

Development of DBD Plasma based KrCl* (222 nm) and XeI* (253 nm) Excilamps and their Characterization

3.1 Introduction

The Dielectric barrier discharge (DBD)-based exciplex/excimer sources are the spontaneous source of far UV-C (222 nm) and UV-C (253 nm) light based on the transitions of rare gas and halide excited complex reactions. The prominent feature of such sources is their stability in the excited state without self-absorption in the ground state and the absence of mercury inside the lamps. Also, their spectral characteristics can be tuned by tuning supplied voltage, gas pressure and frequencies. They are more suitable for immediate usage in disinfection/sterilization due to instantaneous start-up [Prakash et al., 2017]. Dielectric barrier discharge (DBD) plasma-based excimer lamps are also sometimes called electrodeless lamps since, in many cases, no electrode is in direct contact with the gases in this arrangement. This results in a long lifespan of lamps because metal sputtering and electrode erosion do not occur on the inner walls of the quartz in this situation [Zhang et al., 2000] [Oppenlander, 2005]. Also, excimers/exciple sources provide very intense B-X transition in the case of rare gas only, but for a mixture of rare and halide gases, some weak transition also occurs along with intense B-X transition in UV/VUV range that allows them to have a high conversion efficiency of the electrical input to the optical output. Studies have shown that for the case of Kr/Cl₂ exciplex, a very intense B-X transition appears at 222 nm with some weak transitions, i.e., D-X, B-A, and C-A at 200 nm, 235 nm, and 240 nm, respectively [Lomaev et al., 2012] [Ahlawat et al., 2024b]. By adjusting operational parameters like input power, gas pressure, and discharge gap, it is possible to adjust the contribution from different electron transition bands and their bandwidths [Rahmani et al., 2009].

During plasma discharge, the heating of both the gas mixture and quartz becomes a significant challenge, especially at higher gas pressures. This issue is particularly pronounced in filamentary discharges, which are commonly encountered in various plasma-based sources. However, there is a noticeable lack of comprehensive studies focusing on the impact of bipolar pulsed-powered sources, specifically in the context of DBD plasma-based KrCl* and XeI* excilamps. Bipolar pulse-powered DBD plasma excilamps have the potential to offer several key advantages over traditional AC, DC, RF, and microwave sources. The primary benefit lies in their ability to deliver energy in short, high-voltage pulses. This method not only reduces the overall heat accumulation but also helps to minimize electrode heating, a significant concern with conventional discharge techniques. This approach can help minimize electrode heating, addressing one of the key challenges associated with traditional discharge methods [Ahlawat et al., 2024b].

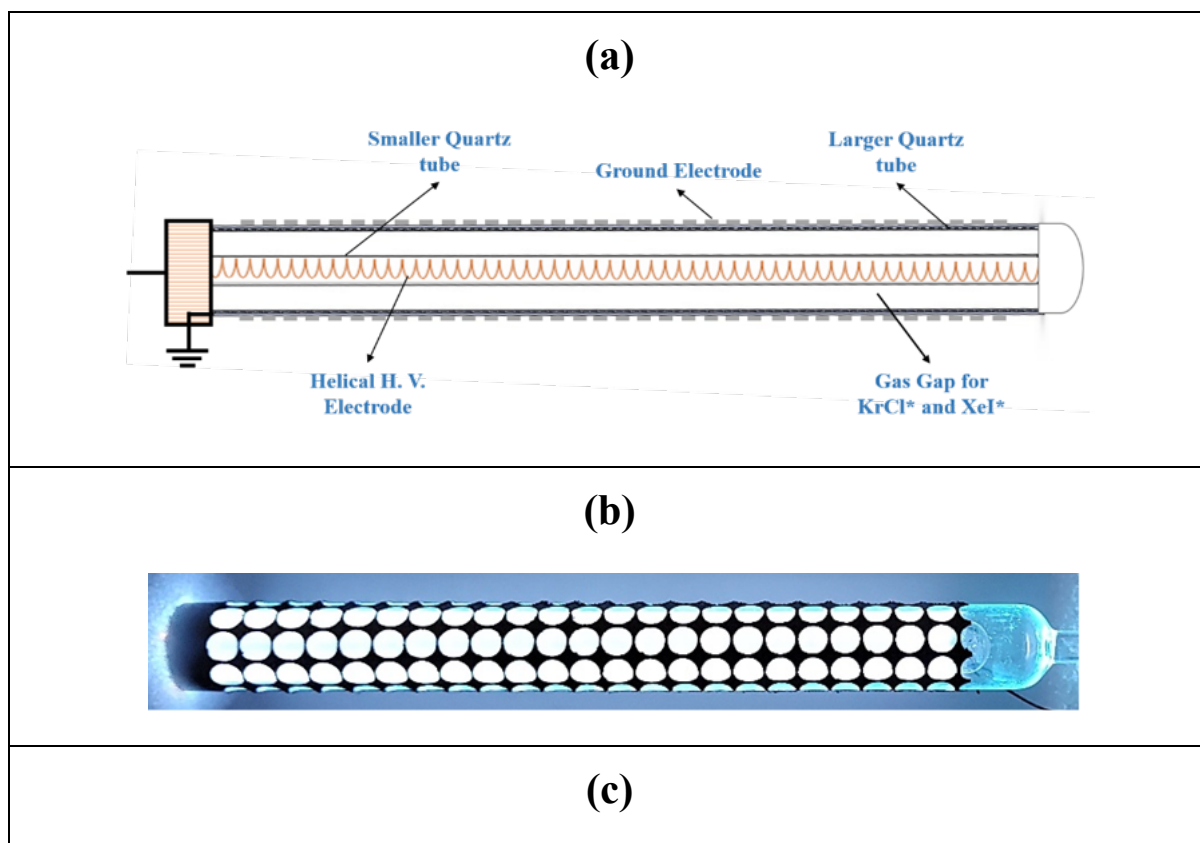
DBD plasma-based exciplex lamps are widely used for UV production without any elemental mercury [Prakash et al., 2017] [Loukil et al., 2022]. Due to their ability to interact with and destroy microbial cells, spores, and viruses, DBD plasma-based excilamps that emit wavelengths at 222 nm (KrCl*) and 253 nm (XeI*) are increasingly popular. These excilamps are being utilized in a variety of sectors, including the food industry for fruits and vegetable surface decontamination, milk sterilization, and surface sterilization of objects as well as these are employed in wastewater treatment, water and air disinfection, and showcasing their versatility

and effectiveness across different applications [Gadodia et al., 2024] [Sheng et al., 2023] [Ning et al., 2023] [Ahlawat et al., 2024c] [Buonanno et al., 2024] [Zhao et al., 2023] [Jangra et al., 2024].

