Technology Note 42

PURELAB® Chorus 1 Xe

Xenon Excimer Lamp Technology: A transformative step in the purification of laboratory water by ELGA

ELGA VEOLIA

As a subsidiary of Veolia, ELGA is committed to creating environmentally sustainable products. Our customers depend on the high-quality water produced by our products for critical tasks such as trace analysis.

It is crucial that this purity is not diminished when introducing new technologies. Our team of engineers and scientists have collaborated with industry experts to create a new generation of UV lamps for water purification. These lamps not only eradicate the use of mercury but also extend the consumable's service lifetime significantly.

Additionally, by eliminating mercury from our UV lamps, we also remove the need for specialist waste disposal measures. Our Xenon lamps are free from hazardous materials, making their disposal or recycling straightforward and safe.

Mercury UV in water-purification

For over a century Mercury Vapour lamps have been used in water treatment; the two peaks of UV emission from this lamp make the light particularly suitable for sterilisation of microorganisms (254nm) and also the decomposition of dissolved organic molecules (185nm).

The negative environmental and health effects of Mercury exposure are well-known and acknowledged. Mercury is bioaccumulative, meaning it can build up in organisms causing issues even when present at low levels. Human activity is the main source of Mercury release from the earth's crust.

In response, regulatory bodies are implementing measures to address this issue. For instance, the UN Minamata convention outlines plans to completely prohibit the import and export of goods containing mercury. The Mercury UV technology commonly used in small-scale water purification systems and such applications is currently allowed by regulations as it is accepted that alternatives have not been fully adequate.

While suitable alternative technologies to control levels of microorganisms are available (such as filtration), substitution for the 185nm light treatment has been more of a challenge.

Mercury Free UV

There are a variety of non-mercury lamp types that can generate UV in the high-energy region required for the degradation of organic molecules, including Krypton Chloride and Xenon Excimer gas lamps, for example. Currently, LEDs are not able to produce the wavelengths and quantities of light required.

Xenon Excimer UV Lamps

ELGA has chosen Xenon Excimer lamps as the preferred technology for mercury-free water treatment in purifiers delivering low TOC (Total Organic Carbon) water.

The lamps emit light with a peak at 172nm where photons are approximately 7.5% more energetic than that at 185nm.

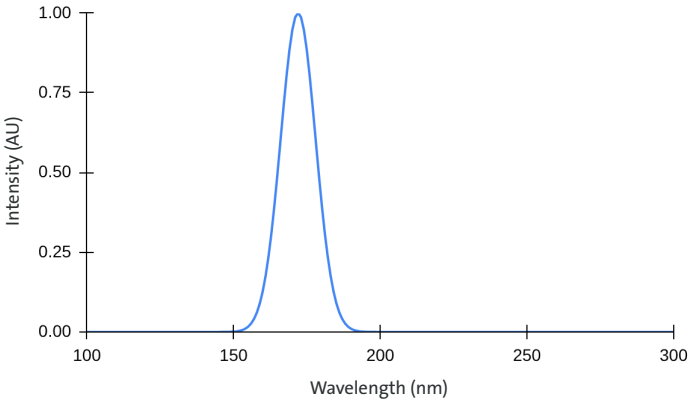


Figure 1: Emission spectrum of Xenon excimer lamp.

Radiation at 172nm has a photon energy of 7.2 meV or 166 kcal/mol. This is high enough to break most bonds, including C-F bonds found in the topical PFAs as shown in Figure 2. This energy also dissociates oxygen molecules dissolved within the water and water molecules themselves, generating ozone and hydroxyl radicals which also act to oxidise organic molecules. It is not energetic enough to dissociate nitrogen.

