Conversion Efficiencies of Electron Beam Energy to 337 nm Light Originating from N_2 $C\ ^3\Pi_u$ excited with Continuous Electron Beams

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The study of ultra high energy cosmic rays is a research topic of high interest. When interacting with the Earth's atmosphere the primary cosmic ray particle transfers its energy in a cascade of collisional processes which lead to the formation of a large number of secondary energetic particles. Finally, low energy electrons and positrons carry a significant part of that energy and excite molecules in the atmosphere with large cross sections. The optical deexcitation of those molecules can be observed as air fluorescence in the form of a so called extended airshower [1].

We try to simulate conditions which lead to air fluorescence in our laboratory. An experimental setup to study fluorescence of pure nitrogen under electron beam excitation has been constructed. A continuous electron beam ($8\ \mu A,\ 12\ keV$) from an electron gun was sent through a thin ceramic membrane [2] into a gas cell filled with pure nitrogen at pressures ranging from 150 to 1000 hPa. Fluorescence spectra of N_2 (Fig. 1) recorded for a wavelength range from 200 nm to 1200 nm show in addition to the $C\ ^3\Pi_u$ bands also some bands which could be related to the otherwise rarely observed Gaydon-Herman green System [3]. The spectra also show, that the gas is free from impurities.

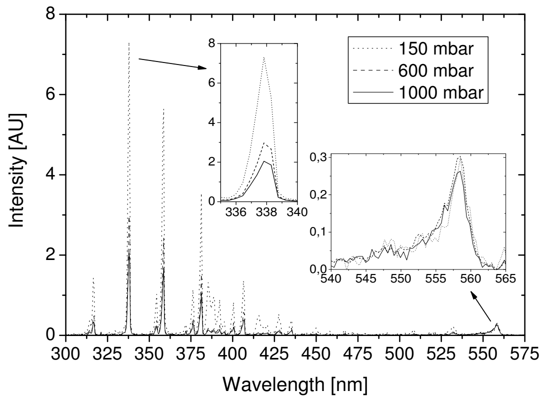

Fig. 1: Spectra of electron beam excited N_2 at three different pressures. The effect of quenching can be seen at the 337 nm transition (left insert). The right insert shows a magnification of the Gaydon-Herman green transition at 558 nm, which seems to be unaffected by the pressure change.

Furtheron, the absolute photon flux emitted from the $C\ ^3\Pi_u \rightarrow B\ ^3\Pi_g,\ v' = v'' = 0$ transition of N_2 at 337 nm and its pressure dependence have been measured. Using these data the conversion efficiency of electron beam power deposited in the gas to light power originating from that transition Φ_{337} was calculated.

An absolutely calibrated Si photo-detector was used to measure the power of 337 nm light emitted by the N_2. An interference filter (only transmissive around 337 nm) was used to separate the observed transition from all other transitions and the background light. The excitation power was determined by measuring the electron beam current after transmission through the membrane using a Faraday cup combined with a simulation of the residual energy using the program package Geant4, taking the energy loss of the electrons in the foil and backscattering of electrons from the gas volume into account [4] [5].

A problem concerning the 337 nm light-power measurements was that the membrane reflects light. Therefore, the Si photo-detector detected additional light which was reflected off the membrane, leading to an overestimation of light emitted into 4π. This issue was solved by measuring the reflectance of the membrane in the observed wavelength range and correcting the light signal accordingly. Another aspect is that the light emitting volume becomes large at reduced pressures. Therefore, the light source could no longer be treated as being point-like. However the spacial distribution of the light emitting volume could be simulated using the program Casino [6] and the detector signal was corrected using these simulation data. The final efficiency results are shown in Fig. 2.

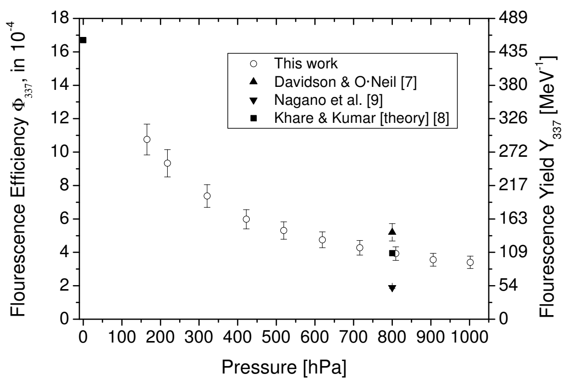

Fig. 2: Conversion efficiencies for the 337 nm emission from N_2 at various pressures. Efficiency Φ_{337}: ratio of power of light emitted to electron power deposited in the gas; and Yield Y_{337}: emitted photons per deposited MeV in the gas.

The efficiencies Φ_{337} are strongly pressure dependent (see Fig. 1 and Fig. 2) as predicted due to self quenching of N_2. The measured values are in reasonable agreement with previously published values from other groups [7], [8], [9].

References

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