In this chapter, the development of energy-efficient and self-cooled DBD based KrCl* and XeI* excilamp with a very narrow and intense spectrum peaking at a wavelength of 222 nm and 253 nm, respectively is reported [Ahlawat et al., 2024a]. Optimization of high voltage electrodes has been carried out to minimize the lamp heating without using any external cooling. The developed excilamps are also optimized for the maximum absolute irradiation intensity by varying electrode shape, input power, and gas pressure to achieve maximum electrical to UV conversion efficiency at low gas pressure with homogeneous diffuse discharges and with minimal lamp heating.

3.2 Design and Development of far UV-C KrCl* (222 nm) and UV-C (253 nm) Excilamps

The schematic view of the designed exciplex UV light sources is shown in Figure 3.1 (a). The exciplex UV source consisted of two quartz tubes with a wall thickness of 1.5 mm and fused co-axially at both ends with a glass blowing process maintaining a gas/discharge gap of 1.5 mm. The dimensions of the outer quartz tube are 16 mm OD and 13 mm ID, and the inner quartz tube is 10 mm OD and 7 mm ID having the same length of 160 mm in both cases. A stainless-steel electrode made up of a sheet with a thickness of 0.1 mm and circular apertures of 5 mm is used on the outer surface of the larger quartz tube, which acts as the grounded electrode. A helical moulded copper wire tightly fitted inside the smaller quartz tube acts as a high-voltage electrode in the co-axial DBD configuration and is hermetically sealed for electrical isolation. The length of the developed exciplex lamps is 15 cm with an outer diameter of 1.6 cm, corresponding to the surface area of $\sim 75 \text{ cm}^2$. The original view of the developed 222 nm and 253 nm exciplex UV sources can be seen in Figure 3.1 (b) and 3.1 (c).



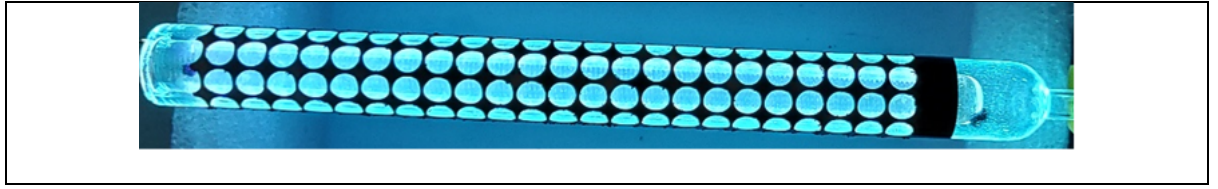


Figure 3.1: (a) Schematic view of designed exciplex UV sources, original view of the exciplex UV lamp (b) KrCl* (222 nm), and (c) XeI* (253 nm).

To optimize the high voltage electrode for the minimal heating of the developed lamp, we started with the rod-type electrode as a high-voltage electrode of the excimer lamp, but in this case lamp heating was quite high (150 °C), and the barrier quartz was often breaking. Then, we considered reducing the electrode's contact point and made helical grooves on the aluminium rod with a pitch of 0.9 mm, as shown in Figure 3.2 (a). The heating reduced slightly (120 °C), as can be seen from the IR camera image in Figure 3.2 (a). However, the long operation of the lamp was still challenging. We then utilize the helical electrode of the wire alone with an approximate same pitch of 0.99 [Figure 3.2 (b)], from which air can pass through easily and gas/quartz temperature was reduced to ~ 100 °C [see IR camera image in Figure 3.2 (b)]. Nevertheless, the heating of the gas/quartz required external control with external cooling. Then, we varied the pitch of the helical electrode further and tried to optimize the pitch value at which we got the minimal heating (< 70 °C), which can be seen in Figure 3.2 (c). This minimal heating leads to homogenous discharge without filaments in plasma discharge. We varied the pitch so as to see the diffused discharge with lesser heating in the lamp. In the case of a larger pitch of 5.5 mm, the discharge was very weak, and no diffused discharge was possible for any combination of applied voltage and gas pressure due to very few contact points. The optimized pitch obtained experimentally was around 2.1 mm, and the lamp heating was controlled by optimizing the pitch of the helical electrode without any external cooling. The actual picture of the H.V. electrodes with IR camera images of developed lamps are shown in Figures 3.2 (a) to 3.2 (c).