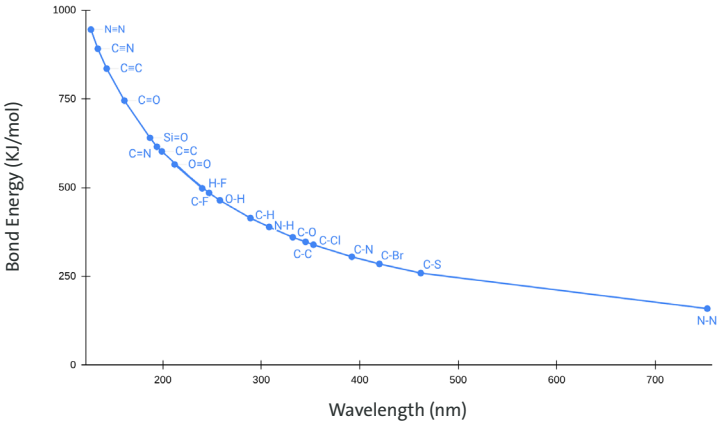


Figure 2: Bond energy versus wavelength of light.

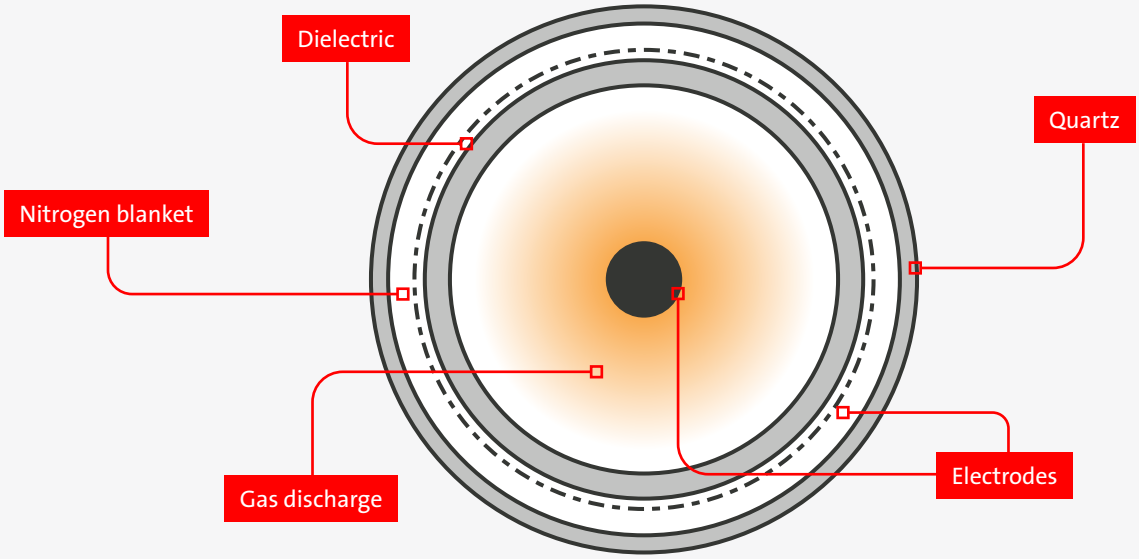
How does it work?

Use of dielectric-barrier-discharge through a xenon gas medium is an extremely efficient method of generating high energy UV light.

Xenon Excimer lamps operate via a Dielectric-Barrier-Discharge (DBD), where electricity is discharged into a low-pressure xenon-gas filled gap between two electrodes. This discharge produces highly unstable Xe_2 molecules, known as excimers, which emit UV light as they dissociate. The quartz dielectric material between the electrodes prevents the discharge from forming a dc-arc in the discharge gap.

The system developed by ELGA is driven by high voltage pulses in the kV range, resulting in highly efficient high-energy UV generation from electricity.

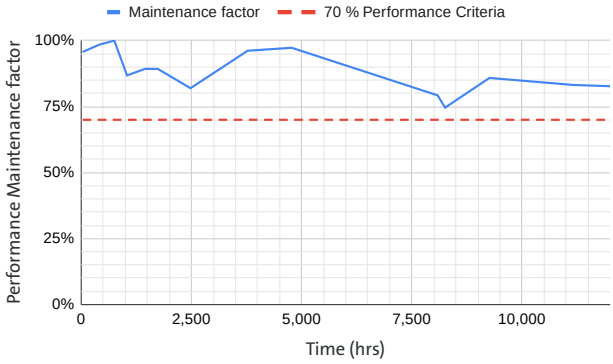
Figure 3: Components of the DBD Xenon excimer lamp.



