

Chapter 6

Conclusion

6.1 Demonstration of New Pumping Method

This project report had detailed the idea and construction of a new pumping method for short wavelength lasers. Various considerations and previous attempts were discussed and compared; eventually leading to this alternative method in order to realize an efficient vacuum ultra-violet and even XUV lasers.

Since the method described in the present report employing transverse pin discharge has resulted in high current density, it was aptly named transverse arc array laser. It has successfully demonstrated lasing action in nitrogen gas, for which the high-gain 337 nm line was obtained.

This study show that the new arc array discharge circuit is capable to produce laser output due to its fast discharge characteristics. More importantly, it has demonstrated a new way of electrical discharge pumping method that can be scaled up to higher energy coupling through arc discharge. Further work is needed to scale up the input energy needed to pump gases to higher state of ionisation for output in the VUV and soft x-ray region.

This new pumping method is expected to be a viable alternative for pumping VUV and XUV lasers. Its advantages lied in the enormous scalability in terms of discharge energy and gain volume. The energy can be scaled by varying the discharge parameters of each individual pin, such as voltage and capacitance, which is relatively simple in a transverse discharge. The gain volume can be increased by simply adding more pins to the array along the optical axis.

In the present discharge method, the greatest design challenge is the isolation and synchronization of the discharge. This is important to ensure the pins discharged uniformly at a desired pumping energy. The energy of a charged capacitor must release its energy to their respective pins and not to their neighboring pins. All the pins must also fired at the same time in order to obtain a large active volume and to ensure lasing.

The electrical circuit of the present experiment was designed to provide the requirements of isolation and synchronization. Every pin is fed by a separate capacitor, which is charged up separately by charge transfer from the storage capacitor. Although the storage capacitor is charged commonly, the isolation of different peaking capacitors were ensured by having separate by-pass resistor. All the discharge may be able to initiate simultaneously due to the common spark gap that governed the switching mechanism.

In the present experiment, results were obtain which directly proved that the proposed system is a viable and practical approach to obtain high brightness VUV and XUV lasers. This novel system had managed to deliver 1.4 mJ of nitrogen laser output

using 2 nF peaking capacitors and 1.2 mJ of optical energy when using 5 nF capacitors. Current pulse may go as high as 5 kA in less than 80 nsec.

The discharge waveforms suggest that actually two current pulses were present in the discharge and most of the laser energy was derived from the first current prepulse, which was relatively low in energy. This has led to low energy output of the laser since laser action was terminated before the arrival of the main pulse. This may seem unfavourable to a fast lasing scheme like N₂ laser. In other types of short wavelength laser, it may be useful to create a homogenous discharge column using the fast prepulse before the dumping of energy by the main pulse.

6.2 Suggestions for Future Studies

Although in the present study, the viability of the transverse arc array laser is demonstrated, more in-depth studies is needed to realize its practical applications. There are some aspects of circuitry which are not covered in the present studies. More efforts should be made to investigate the current distribution of the array. The presence of a discharge in a particular pin can be determined by measuring the current return of each pin.

More energy should be pumped in to obtain even higher current density. This may enable the laser to be operate at even shorter wavelength. From results obtained and the analyses carried out, the most effective way is to reduce the capacitance but at the same time increase the voltage to create a fast and yet high current pulse. From the

analysed results, it is shown that a stray capacitance of 40 pF is already enough for lasing, therefore it may be wise that to keep the capacitance low for a fast circuit and pump in higher voltage. Transmission line type capacitors such as coaxial cables may be used to replace the door-knob capacitor to accomplish the purpose. Consequently, a Marx generator may be needed for the very high voltage required.

Higher discharge current can also be obtained provided the laser had a fast discharge time. This will require the setup configuration to have the lowest inductance possible. New layout must be planned and the spark gap, which gives rise to significant inductance due to high magnetic flux density must be improved. Low inductance switching means, such as rail gap should be employed.

For the laser to operate in vacuum ultra-violet and XUV region, more stringent construction considerations of the laser chamber must be observed. The channel must be able to hold high vacuum in order to avoid impurities. Low pressure will also minimize reabsorption. New optics had to be sourced. As most conventional optical window and front surface mirror did not perform well on wavelength below 200 nm. New optical materials such as MgF and CaF should be used. Mirrors can be replaced by multilayer dielectric coated mirror. This will enable the setting up of an effective resonance cavity.

Different types of gases can be tested. Gases such as hydrogen, helium, oxygen, nitrogen, neon and argon are known to have emission lines below 200 nm. Furthermore, the gases are non-toxic and not corrosive, making them easy in handling and ideal sources of lasing gas. These gases should be tested in different discharge

conditions and the output be scanned through a broad spectral range to identify high gain lines. This is a vital work in order to discover new VUV and XUV laser lines.