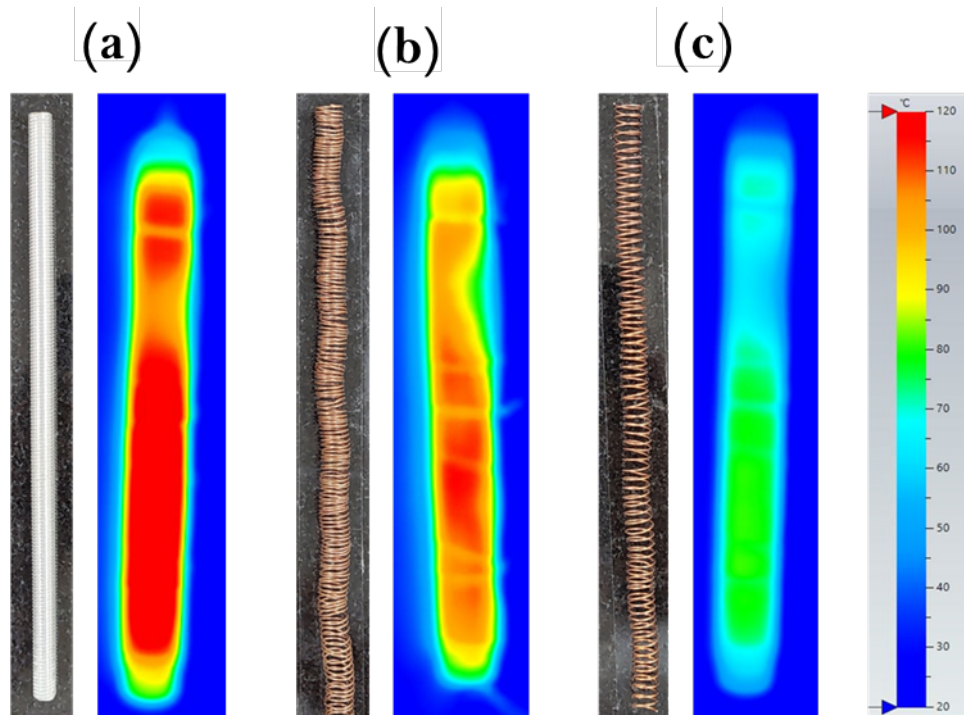
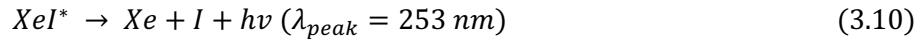
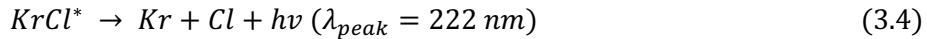


Figure 3.2: Actual picture of the H.V. electrodes with IR camera images of developed lamp (a) with solid aluminium rod, (b) helical electrode with pitch 0.99 mm, and (c) helical electrode with pitch 2.1 mm.

3.3 Exciplex Source Characterization

3.3.1 Formation of KrCl* and XeI* Excimer

Excitation of the gases and the creation of KrCl* and XeI* exciplex molecules occur when a significant voltage is applied between the electrodes of exciplex sources. Within a few nanoseconds of excitation, KrCl* and XeI* exciplex molecules decompose and release UV photons at the wavelengths of 222 nm (see reactions 3.1 to 3.4) and 253 nm (see reactions 3.5 to 3.10), respectively, as follows [Ahlawat et al., 2024c] [Ahlawat et al., 2024d];



Gas pressure optimization is performed at different applied voltages and frequencies for the exciplex lamps' maximum intensity output. For the KrCl* exciplex source, the optimized pressure of the Kr/Cl₂ gas mixture is 140 mbar, and the maximum intensity is recorded at 27.5 kHz. In the case of the XeI* exciplex source, the maximum intensity is obtained at 200 mbar gas pressure and a frequency of 25 kHz.

In the excilamp system, the recombination phase during the off-time involves: Decay of exciplex states (e.g., KrCl* → Kr + Cl + hν), Recombination of ionic species (e.g., Kr⁺ or Xe⁺ with electrons), and collisional quenching with buffer gases (if present). These recombination processes are critical for re-establishing baseline plasma conditions before the next voltage pulse. The timing and length of the off-time influence how efficiently the excimer-forming states are repopulated in the following pulses.

3.3.2 Electrical Characteristics of Exciplex Sources

Figure 3.3 (a) and 3.3 (b) show the current-voltage waveforms of UV₂₂₂ and UV₂₅₃ exciplex sources, respectively, operating at an applied voltage of 9 kV. The obtained discharge current and respective discharge power of the 253 nm exciplex lamp is less than that of the 222 nm exciplex lamp at various applied voltages because of the increased gas pressure. This is because if we increase the gas pressure, more species are present for ionization and the ionization energy drops, which causes avalanches to occur at lower voltages [Zhuang et al., 2010]. The calculated input power and power consumed in one duty cycle (DC) for UV₂₂₂ and UV₂₅₃ lamps at an optimized frequency is shown in Table 3.1.

The UV₂₂₂ and UV₂₅₃ exciplex sources have been operated with an operational time (T_{on}) and shutting time (T_{off}) of 2 μs and 38 μs, respectively, at a pulse repetition frequency (PRF) of 25 kHz. The corresponding duty ratio of the waveform is 0.05 (duty cycle ~ 5%). While at a PRF of 27.5 kHz, the T_{on} and T_{off} of 2 μs and 34.4 μs, respectively, with a duty ratio of 0.055 (duty cycle

~ 5.5%). A typical voltage and current waveform of the UV₂₂₂ and UV₂₅₃ exciplex sources is shown in Figure 3.3 (c) and 3.3 (d).

$$Duty\ ratio = \frac{T_{ON}}{T_{ON} + T_{OFF}} \quad (3.11)$$

The average input electrical power for the optimized excilamp can be estimated from the V-I characteristic of the DBD plasma system by multiplying the voltage and current waveforms and then integrating them over a time period as [Jangra et al., 2023b] [Jangra et al., 2023a],

$$P_{in} = \frac{1}{T} \int_0^T v(t)i(t)dt \text{ [Watt]} \quad (3.12)$$

$$P_{DC} = Duty\ ratio \times P_{in} \quad (3.13)$$

Where P_{in} is the input power (in Watts), $V(t)$ is the applied voltage with respect to time, and $I(t)$ is the current profile with time. Accordingly, the energy consumed per pulse has been estimated for the 2 μ s pulse width that results in 31.13 W and 25.8 W of input power for UV₂₂₂ and UV₂₅₃ lamps, respectively, at the applied parameters of 9.0kV/27.5 kHz.

Table 3.1: Average input power and power in one DC for UV₂₂₂ and UV₂₅₃ lamps at optimized frequencies.

