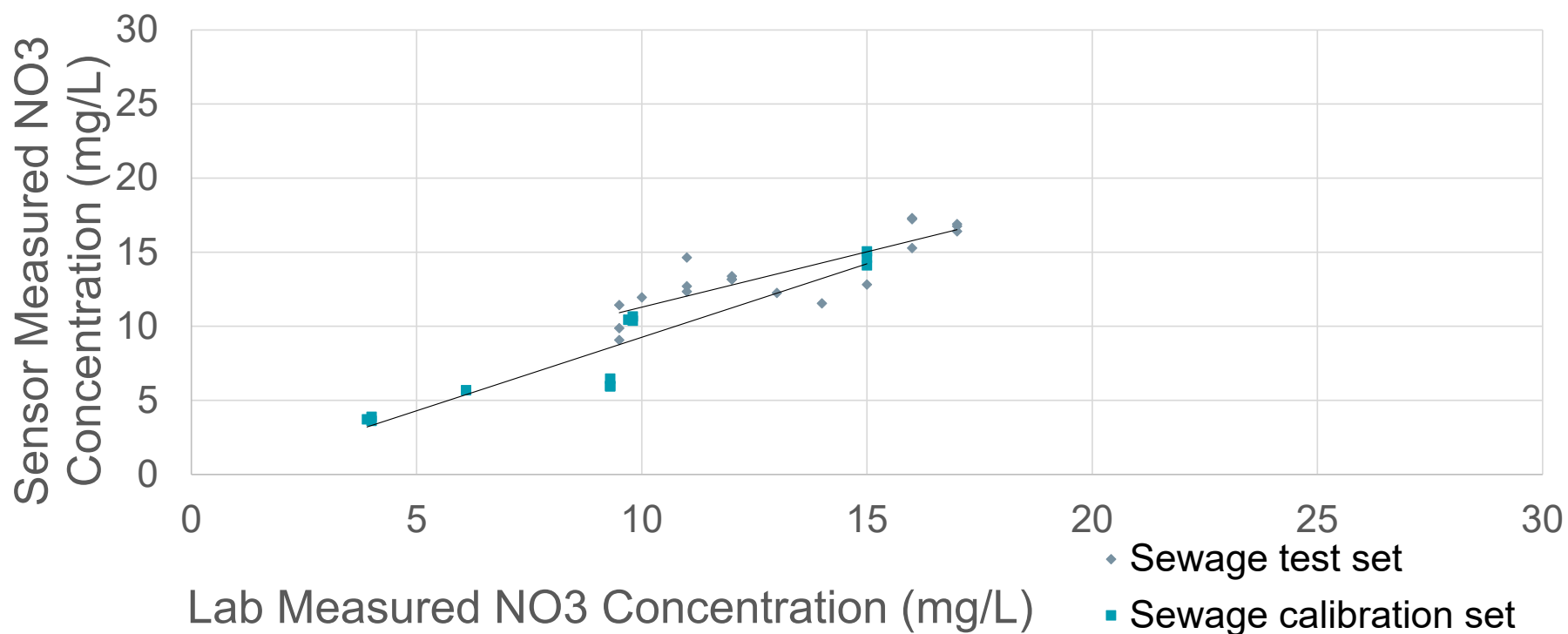
Linearity check result in doped tap water

NO3 Doped Tap Water



Linearity check result in raw and treated sewage at Massachusetts Alternative Septic System Test Center (MASSTC)

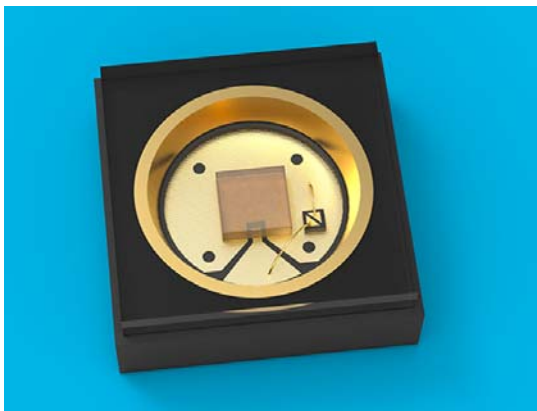
NO3 Raw and Treated Sewage



“Optan” UV-C LEDs from Crystal IS

Ideal for water quality monitoring (UVT, TOC, COD, PAH), Ozone, SOx, etc.

