ELECTRON BEAM INDUCED LIGHT EMISSION

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Abstract. Electron beams with a particle energy of typically 12 keV are used for collisional excitation of dense gases. The electrons are sent through ceramic membranes of only 300 nm thickness into gas targets. Excimer light emission from the pure rare gases and from gas mixtures are studied for the development of brilliant VUV and UV light sources. The application of the technology for gas kinetic studies is described and its potential for building very small electron beam pumped lasers is discussed.

1. INTRODUCTION

Collisional excitation of atoms and molecules by electrons is a key process in all low temperature plasmas. Two conditions can be distinguished. In one case the electrons gain their energy from an electrical field in the plasma. In the other case they are injected into the plasma and loose energy continuously until they are thermalized. The two conditions refer to gas discharges and electron beam excitation, respectively. In nature they are found for example in the form of the lightning stroke and the aurora borealis.

In practical applications such as plasma light sources, arc- and fluorescent lamps, the concept of discharge excitation has dominated over the last century whereas gas excitation and plasma formation by electron beams had almost exclusively been used for fundamental research and in some high power laser or plasma devices. About ten years ago the authors have introduced the concept of low energy electron beam excitation of dense gases for both fundamental research and practical applications [1]. It revisits experiments which had been performed in the late 18 hundreds by P. Lenard [2]. He had sent electrons through thin aluminium foils (sometimes called “Lenard-windows”) into dense gases. Our key innovation was to replace the aluminium windows by extremely thin (300 nm) and vacuum tight ceramic membranes, silicon nitride or combinations of silicon nitride and oxide, in particular. Those membranes can be manufactured on silicon wafer frames using solid state technology.

2. GENERAL ASPECTS OF LOW ENERGY ELECTRON BEAM INDUCED EXCITATION OF DENSE GASES

The basic concept of all experiments described here is shown in the inset of Fig. 1. A beam of typically 12 keV electrons is sent from a vacuum part of the system through a 300 nm thick ceramic membrane into a gas target. The electrons are slowed down predominantly by inelastic Coulomb collisions with the electrons in the membrane and the gas, respectively. The energy loss along the trajectory of the individual electrons may be described by the Bethe formula. However, angular scattering is an important process which strongly influences the spatial distribution of the power density deposited in the target as well the overall size of the beam excited volume. Therefore, numerical modelling has to be used to describe the energy deposition precisely. Scaling laws are available from the literature for a limited energy range [3]. They show that the energy deposition depth r_E of an electron beam with particle energy E in the 10 keV range scales like $r_E = \alpha E^n$. The exponent n

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