Applied Voltage (kV)	7.0	7.5	8.0	8.5	9.0
Input Power UV ₂₂₂ (W)	18.03	22.32	24.71	27.53	31.13
Power in One DC	0.90	1.12	1.24	1.38	1.56
Input Power UV ₂₅₃ (W)	12.22	15.63	18.24	22.67	25.8
Power in One DC	0.67	0.86	1.01	1.25	1.42

3.4 Optical Characteristics of Exciplex Sources

The optical emission spectra (OES) of the developed exciplex lamps are shown in Figure 3.4 (a) and 3.4 (b). Figure 3.4 (a) shows that the primary emission line at 222 nm corresponds to the characteristic emission of B-X transitions of the KrCl* exciplex. This wavelength is well known for its germicidal and surface modification properties and is widely utilized in various applications requiring safe and efficient UV-C radiations [Ahlawat et al., 2024b] [Payne et al., 2022]. In these spectra, some weak emission lines at 235 nm, 240 nm, and 258 nm are also observed, corresponding to B-A, C-A, and Cl_2^* transitions of KrCl* exciplex, respectively. For the XeI* exciplex lamp, a prominent 253 nm spectral band corresponding to the B-X transition is observed along with a weak fused band at 265 nm (C-A transition for XeI*), 320 nm (B-A transition for XeI*)

and 206 nm (D-A transitions for I_2^*) as can be seen in **Fig. 4 (b)**. The emission lines are caused by different processes of excitation and relaxation of the excited species within the excilamps.

The narrow and intense spectral band at 222 nm and 253 nm is recognized as quite beneficial, and the full width at half maximum (FWHM) of UV excimer sources plays a crucial role in attaining it. In the developed excilamps, we found a significantly narrow spectral range (1.7 nm for 222 nm and 1.9 nm for 253 nm) that operates at low pressure with minimal lamp heating. This finding presents an intriguing advantage in the non-thermal treatment of food and beverages.

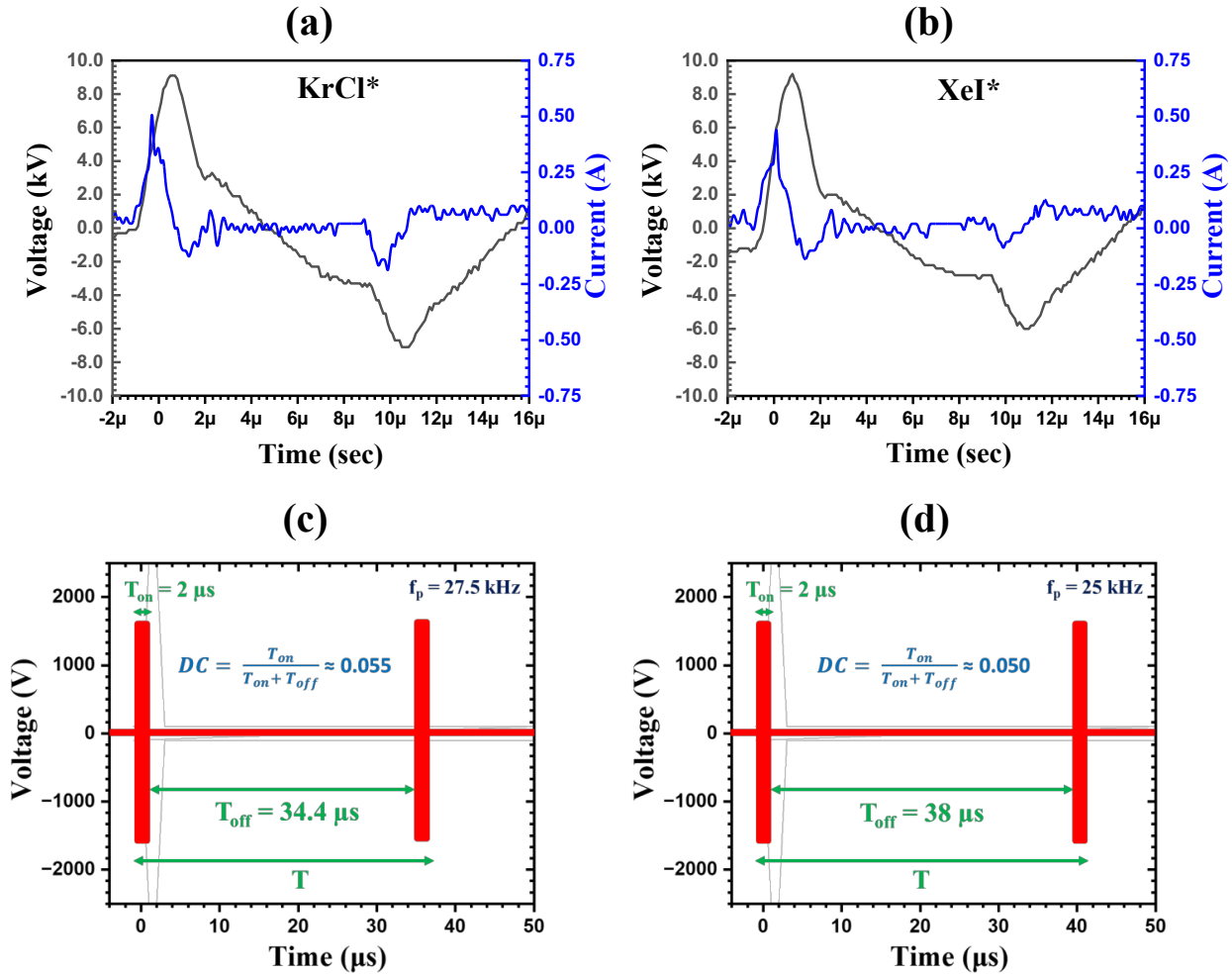


Figure 3.3: Typical V-I characteristics of (a) KrCl* (222 nm) exciplex lamp (b) XeI* (253 nm) exciplex lamp at 9 kV/27.5 kHz. Typical waveform of pulse power source at (c) 27.5 kHz PRF and 5.5% duty cycle, (d) 25 kHz PRF and 5% duty cycle.

Efficient cooling is an essential condition for attaining high radiation power density. Previously, water-cooled excimer lamps were used, which cannot be used for air disinfection. Also, water cooling substantially complicates the design and increases the cost of the system. In the case of Schitz et al. [Schitz et al., 2008], in which they have reported the air-cooled excimer lamp with a flat window output. Two parallel cylindrical radiators were installed in a chamber having a flat quartz window for output. With air cooling, they have obtained 110 °C of the temperature of the excilamp. They have installed two cooling fans, one for the inner high voltage electrode and the other for the complete excilamp. In our case, we have not used external cooling, water, or air cooling. We have designed the H.V. electrode in such a way that the temperature of our excilamp remains well below 120 °C for longer operation. The main reason for the controlled heating is the homogenous discharge at low gas pressure and the helical molded copper wire electrode with optimized pitch.

