Spatial Distribution of Fluorescent Light Emitted from Neon and Nitrogen Excited by Low-Energy Electron Beams ◇

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The spatial distribution of the densities of excited and ionized species created by an electron beam in dense gases is an important information necessary e.g. for gas kinetic studies [1] and for the development of electron beam pumped lasers and light sources [2]. In this study side-view intensity profiles of fluorescent light were measured for neon and nitrogen excited with 12 keV electron beams at gas pressures from 250 to 1400 hPa. A CCD camera (OMA vision, EG&G PAR) was used to register the spatial distribution of the intensity of the fluorescence. The camera had 512 x 512 pixels and was operated in the 18-bit gray-scale mode. The camera was gated observing light which was emitted within a 200 ns time window synchronized with 300 to 500 ns electron beam pulses of 2 to 5 kHz repetition rate.

The main contribution to the detected intensity was due to 3p → 3s transitions in atomic neon and, in case of nitrogen, from $C^3\Pi_u \rightarrow B\ ^3\Pi_g$ transitions in molecular nitrogen. As an example, digital images of the fluorescent light from neon excited with electron beam is shown in the upper row of Fig.1 (inverted grey-scale). Intensity profiles were extracted from the digital images using the ImageJ software. Fig. 1 (bottom row) shows intensity profiles along the electron beam axis obtained from the corresponding images above.

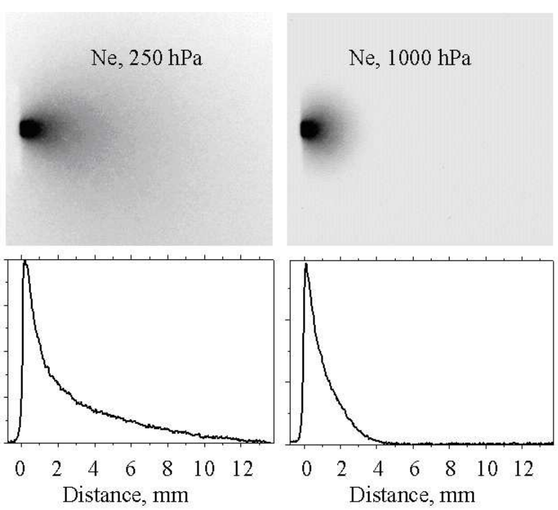

Fig. 1: Upper row: images of fluorescent light from electron beam excited neon (side view). Bottom row: Intensity profiles along the electron beam axes extracted from the images above.

The measured intensity profiles were compared with results from numerical Monte Carlo simulations of electron stopping and scattering. A publicly available [3, 4] program CASINO v2.42, which performs three-dimensional simulations of electrons interacting with solid targets was used here to calculate the spatial distribution of energy deposited by the primary electrons in the entrance foil and the target gas. The energy deposited in the gas target is split between excitation energy of the target atoms, ionization energy and the kinetic energy of secondary electrons produced in ionizing collisions. Recombination and subsequent optical transitions lead to the emission of visible light. This light, however, was not registered here since it is emitted on a time scale which is long compared with the 200 ns observation time of the gated camera. We deliberately excluded this light from our study since it can be strongly influeced by impurities or complex gas kinetic processes in the target gas (see e.g. our contribution "Energy transfer processes in neon hydrogen mixtures excited by electron beams" in this report).

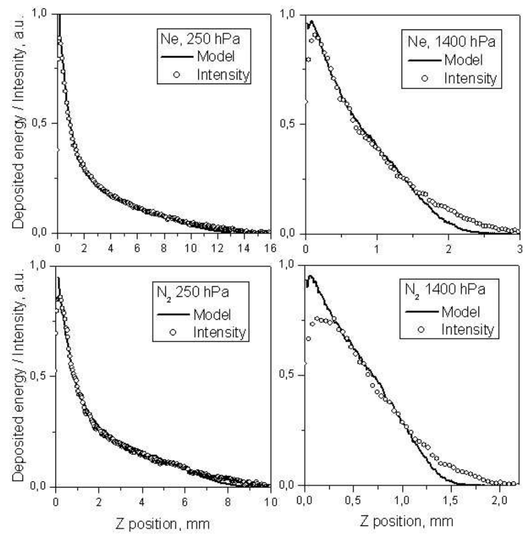

Fig. 2: Intensity profiles of fluorescent light and simulated energy deposition profiles along the electron beam direction in neon (upper row) and nitrogen (bottom row).

The other light producing mechanisms are collisional excitations of target atoms directly into the upper levels of the observed optical transitions both via collisions of the primary and the secondary electrons. Since the energy distribution of the secondary electrons is much better matched with the energy dependence of the excitation cross sections of the upper levels, most of the light observed here is produced via these secondary electrons. Based on stopping- and electron scattering data for neon and nitrogen it can be shown that the secondary electrons deposit their energy locally with respect to the spacial resolution of our experiment. Therefore, if the light emission produced directly by the primary collisons and the light produced via the intermediate step of producing secondary electrons are both proportional to the primary energy deposition, the light intensity should be directly proportional to the en-

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ergy loss of primary electrons which can be modelled using the CASINO program. The extension to which this assumption is valid was testet by the experiments described here.

A comparison of neon and nitrogen fluorescence data with the numerical calculations (see examples in Figs. 2 and 3) shows a close correlation between the light emission and energy deposition data for a rather wide range in the target gas.

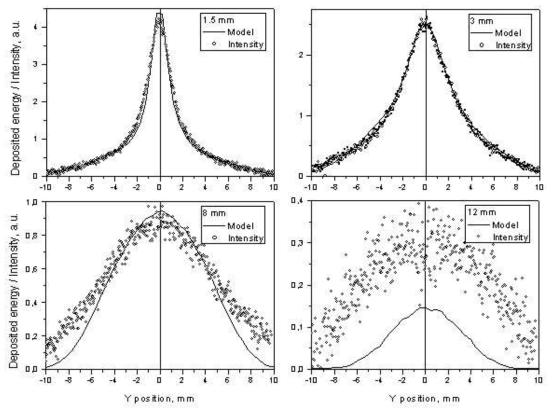

Fig. 3: Intensity profiles of fluorescent light and simulated energy deposition profiles perpendicular to the electron beam for a neon pressure of 250 hPa.

The main discrepancies appear in the vicinity of the entrance foil and at the rim of the excited gas volume. The first discrepancy is very likely just due to the limited resolution of the optical imaging and, in part, due to the fact that the simulated electron beam profile was somewhat different from the actual beam profile. The nature of the discrepancy near the rim of the excited volume may have to do with the energy dependence of the excitation cross section but the trend and the quantity of the effect is not yet understood. The relatively good correlation of experimental and simulated profiles, however, demonstrates that CASINO can also be used for calculating spatial distributions of excited species in a gas target to a precision which is sufficent for most practical applications.

References

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