

# Electric Field Measurements in Plasmas with E-FISH Using Focused Gaussian Beams

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Electric field induced second harmonic (E-FISH) generation is a non-linear optical phenomenon which has recently been re-purposed as a diagnostic for non-intrusive electric field measurements in plasma assisted systems [1,2]. The method essentially relies on the second harmonic response of a centrosymmetric medium (viz. plasma) to an externally applied electric field. Second harmonic generation is prohibited in the absence of this applied field due to symmetry considerations. Since its conception, this method has been used to measure electric fields in a multitude of plasma configurations such as ionization waves, DC corona, pin-to-plane, and surface barrier dielectric discharges as well as atmospheric pressure plasma jets [3].

A notable aspect of the above studies is the reliance on a plane-wave approximation to characterize the E-FISH signal even though focused laser beams are almost always used. The assumption is that the non-linear interaction occurs at the focal region of the pump beam, where the laser intensity is the highest, and the propagation may be satisfactorily approximated by a plane wave. In this study, we revisit this assumption by examining the effect of the length of the applied electric field profile on the E-FISH signal using a focused Gaussian beam description [4]. This is realized by performing theoretical simulations and experiments on a canonical electrode geometry comprising two parallel plates, separated by an interelectrode gap height of 5 mm (see inset of figure 1b) below). A uniform electrostatic field is applied across the gap via a 2 kV DC voltage.

Figure 1 plots the E-FISH signal as a function of electrode length, where the experiments have been conducted using a 1064 nm, 3 ns pulsed laser with a pulse width of 3 ns. These results, obtained for 3 different Rayleigh ranges, clearly show that the signal is influenced by changes in the (DC) electric field well beyond the focal region, exhibiting oscillations of decreasing amplitude as the electrode length is increased. This runs contrary to earlier expectations (on the signal origin) based on the plane-wave approximation, and can lead to inaccuracies in both the magnitude and spatial resolution of an electric field measurement. Further analysis shows that this behaviour is due to intrinsic phase variations in the focused laser (far) field, more specifically the Gouy phase shift, which are not captured by the plane-wave description [5]. Incidentally, similar effects of the Gouy phase shift have also been well-studied in the second and third harmonic generation microscopy literature [6].

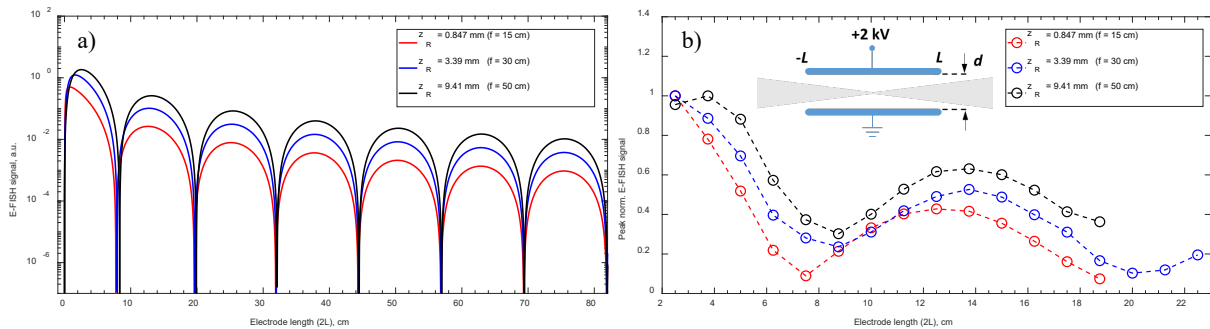


Fig. 1 E-FISH signal as a function of electrode length based on a) theory and b) experiments (peak-normalized values).

Two possible strategies for mitigating this issue – the first based on intersecting two laser beams to localize the signal, and the other on the use of numerical simulations to implement data corrections – will be discussed.

## References

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