The emission intensity of DBD-based excimer lamps is directly related to the temperature [Schitz et al., 2021]. Figure 3.4 shows the variation in temperature and emission intensity with respect to the different electrode configurations. As can be seen from the figure, an increase in the electrode's pitch helps lower the temperature of the excimer source and simultaneously increases the UV intensity. However, a larger pitch (> 5 mm) causes a decrease in intensity because of few contact points and partial discharge of the $\text{KrCl}^*/\text{XeI}^*$ gas mixture. The emission intensity is also indirectly related to the spiral turns because in the solid rod and lower pitch helical electrodes, the temperature becomes high, and it tends to decrease the emission intensity despite having more contact points for the discharge.

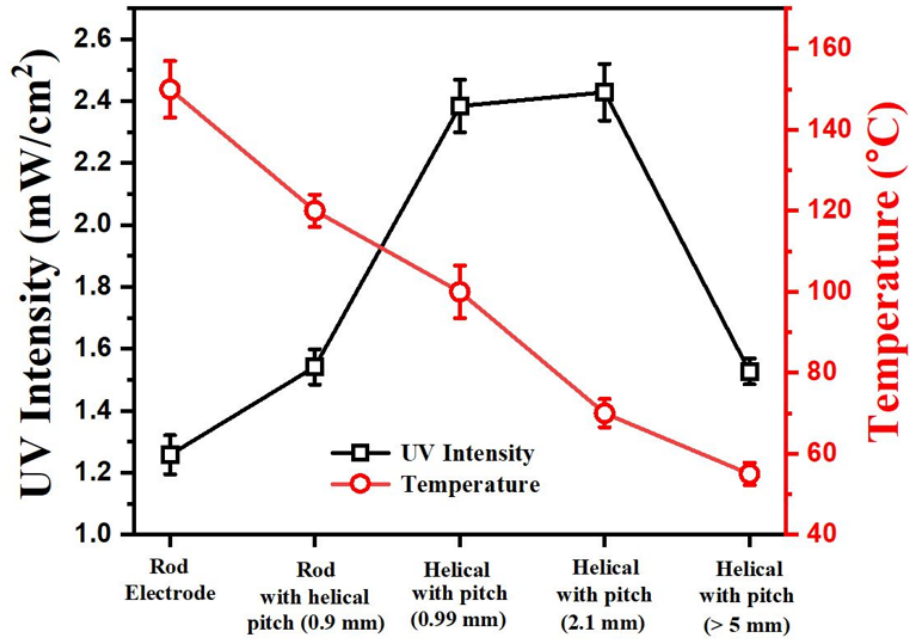


Figure 3.4: Temperature and emission intensity with respect to the different electrode configurations.

The experiments are performed by varying three different parameters, i.e., gas pressures, applied voltages and pulse repetition frequencies at all possible combinations. It can be observed that at every gas pressure, the maximum absolute UV irradiation is recorded at 27.5 kHz and 25 kHz for UV_{222} and UV_{253} lamps, respectively. Further, an increase in the frequency causes an intensity drop to some extent, which validates that these frequencies can be considered the optimized condition in our study. While increasing the gas pressure, the intensity increases to the total gas pressure of 140 mbar and 200 mbar for UV_{222} and UV_{253} lamps, respectively, and then decreases, which can also be seen in Figure 3.5 (a) to 3.5 (b). These results clearly indicate that 140 mbar pressure and 27.5 kHz frequency can be considered the best combination for the developed far UV-C (UV_{222}) excimer lamp for maximum UV irradiation. For UV_{253} lamps the optimized combination is 25 kHz frequency and 200 mbar pressure.

At a higher frequency than 27.5 kHz, the UV light intensity decreases. This is because, at a higher frequency, the off period of discharge becomes shorter, and residual ions and electrons increase. This reduces the electron temperature during the next pulse. This means the population of higher levels of atoms may decrease, and so the UV-C radiation. The three-body recombination rate increases with increasing gas density at lower pressure [Bhave et al., 1995]. However, in the high-density regime, the excimer's dissociation and quenching rate become larger, owing to the enhancement of collisions between the excimer and other heavy particles [Feng et al., 2006; Zhuang et al., 2010]. Thus, the spontaneous emission of the excited molecules is reduced

correspondingly. So, the intensity starts decreasing at high pressure due to quenching. Since voltage is directly proportional to the intensity, as we are increasing voltage, the intensity is increasing, but after 9 kV, more power dissipated in heating rather than radiation and lamp heating becomes challenging due to the capacitive nature of the discharge [Tellinghuisen et al., 1980]. Therefore, we restricted ourselves to 9 kV of applied voltage.