Optan 3535



Package : Surface mount
Output power:
4mW to 8mW (255nm, 275nm)
50 μ W to 500 μ W (235nm)
Viewing angle 120 ° (Lambertian radiation pattern)
3.5 x 3.5 x 1.28mm

Optan TO-39 Ball Lens



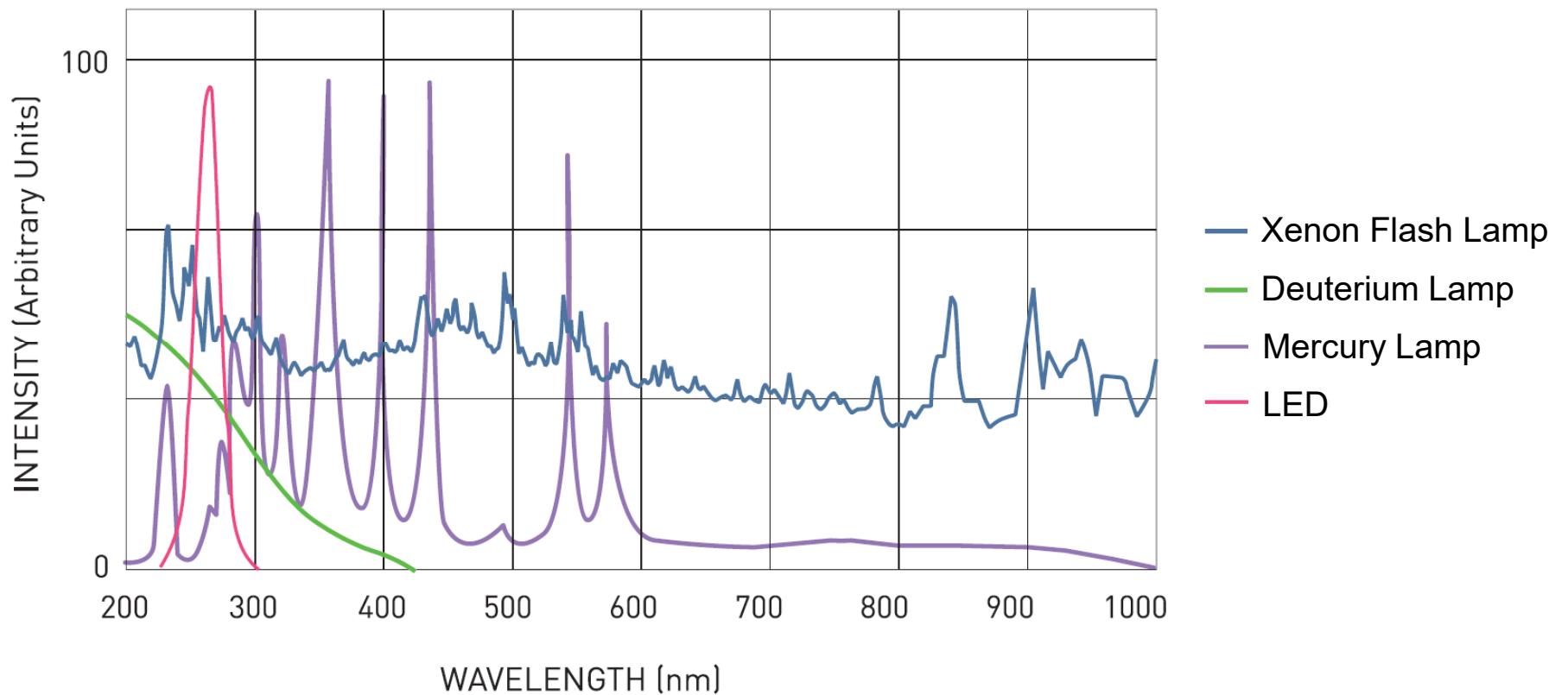
Package : Hermetic To-39
Output power:
0.5mW to 5mW
250, 255, 260, 275, 280nm
Viewing angle 15° (focused radiation pattern)
8.4mm ϕ x 8.2mm

