Tangential and Normal Electric Field Imaging using Mueller Ellipsometry for kHz driven Atmospheric Jet in Controlled Environment

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Imaging Mueller Ellipsometry is applied for the kHz-driven atmospheric pressure plasma jet (APPJ) to measure electric fields in a controlled environment to study the effect of different gas mixtures. The method exploits the electro-optic effect of dielectric BSO and Fe:LiNbO$_3$ crystals to visualize the induced electric field. This field is present due to charges deposited on the target surface by the APPJ. This induces a local change of refractive index according to the Pockels effect. For the first time a Fe:LiNbO$_3$ crystal is examined under exposure of an APPJ, which reveals imaging about the tangential field components.

1. Introduction

The field induced on surfaces as well as the charge transferred to a target are key parameters for the control of any application of atmospheric pressure plasma jets (APPJ). These parameters are in particular strongly dependant on the composition of the surrounding atmosphere in which the APPJ is expanding.

Using the Pockels effect it is possible to measure electric fields induced in dielectric targets. This can be imaged by measuring the retardance light experiences as it travels through the crystal. Electric fields are induced by charges deposited by the APPJ, which is operated at 2 kV with a 30 kHz sine wave. Every positive half period a guided ionization wave is generated and deposits charges at the surface. These are removed with a weak back discharge when the voltage polarity changes [1].

Mueller Ellipsometry is a more general form of Ellipsometry, since it allows depolarization of the light by the sample. As such a complete measurement includes information about the optical properties of the target regarding dichroism, retardation and depolarization. This is important to correctly describe what is happening in the target when it is in contact with the guided ionization waves.

2. Imaging Mueller Ellipsometry and experimental setup

Figure 1 shows the obtained Mueller matrix of BSO after impact of the ionization wave created by the APPJ. Using the differential decomposition method the measured Mueller matrix is analysed to obtain the optical properties of the used crystals. As the light travels at normal incident through the target the induced linear retardance relates to the normal electric field component when the BSO crystal is used. It relates to the tangential component when using Fe:LiNbO$_3$. This is due to the respective crystal structure and orientation, i.e. cubic 23 symmetry for BSO and trigonal 3m for Fe:LiNbO$_3$, while both have a z-cut orientation.

The normal component of the field is strongest at the impact point where the charges are deposited. This is visible in the induced retardance, visible in the matrix elements (3, 4) and (4, 3). The tangential field would show a larger spread within the crystal (figures not included). The images are an average throughout the thickness of the crystal, which is 0.5 mm. The APPJ is targeting the crystal at 45 degrees horizontally and is positioned on the left hand side of the figures. Both the APPJ and target are within an airtight glass cell which allows for measurements in a controlled environment.

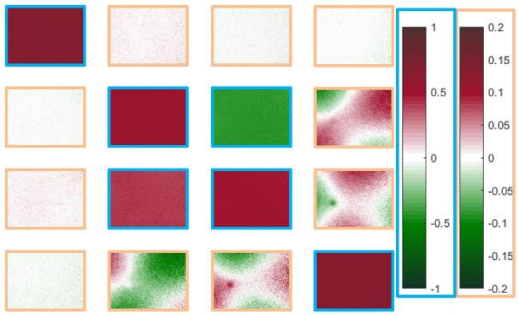

Figure 1: The measured Mueller matrix (rad) of BSO under exposure of the APPJ, after impact of the guided ionization waves. Using 1μs exposure time and 6.7 x 8.9 mm^2 image size.

We have already performed an extensive parametric study with a jet expanding in the room air [2]. This new study investigates the normal and tangential surface field with a similar APPJ in a controlled gas environment.

3. References

[1] E. Slikboer, O Guaitella, A. Sobota, Plasma Sources Sci. Technol. **25.3** (2016) 03LT04

[2] E. Slikboer, E. Garcia-Caurel, O. Guaitella, A. Sobota, Plasma Sources Sci. Technol. **26.3** (2017) 035002