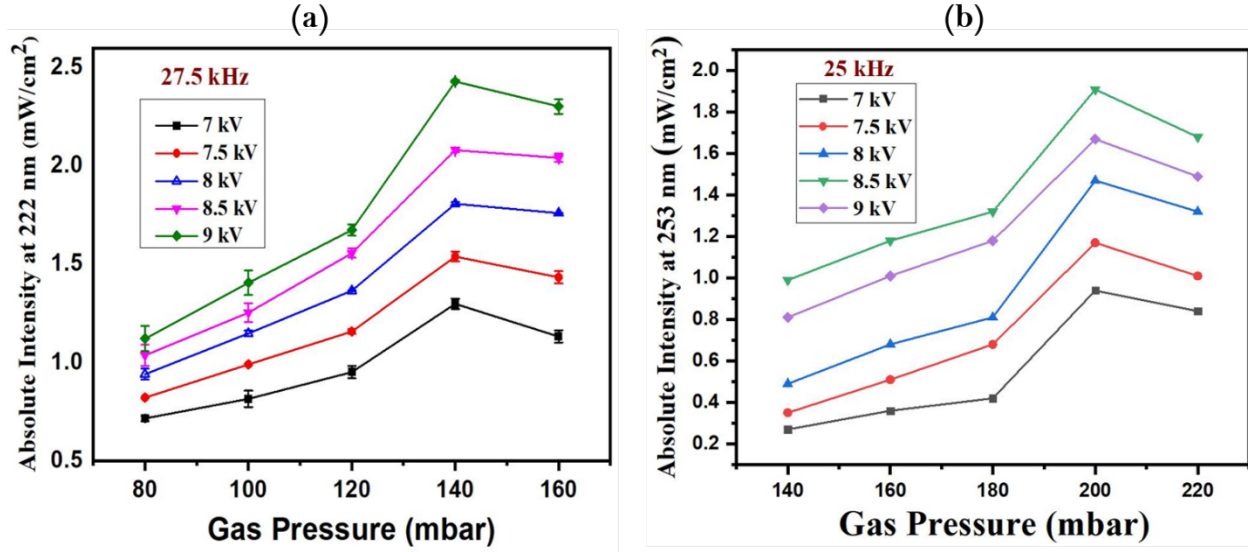


Figure 3.5: Absolute UV intensity at different combinations of applied voltages and total gas pressure (a) for UV₂₂₂ lamp at a fixed frequency of 27.5 kHz and (b) for UV₂₅₃ lamp at a fixed frequency of 25 kHz.

The optical emission spectra (OES) of the developed exciplex lamps are shown in Figure 3.6 (a) and 3.6 (b). Figure 3.6 (a) shows that the primary emission line at 222 nm corresponds to the characteristic emission of B-X transitions of the KrCl* exciplex. This wavelength is well known for its germicidal and surface modification properties and is widely utilized in various applications requiring safe and efficient UV-C radiations [Ahlawat et al., 2024b] [Payne et al., 2022]. In these spectra, some weak emission lines at 235 nm, 240 nm, and 258 nm are also observed, corresponding to B-A, C-A, and Cl_2^* transitions of KrCl* exciplex, respectively. For the XeI* exciplex lamp, a prominent 253 nm spectral band corresponding to the B-X transition is observed along with a weak fused band at 265 nm (C-A transition for XeI*), 320 nm (B-A transition for XeI*) and 206 nm (D-A transitions for I_2^*) as can be seen in Figure 3.6 (b). The emission lines are caused by different processes of excitation and relaxation of the excited species within the excilamps.

The narrow and intense spectral band at 222 nm and 253 nm is recognized as quite beneficial, and the full width at half maximum (FWHM) of UV excimer sources plays a crucial role in attaining it. In the developed excilamps, we found a significantly narrow spectral range (1.7 nm for 222 nm and 1.9 nm for 253 nm) that operates at low pressure with minimal lamp heating. According to J. Y. Zhang and I. W. Boyd [Zhang et al., 1996], at lower pressure (100 mbar), their FWHM for the far UV-C excimer source was around 8 nm. Another group [Brau et al., 1975; Tellinghuisen et al., 1980] at high temperatures has shown broader FWHM, and the gas temperature plays a role in the width of this band. Both weaknesses have been eradicated in our new design due to the new electrode geometry in the DBD configuration and the narrow-confined gas gap. As we changed the gas pressures, we got a broader band spectrum of 222 nm, e.g., FWHM > 3 nm is observed in the case of 450 mbar working gas pressure. The transitions other than B-X (222 nm) can be removed using an appropriate optical bandpass filter that blocks the wavelengths above 230 nm and gives a safe wavelength that can be used in occupied environments [Buonanno et al., 2017].

The total emitting area of the excilamps was $\sim 75 \text{ cm}^2$ for the 150 mm arc length. A pre-calibrated UV power meter at 222 nm and 253 nm wavelength has been used for the absolute intensity measurements. The distance of the photodetector has been kept at 10 mm from the exciplex lamps. The absolute UV intensity for UV₂₂₂ and UV₂₅₃ lamps at different power settings is shown in Figure 3.6 (c) and 3.6 (d). An increase in power increases the UV irradiation, but after a certain limit, lamp heating becomes challenging, and consequently, a decrease in UV irradiation is observed. At an optimized parameter, a maximum UV intensity of 2.445 mW/cm² and 1.91 mW/cm² is recorded for 222 nm and 253 nm exciplex lamps, respectively. Generally, UV light irradiation onto a substrate is defined in terms of UV dose, corresponding to UV light intensity with irradiation time. The UV dose is calculated by using the following relationship [Ahlawat et al., 2022] [Ahlawat et al., 2023];

$$UV_{Dose} \left(\frac{mJ}{cm^2} \right) = UV_{Intensity} \left(\frac{mW}{cm^2} \right) \times Treatment\ Time\ (s) \quad (3.14)$$

By adjusting the treatment time of excilamps, the UV doses delivered for the different substances can be adjusted accordingly.