LEDs applied in water quality monitoring

UV-C (Ultraviolet –C) : 200nm to 280nm

Compound/Parameter	LED wavelength
Nitrate	235nm and 255nm
PAH (polyaromatic hydrocarbon)	255 nm
UVT/UV 254/SAC (spectral absorption coefficient)	255 nm
COD (chemical oxygen demand)	255 nm
TOC (total organic carbon)	275 nm
BOD (biological oxygen demand)	280 nm
Oil-in-water	280 nm
Tryptophan like fluorescence	280 nm
Tyrosine, Phenylalanine fluorescence	235 nm

“Monochromaticity” of LED : Filters not required



Crystal IS and Aluminum Nitride (AlN) crystal

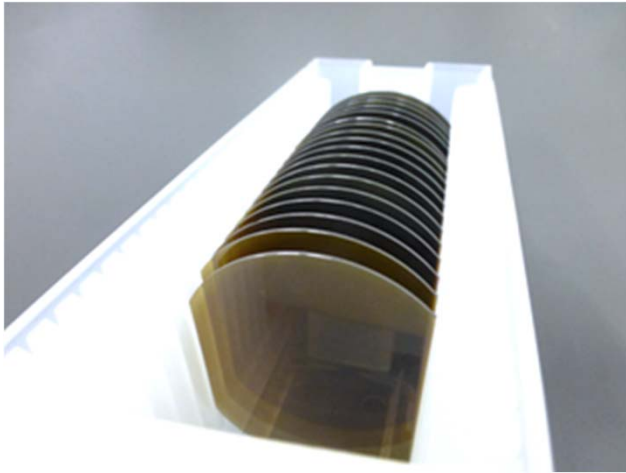
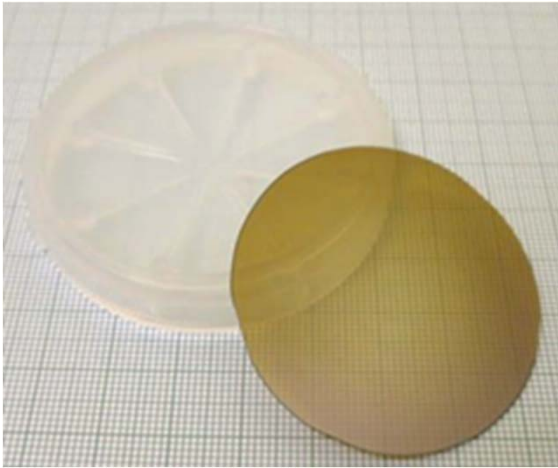
Established 1997

Become an Asahi Kasei company 2011

World's only UV-C LED manufacturer on AlN crystal substrates

Low defect density,
Low UV absorption
2" AlN substrate

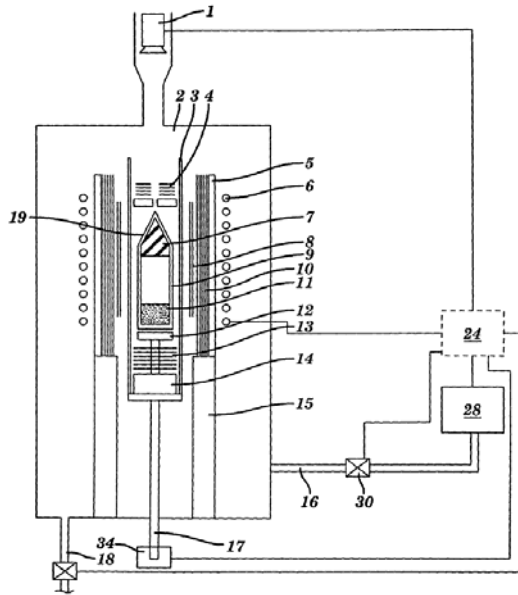
Looks tinted for human
eyes, but very
transparent in UV
(typ. 22cm^{-1} at 265nm)



