Topic number: 5
Plasma diagnostics

Thomson, Raman and Rayleigh scattering on atmospheric plasmas

A.F.H. van Gessel*, E. Carbone, A. Pageau, P.J. Bruggeman,
J.J.A.M. van der Mullen

Department of Applied Physics, Eindhoven University of Technology,
P.O. Box 513, 5600 MB Eindhoven, The Netherlands
***a.f.h.v.gessel@tue.nl**

Introduction

Atmospheric pressure plasmas are the subject of growing interest, due to their applicability in many fields, including material processing, surface treatment and medical applications like wound healing and bacterial inactivation [1]. The discharges have relatively low gas temperatures and are non-LTE, and have the practical advantage that there is no need for a complicated vacuum system.

Plasma sources

In this paper we describe active spectroscopy measurements performed on two types of atmospheric pressure plasma's: a surfatron microwave discharge and a pulsed RF jet. In the case of the surfatron microwaves of 2.45 GHz are coupled into the plasma via a surfatron launcher device [2]. The plasma is sustained inside a capillary tube.

In the RF jet a ring electrode is mounted around a capillary tube, and a grounded electrode is positioned after the end of the tube. The electrode is connected to a high voltage RF power source (15.6 MHz), which is pulsed such that the discharge is switched on about 5% of the time.

As a gas mixture we use mainly helium or argon, with a small amount of oxygen.

Laser scattering

Three types of laser scattering are monitored: Rayleigh scattering (scattering on heavy particles), Thomson scattering (scattering on free electrons) and Raman scattering (scattering on molecules). We use a laser beam from a pulsed Nd:YAG laser (532 nm), which is focused inside the plasma near the end of the capillary tube.

Rayleigh Scattering is used to determine the gas temperature T_g. The intensity of the signal is proportional to the heavy particle density, which–with known pressure–gives T_g.

Thomson Scattering is used to determine the electron temperature T_e and the electron density n_e. n_e is proportional to the intensity of the signal, while T_e is provided by the Doppler broadening. The Thomson signal is very weak, and can easily be obscured by the Rayleigh signal and false stray light. The Thomson signal however is much more Doppler broadened than the Rayleigh signal, which makes it possible to filter out the Rayleigh signal by applying a notch filter. This filtering is done optically by the use of a Triple Grating Spectrometer (TGS) [3].

The third type of laser scattering is *Raman Scattering*, mainly from O_2 and N_2. It is used for the calibration of the wavelength of the TGS and the absolute intensity. The intensity needs to be absolutely calibrated in order to calculate the electron density from the Thomson signal. The Raman signal can also be used for determining the temperatures and densities of O_2 and N_2. Since the experiments are done in ambient air, Raman scattering is always present. Separating the Thomson signal from the Raman signal is done by a specially designed fitting process. An example of a Raman signal is shown in figure 1. An example of a Thomson signal with a superimposed Raman signal is shown in figure 2.

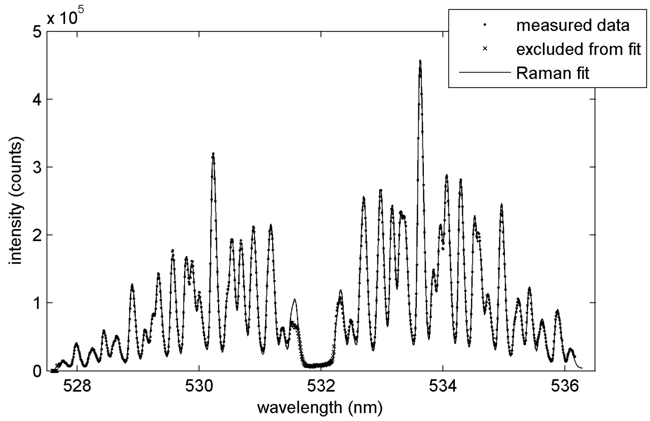

Figure 1. Raman signal of ambient air at room temperature (300 K). The fit is used to calibrate the wavelength and absolute intensity of the setup.

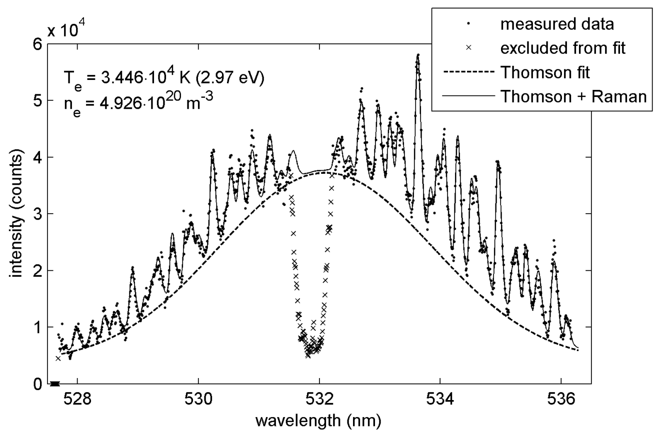

Figure 2. Thomson signal with superimposed Raman signal of a surfatron plasma with argon. The Thomson signal has a Gaussian shape, where the width gives the electron temperature and the intensity the electron density.

References

[1] L.J.M. van den Bedem, R.E.J. Sladek, M. Steinbuch and E. Stoffels, conf. proc. 27th ICPIG 18 (2005)

[2] M. Moisan, Z. Zakrzewski and R. Pantel, J. Phys. D: Appl. Phys. 12, 219 (1979)

[3] N. de Vries, J.M. Palomares, W.J. van Harskamp, E. Iordanova, G.M.W. Kroesen and J.J.A. van der Mullen, J. Phys. D: Appl. Phys. 41, 105209 (2008)