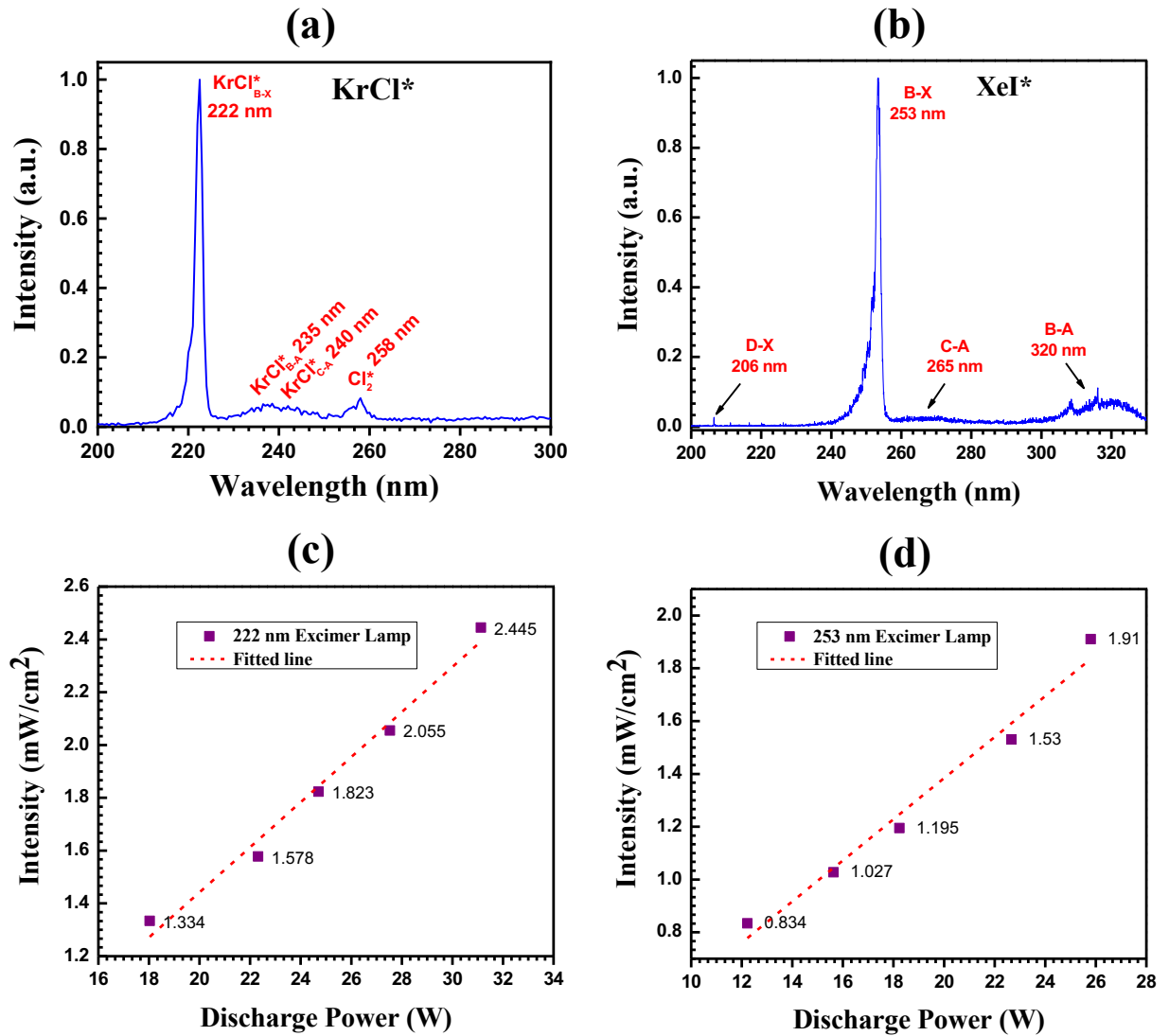


Figure 3.6: Optical emission spectra and absolute UV irradiance of (a, c) UV₂₂₂ nm and (b, d) UV₂₅₃ nm exciplex lamps.

3.5 Electrical Input to Optical Output Power Conversion Efficiency

The UV₂₂₂ and UV₂₅₃ excilamps have also been evaluated for their efficiency in converting electrical power to optical power. The excimer light source is linear, meaning that the diameter of the lamp is significantly less than its length. Therefore, we employed the Keitz formula (equation 3.15) for measuring the UV radiation power (P_{out}) [35]. According to it, the distance (D) of the UV photodetector from the light source must be greater than twice the length of the lamp (L). After $D > 2L$, the UV output power becomes constant, i.e., distance does not play an essential role after this point [Sasges et al., 2012] and can be seen from Figure 3.7 (a) and 3.7 (b) [Figure 3.7 (a) and 3.7 (b) shows the absolute UV irradiance for the UV₂₂₂ and UV₂₅₃ lamp with respect to the distance from the lamp, respectively]. Accordingly, the saturated irradiance intensity value obtained from this figure has been used to calculate P_{out} .

$$P_{out} = E \cdot \frac{2\pi^2 DL}{2\alpha + \sin 2\alpha} \quad (3.15)$$

In our case, the arc length of the lamp is 15 cm and therefore, the photodetector was placed at 31 cm at an angle of 13.57° to measure the corresponding UV irradiance. The high efficiency of the excimer light source will result from high output radiated power and reduced heating of the gas/lamp. Also, additional elements, such as the mode of discharge (filamentary or diffuse) and the thickness of the dielectric material, can affect the efficiency of the excimer lamp. The calculated UV output power at 9 kV/27.5 kHz and 9 kV/25 kHz at different gas pressures for UV₂₂₂ and UV₂₅₃ excilamps is shown in Table 3.2, respectively. The input power (P_{in}) for these operational parameters is 31.13 W and 25.8 W, respectively.

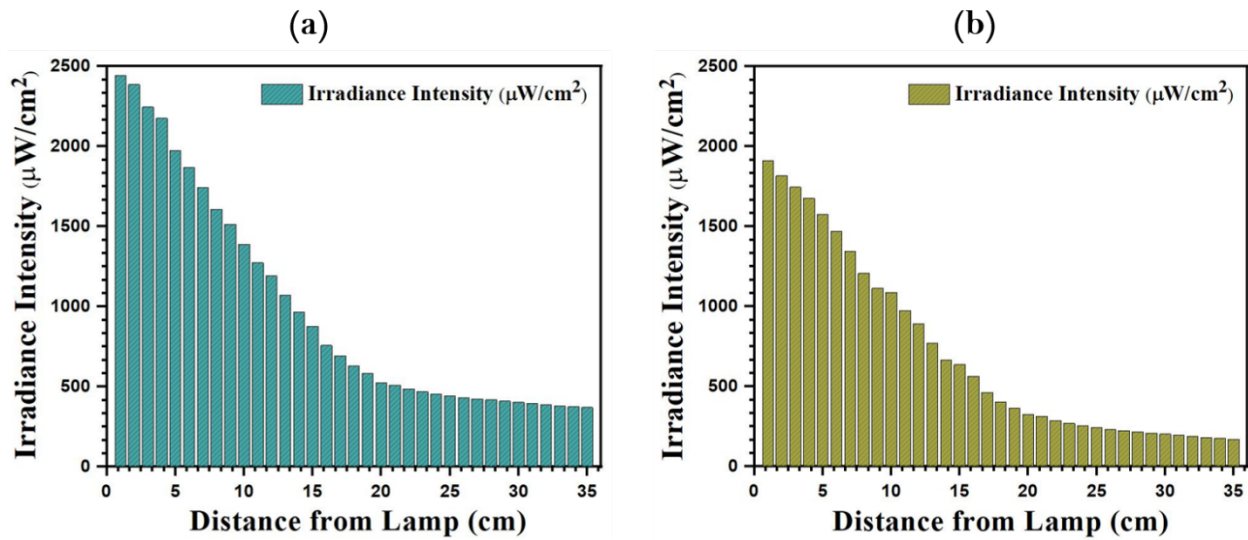


Figure 3.7: Effect of the distance on absolute UV irradiance (a) for the developed UV₂₂₂ lamp, (b) for the developed UV₂₅₃ lamp.