High quality AlN substrate is basis of bright, long life UV-C LEDs

High quality AlN and epitaxial layers

Comparison of crystal quality in transmission electron microscope



Concept of sublimation-condensation crystal growth

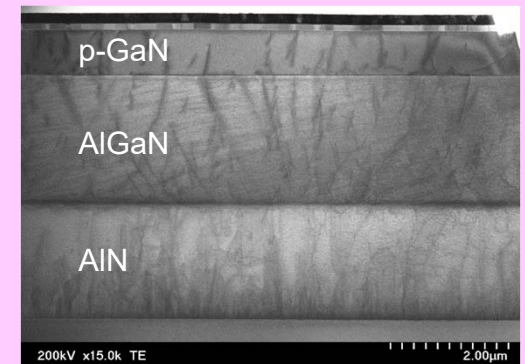
>2,200C extremely high temperature

Crystal IS LED on AlN substrate



No dislocation seen in the field

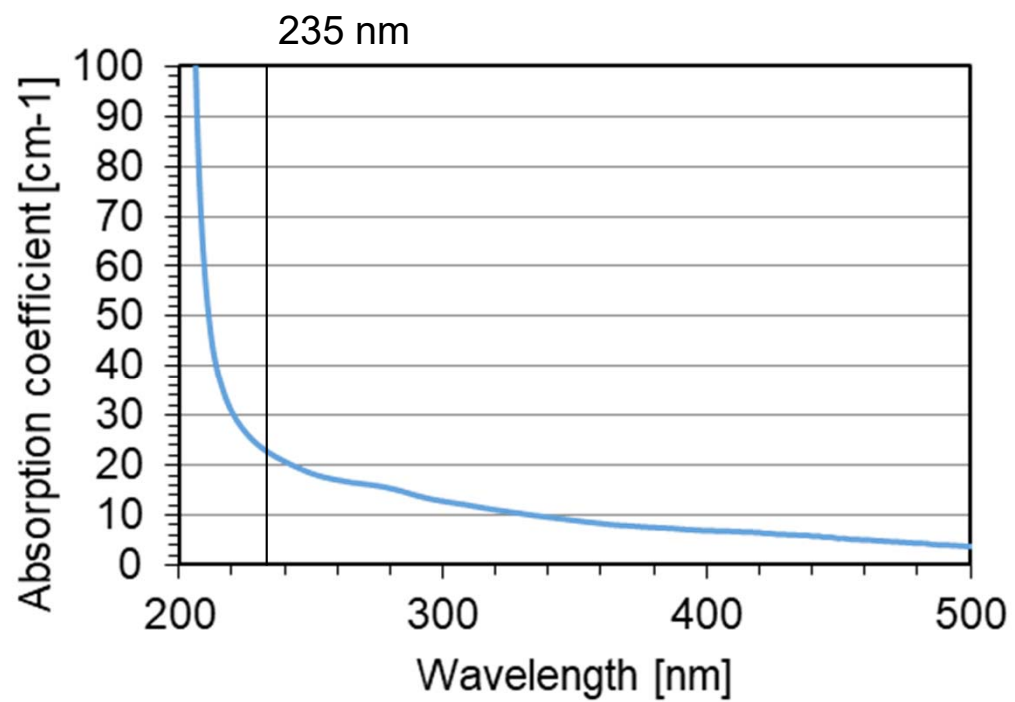
Other maker on Sapphire substrate



Many dislocations propagated through epi layer are evident

Low defect density in epi-layer is the key to high performance UV-C LEDs

UV transparency in the AlN substrate



In our flip-chip structure, light has to go through AlN substrate.