Vastly Extended Life

One potential drawback of Xenon Excimer lamps is that their lifespan can be short when compared to mercury UV lamps. Xenon Excimer lamps are often used in component cleaning and treatment in the electronics industry, for example, where systems are designed to deliver brief high intensity emission; such operation damages the lamp parts, including the quartz, leading to shortened life. In line with the ecological focus of the Veolia group, it is the strategy of ELGA to increase the life of consumable items within products. Through close collaboration with UV lamp manufacturing experts, the development teams have created a new Xenon Excimer system, that we expect to operate within the ELGA purification system for up to 5 years.

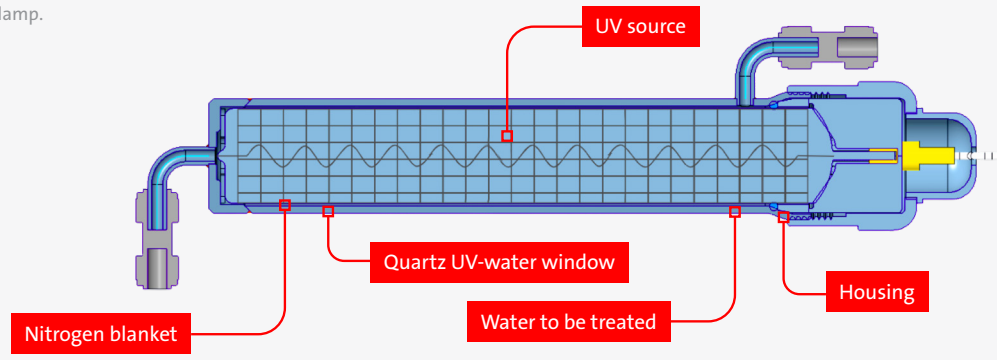
This extended service lifetime (>10,000 hours on-time) is due to a number of factors; unlimited on/off capability that separates the technology from that of the Hg alternative, and improved lamp design which limits the oxidative damage to the quartz. Benefits of this include significantly reduced waste and inconvenience, from manufacturing to delivery, and within the lab.



Designed for Water Treatment

Once generated, transfer of 172nm UV light into water for effective treatment requires careful consideration as the light is readily absorbed. ELGA's Xenon UV system has been designed specifically for water treatment, with a focus on maximizing the efficiency of UV delivery into the water and the treatment of organic impurities. To maximise UV transfer into the water, ELGA have integrated the 'water-window' into the UV component and placed an inert nitrogen-filled 'blanket' (which does not absorb the UV light) between it and the UV source. Gases other than nitrogen can absorb the UV light limiting that reaching the water. In the case of air, the highly energetic 172nm light is absorbed very efficiently by the oxygen (21%) to generate toxic ozone (as seen in the Earth's 'Ozone-layer'), which could be harmful to local personnel should it leak from the component. The ELGA solution eliminates such losses and the associated potential issue of ozone generation.

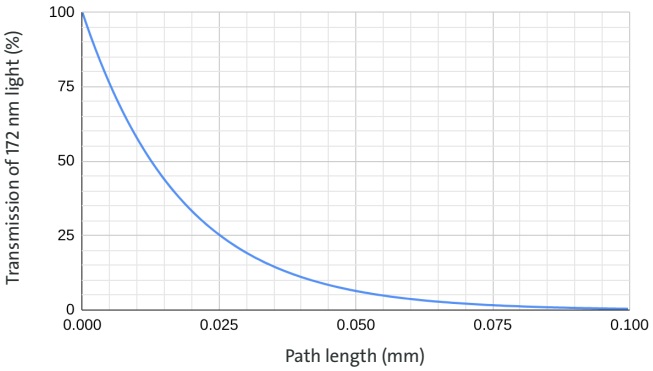
Figure 4: Cross-section of the ELGA Xenon Excimer lamp.



Further optimisations have been made by ELGA to maximise the exposure of water to the UV as it passes through the reactor. A key factor to consider when using 172nm radiation is its limited penetration depth due to its absorption by water; the absorption coefficient of pure water is ~550 cm^{-1} and hence the effective penetration depth is only 0.036 mm.