Table 3.2: The UV output power for the UV₂₂₂ and UV₂₅₃ excilamp with respect to the increasing gas pressure of the lamp.

Gas Pressure (mbar)	80	100	120	140	160
222 nm Output Power	1.7	2.23	2.72	3.906	3.589
Gas Pressure (mbar)	140	160	180	200	220
253 nm Output Power	1.93	2.87	3.28	4.46	3.92

Figure 3.8 (a) and 3.8 (b) shows the electrical to optical conversion efficiency of the UV₂₂₂ and UV₂₅₃ excilamp at optimized electrical parameters with varying gas pressures, respectively. The maximum efficiency of $\sim 12.53\%$ and $\sim 17.27\%$ for the UV₂₂₂ and UV₂₅₃ excilamps has been achieved at the gas pressure of 140 mbar and 200 mbar, respectively.

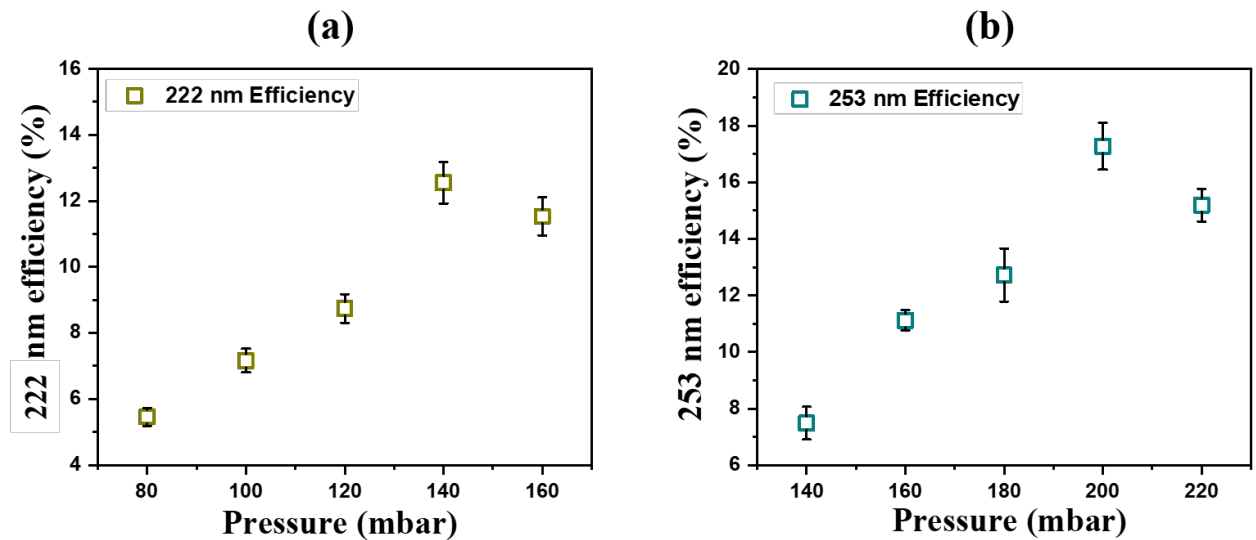


Figure 3.8: The electrical to the optical conversion efficiency of (a) UV₂₂₂ and (b) UV₂₅₃ excilamp at varying gas pressure and optimized electrical parameters.

In general, in this type of excimer sources, two types of discharges occur, i.e., diffuse and filamentary, which are primarily dependent on gas pressure. The mode of discharge plays an essential role in their efficiency evaluation because, in diffuse discharges, both efficiency and temperature remain low. Previous studies show that the local heating of the quartz tube could be controlled by producing a diffuse discharge than the spark or streamer [Schitz et al., 2021]. Filamentary discharges can provide high efficiency but with a limitation of access heating of the lamp [Michael A. Lieberman, 2003]. In our case, the discharges are at low pressures, which indeed occurs in diffuse modes and also, due to the confined gas gap, we got a very narrow and intense band at 222 nm (FWHM of 1.7 nm) and 253 nm (FWHM of 1.9 nm). It leads to higher efficiency of the lamp at a much lower breakdown voltage. This prodigious conversion efficiency at low input power has been obtained due to the lamp geometry and bi-polar pulse power source, providing an immediate discharge with lower pulse repetition frequencies.

3.6 Conclusion

In this chapter, we have shown a successfully developed 222 nm far UV-C and 253 nm UV-C excimer lamps. The developed lamps have been evaluated in terms of absolute UV irradiation generation and their electrical input to optical output conversion efficiency. High voltage electrodes have been optimized to reduce lamp heating, without using any external cooling. At an optimized parameters of 31.13 W/140 mbar and 25.8 W/200 mbar, a very narrow and intense band peaking at 222 nm and 253 nm have been obtained, respectively, utilizing diffuse discharge with minimized heating. We found a significantly narrow spectral range (FWHM of 1.7 nm for 222 nm and 1.9 nm for 253 nm) that operates at low pressure with minimal lamp heating ($< 70\text{ }^{\circ}\text{C}$). The maximum efficiency of $\sim 12.53\%$ and $\sim 17.27\%$ for the UV₂₂₂ and UV₂₅₃ excilamps has also been achieved at the gas pressure of 140 mbar and 200 mbar, respectively. The developed far UV-C and UV-C excimer lamps are not only safer but also offer a more effective alternative to conventional mercury-based UV-C lamps. Their enhanced safety and efficiency make them particularly suitable for a wide range of applications related to health and environmental protection.