LOW ENERGY ELECTRON BEAM EXCITED LIGHT SOURCES - VUV LIGHT EMISSION CHARACTERISTICS AND APPLICATIONS

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Abstract. Low energy (12keV) electron beam excitation of dense (≈ 1bar) rare gases and rare gas mixtures is used to generate vacuum ultraviolet radiation of specific wavelengths and time profiles. Pulsed (ns to µs), modulated (µs to s), and stable cw gas excitation can be performed regardless of the gas composition. Power densities from 0 to 100W/cm^3 (cw, modulated) or 10kW/cm^3 (pulsed), respectively, can be achieved within the same system.

1. INTRODUCTION

Plasmas of atmospheric gases, most commonly rare gases or rare gas mixtures, but also nitrogen, are frequently used for efficient and brilliant ultraviolet (UV) or vacuum ultraviolet (VUV) light generation. Due to the high reaction rates at elevated gas densities, energy transfer processes, molecule formation and plasma chemistry plays a dominant role. Light emission thus never occurs on the primarily excited ground state transitions of the free rare gas atoms. Excitation energy is rather funneled into specific excimer levels, which can be chosen by gas composition. Due to this energy funneling process, light sources based on e.g. pure rare gas excimer transitions can reach very high efficiencies of the order of 40%. In their vast majority, these light sources are based on dielectric barrier discharges (DBD) [1], and commercially used for ozone generation, water treatment and surface modification [2], since they are easily scalable to large surface areas and large total power output. In this type of discharges, a high pressure glow discharge is ignited and terminated on an insulated electrode. In this way no arc is developed, which would heat up the gas to temperatures which would destroy the rare gas molecules. In an equivalent way, excimer lasers are operated in a short pulsed mode, driving a nanosecond glow discharge in pre-ionized rare gas-halogen mixtures. However, despite their high efficiency, dielectric barrier discharges have the disadvantage for general use to be temporally and spatially unstable. Focusing the emitted light to well defined spots is usually not possible, except in very specific setups [3]. In general, due to their high excitation energy, a pure glow discharge which does not eventually convert into a hot arc, is difficult to sustain in rare gases, since the electrons have to be generated and accelerated in the discharge field to excitation energy levels, however must not reach the ionization energy in an significant amount. Tailoring the electron energy distribution function within the discharge hence becomes of paramount importance. Nevertheless, cw rare gas excimer light sources have been developed, like corona discharges [4] or micro hollow cathode discharges [5].

A very general way of excimer formation is electron beam excitation, where a high energy electron beam is generated in a vacuum region of the setup and sent through a thin, vacuum tight membrane into the high pressure gas. Here, no electron multiplication is needed to sustain the plasma, since the electrons are provided by an external source. The attention can therefore be focused on gas kinetics and plasma chemistry in order to achieve maximum light output. Furthermore, power densities can be driven into the MW/cm^3 without the problems of streamers and arcing. The first excimer lasers were

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