ELGA have increased the efficiency of water treatment by using a wide diameter lamp to more than double the surface area of the water-light interface (>310cm^2); the depth of water path has also been made very shallow to promote a turbulence in the water flow and to maximise the percentage of water that is treated.

Figure 5: Transmission of 172 nm light in pure water.



Performance in Water Purification

Our newly developed UV system has undergone rigorous testing to ensure its performance. In one such test, oxidation of an artificial organic challenge solution was compared to that of the mercury lamp that it will replace and a basic 'off-the-shelf' Xenon Excimer lamp used in competitor's water purification equipment.

In this test Methyl Ethyl Ketone (MEK) was dosed into a 1 l/min flow of ultrapure water to achieve a TOC of ~50ppbC. This challenge solution was directed through the UV treatment and subsequently through a bed of mixed ion-exchange resin; the TOC of the water from this test rig was monitored with and without power to the UV.

The ELGA Xenon Excimer Lamp showed slightly improved performance comparably to the Mercury lamp, while the competitor lamp's performance was lower.

Treatment of Dissolved Organics Challenge by Different UV Lamps

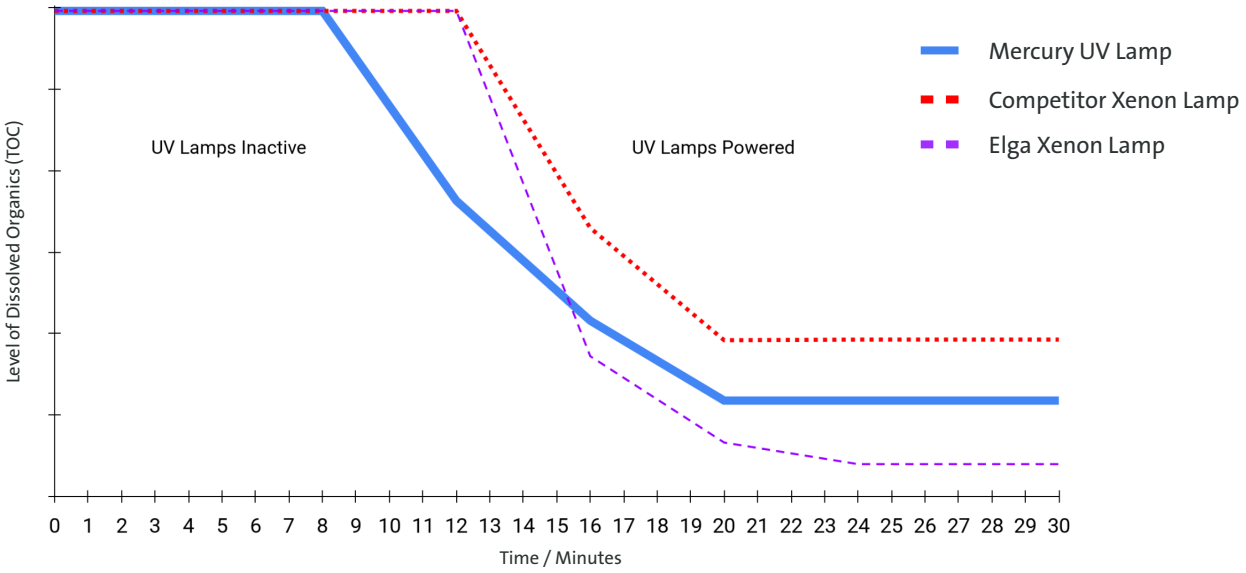


Figure 6: Reduction in TOC achieved by the ELGA Xenon Excimer lamp compared to a Mercury lamp and a competitor's Xenon lamp.

Conclusion

In conclusion, the implementation of Xenon lamps in ELGA products will have a significant positive environmental impact, not only by eliminating mercury waste but also by reducing waste associated with consumable supply through extended working life (manufacturing, distribution, packaging and disposal, for example). These savings significantly reduce the cost of purified water generation for ELGA equipment users and the environment.

There is no compromise in water purity with the ELGA Xenon Excimer lamps; they achieve the same level of TOC control that users rely on. This is because ELGA has gone to great lengths to tailor the Xenon Excimer technology for this purpose.

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