Dielectric Probe for Fully Vectorial Analysis of Electric Field

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***Abstract*— This paper describes the achievements of electric field characterization performed with an electro-optic probe. The millimeter sized sensor allows the mapping of the field vector components as well as their temporal evolution. The very low invasive measurement is ensured over an ultra wide bandwidth (30 Hz – 18 GHz) and offers a dynamics exceeding 120 dB.**

Keyword: Electric field measurements, Electro-optics, Vectorial analysis, UWB, HPEM.

I. Introduction

The exhaustive analysis of the electric (E) field is required for many applications such as antenna radiation pattern, electromagnetic compatibility, on chip diagnostic or even in bioelectromagnetism. The rigorous E-field characterization implies that each component of the field vector have to be actually known as a function of the time in the considered volume of interest. Among the numerous techniques allowing the E-field assessment (*e.g.* antenna, bolomoter, infrared thermography, ...), only passive antennas and electro-optic (EO) probes provide a linear response, which is furthermore selective to the field vector components. Although metallic sensors are mainly used thanks to their high sensitivity and their technological readiness level, they remain quite invasive and frequency bandwidth limited. Pigtailed EO probes are developed since the beginning of the century. They offer an intrinsic bandwidth covering more than 9 decades of frequency and are fully dielectric. Moreover, the response of such transducers can lead to the simultaneous measurement of several field vector components [1]. Finally, EO technique is applicable in severe environments (temperature variations, *in situ* characterization in fluids or plasmas, partial or total discharges).

II. Electro-Optic Sensor

The EO probes are based on the Pockels effect which operates in non-centrosymetric crystals. This EO effect linearly links the refractive indices variations δn of the crystal to the electric field vector $\vec{E}$ [2]:

$$\delta n = \vec{K} . \vec{E} \qquad (1)$$

This latter equation involves the sensitivity vector $\vec{K}$ depending on the crystal transducer and its orientation relatively to the laser beam which probes the E-field induced δn. While The modulus of $\vec{K}$ gives the sensitivity, its direction defines the component of $\vec{E}$ which will be probed. In the particular case of isotropic crystal (<111> cutted), two sensitivity vectors $\vec{K}_x$ and $\vec{K}_y$ allows the simultaneous and balanced measurement of the transverse components E_x and E_y. The two informations are carried out via the induced polarization state modulation (PSM) of the laser beam crossing the crystal. The PSM is treated and analyzed with a servo-controlled optoelectronic instrument ensuring a reliable measurement whatever the temperature environment is. The EO probe itself consists in a smart optical arrangement including the crystal, a gradient index lens and a waveplate. This sensor is fully dielectric and millimeter sized (see Fig.1a). The performances of the EO unit are as follow: a minimum detectable field of 0.1 $V.m^{-1}.H^{-1/2}$, a dynamics exceeding 120 dB, a bandwidth spreading up to 18 GHz, a selectivity greater than 50 dB and a spatial resolution of 1 x 1 x 5 mm^3. Current improvements concern the sensitivity enhancement (down to 1 $mV.m^{-1}.H^{-1/2}$) and the simultaneous analysis of the three components of the E-field achieved with a single EO probe. Some vectorial field mappings will be presented during the conference.

III. Electric Field Vector Characterization

As an example of the EO probe potentialities, Fig.1b illustrates the polarimetric measurement of the E-field associated to an electrical discharge. This results demonstrates that the field behaviour is not only oscillatory but also rotational during the ionization process.

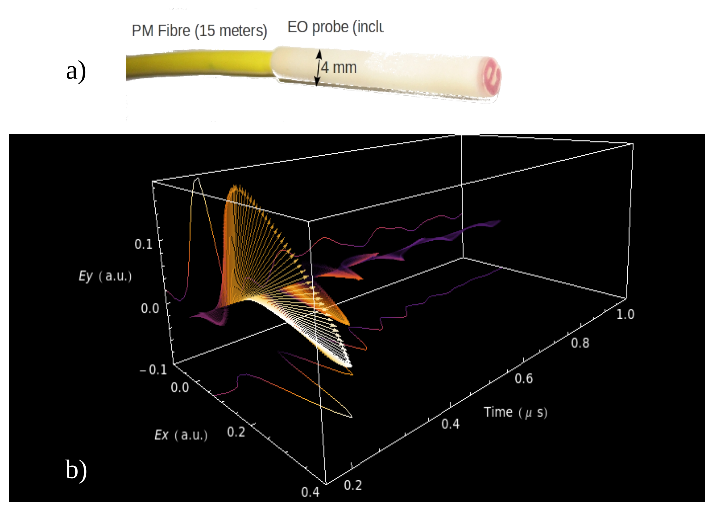

Figure 1. a) Picture of a multilayer dielectric coated EO probe. b) Transient evolution of the transverse electric field vector, associated to an electrical discharge. The single shot measurement is performed with the probe located in the vicinity of the discharge path.

References

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