Electric Fields Measurements in Surface Ionization Waves through Picosecond E-FISH in a Reflection Geometry

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Abstract: Surface-enhanced second harmonic generation is a technique to probe plasma-surface interactions. In-situ measurements of SHG signals during the propagation of a surface ionization wave will be used to characterize surface electric fields, surface charging, and crystallographic structure.

1. Introduction

Surface-enhanced second harmonic generation (SHG) is a surface-sensitive technique used to characterize the properties of surfaces of centrosymmetric materials and their interactions with different environments [1]. The origin of the SHG signal is the breaking of symmetry at the interface between two different media such as the interface between air and a metallic surface [2].

The technique has yet to be deployed during the interaction of a nonequilibrium plasma with a dielectric surface. In the presence of ionization waves induced by the propagation of a nonequilibrium plasma at the surface of a dielectric material, the surface SHG signal will be mixed with the electric field-induced second harmonic (E-FISH) signal from the surface plasma. Because of the latter, SHG techniques could provide additional information related to surface electric fields as well as surface charging. We discuss the design, characterization, and implementation of *in-situ* SHG and surface E-FISH measurements.

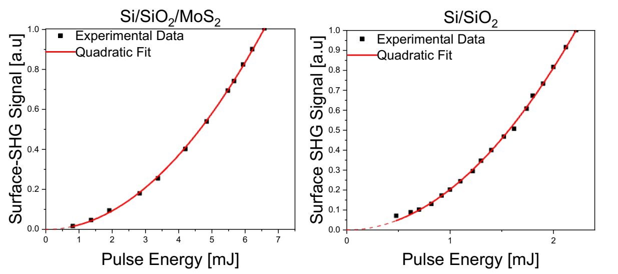

Fig. 1. Intensity of the surface-SHG signal vs pulse energy for different surfaces to verify a second harmonic signal.

2. Methods

The experimental setup is based on a mode-locked picosecond Nd:YAG laser (EKSPLA PL2231-50) operating at 50 Hz, with a pulse duration of 30 ps and a maximum output of 30 mJ at 1064 nm. The fundamental laser beam at 1064 nm passes through a half-waveplate, a polarizer, and another half-waveplate, enabling control over both the intensity and polarization of the incident laser beam. Subsequently, the laser goes through a focusing lens (FL), followed by a long pass filter (>850 nm). Interaction of the incident laser beam with the target surface produces a SHG signal generated at 532 nm. The latter beam, along with 1064 nm incident beam go through a dichroic mirror, which reflects 1064 nm and transmits 532 nm. A dispersion prism is then leveraged to spatially separate the leftover 1064 nm from the desired signal at 532 nm. Finally, another focusing lens focuses the 532 nm SHG beam into a photomultiplier tube fitted with a bandpass filter blocking any leftover 1064 nm signal reflected by the surface.

3. Results and Discussion

The results for SHG from different surfaces without any applied electric fields are pictured in Figure 1. The SHG intensity VS incident laser pulse energy plots depicted in Figure 1 show a quadratic dependence of the SHG signal intensity with the intensity of the incident laser pulse. The quadratic dependence with no offset nor linear term is expected from the textbook definition of a non-resonant second-order $\chi^{(2)}$ process (interface-induced three-wave mixing). This behavior was observed for Si with 95 nm SiO_2 with and without the presence of MoS_2 flakes.

These results hence confirm the ability of our experimental setup to characterize surface SHG signals from different reflective surfaces. The full paper will investigate changes in the SHG signal when electric fields are generated on top of the reflective dielectric surfaces. Additionally, leveraging the latter approach but with MoS_2 as the target surface, and an intensified camera as the endpoint detector, we expect to gain insights into defects formation during plasma treatment of MoS_2 containing semiconductor materials.

4. Conclusion

The ability to measure and verify the SHG signal from a variety of surfaces has been demonstrated, thus leading the way to time-resolved SHG measurements during surface ionization wave propagation across dielectric and semiconductor surfaces.

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