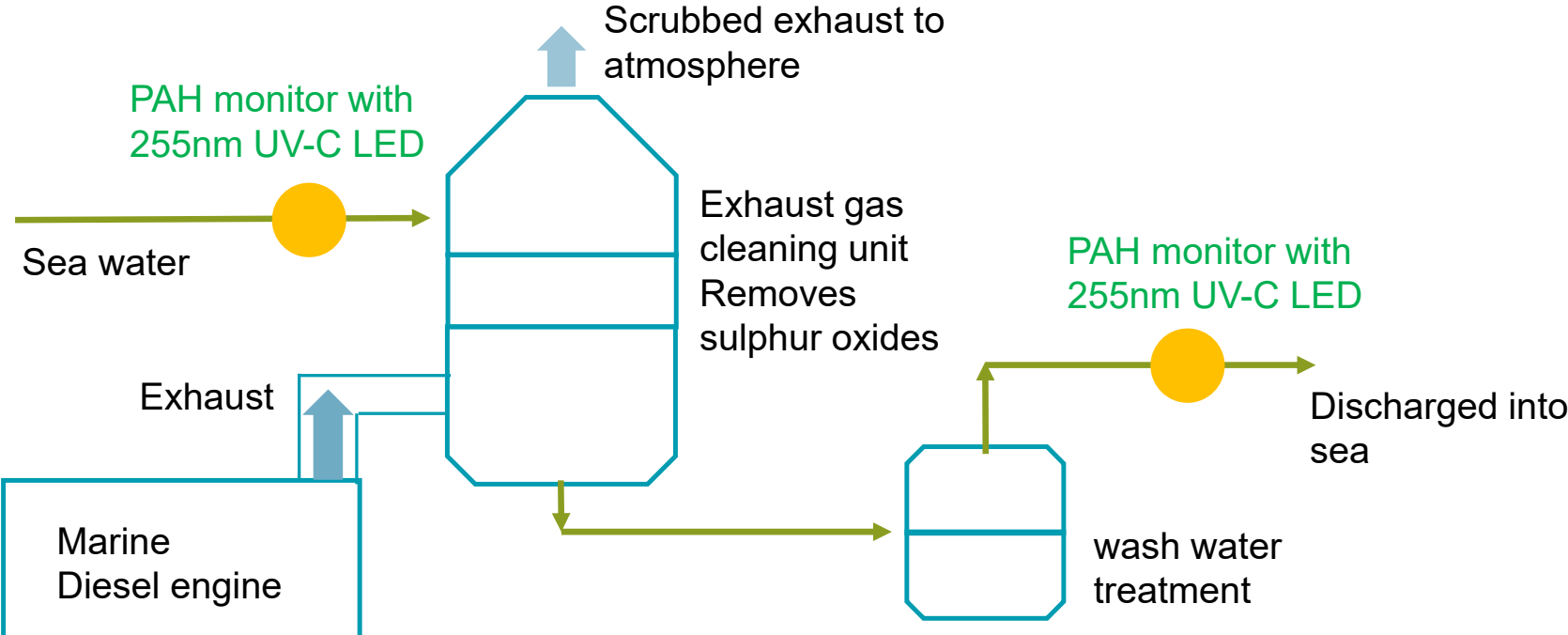
Work to lower absorption in UV-C range had been done extensively.

	Concentration by SIMS
[C]	< 5x10 ¹⁷ cm ⁻³
[O]	< 3x10 ¹⁷ cm ⁻³

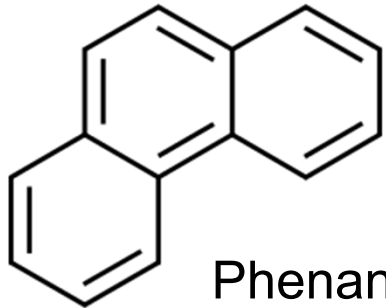
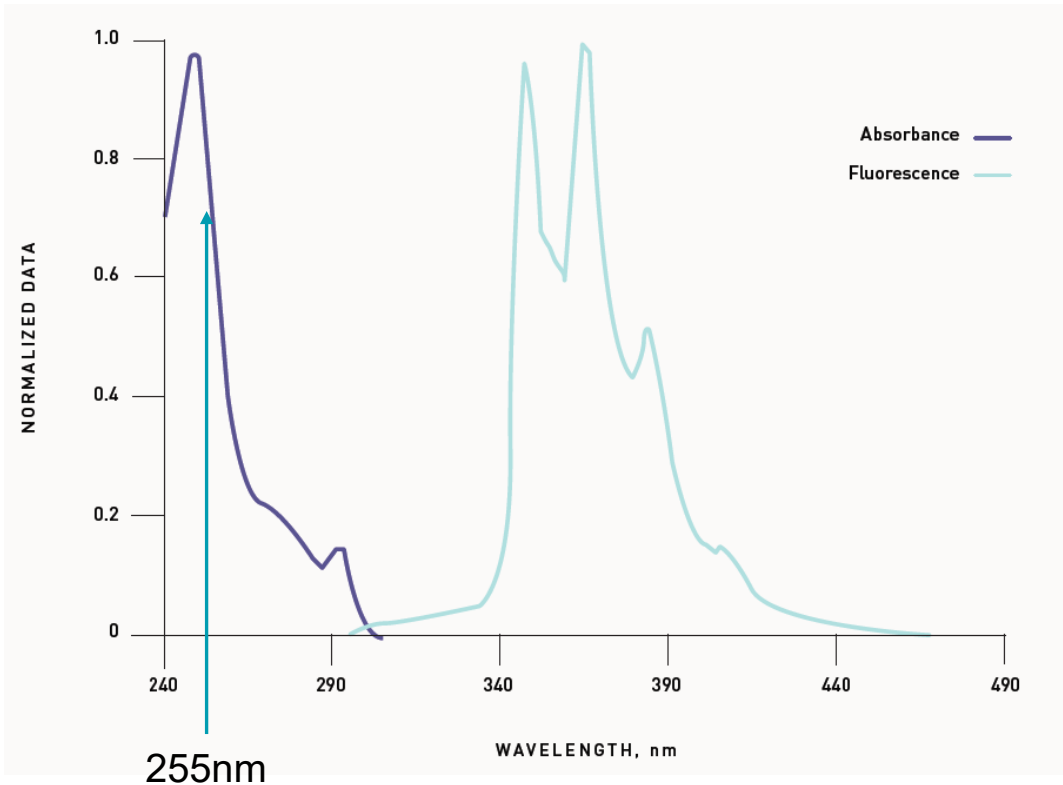
- Low impurity concentrations: C and O
- High UV transparency is accompanied by the high crystalline quality

PAH (polycyclic aromatic hydrocarbons) in marine engine exhaust washing water

Sulphur oxides emitted from combustion fuel is toxic.
Exhaust gas contain PAH results from incomplete fuel combustion that may dissolve in wash water.
Some of PAHs are carcinogenic and/or mutagenic.
PAHs may also bio-accumulate in edible shellfish, which gives them a pathway to humans.



Absorbance and fluorescence spectrum of phenanthrene

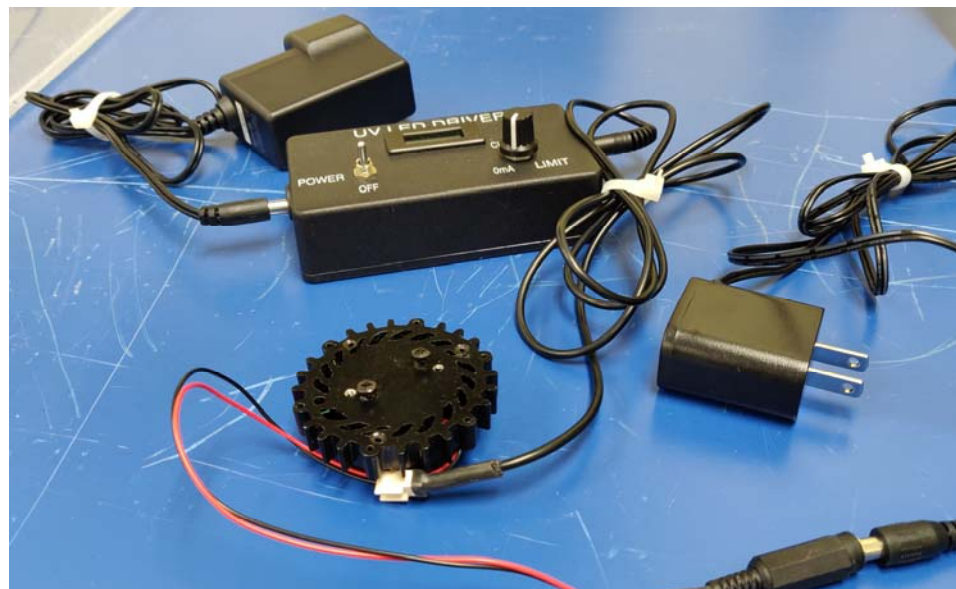


Phenanthrene

Phenanthrene is fingerprint compound for PAH. Its absorption and fluorescence spectrum makes 255nm LED the ideal light source in the detection system.

Technical support from Crystal IS

- In-house and field engineers available for variety of technical support
- Development kit includes heatsink, cooling fan and a constant current power supply
- Photodetector recommendation available based on specific usage information
- Please consult with us!



Easily accessible development kits

Summary

- Importance of nitrate monitoring in water
- Advantage of LEDs over traditional light sources
- Nitrate probe prototype results
- Introduction to “Optan” UV-C LEDs
- Why we can make novel 235nm UV-C LEDs ? : AlN crystals
- Other applications : PAH in ships, fluorescence

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Thank you!