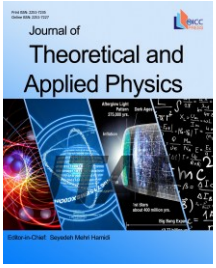


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Research Article

# Laser Induced Fluorescence Enhancement by $MgF_2$ Metasurface

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**Abstract**

We have experimentally examined the effect of all dielectric metasurface onto the laser induced fluorescence in flexible polydimethylsiloxane based structure. The host medium of the Rh6G dye achieved by spin coating over the two dimensional all dielectric $MgF_2$ structure. The spectral fluorescence response of the multilayer sample in four different incidence energies indicate that the field enhancement due to Electric and magnetic dipoles resonance can boost laser induced fluorescence. Adjusting the wavelength due to different unit cell size and also incidence laser power, can open new insights in developing low cost and ohmic loss less devices.

**Keywords:** Magneto-plasmonics; Plasmon; Laser induced fluorescence; Surface lattice resonance

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## 1. Introduction

Laser induced fluorescence (LIF) is a two-step process that involves absorbing a laser photon and then emitting a fluorescence photon from the excited state. For absorption, the laser wavelength (λ Laser) must match the permitted energy transition of the LIF-active molecule (atom). Only a fraction (ΦLIF) of stimulated molecules fluoresce, whereas the remainder relax and do not emit light.

When they relax back into the ground state, sometimes generate fluorescence quanta at longer wavelengths than the exciting laser wavelength, with a typical average stay in the excited higher state, known as the fluorescence lifetime. High detection sensitivity may be achieved by providing a good separation between laser and fluorescence wavelengths using high-quality optical filters or spectrographs. The fluorescence lifespan of a sample can be measured using femtosecond, picosecond, nanosecond, or microsecond lasers and can explained with electronic and vibrational states [1, 2].

In this decade, use of surface plasmon waves to enhance LIF introduce and shows until hundred-fold LIF enhancement. When fluorophore molecule comes into contact with plasmonic nanoparticles, a circumstance may emerge in which the frequency of the fluorescence emission and the frequency of the plasmon resonance coincide. Under such conditions, elastic scattering may result in an amplified emission at the same frequency as the fluorophore. This phenomenon is described as plasmon-enhanced fluorescence. Optimal plasmon-enhanced fluorescence requires a considerable overlap between the metal nanoparticle's localized surface plasmon resonance (LSPR) and the fluorophore's absorption/emission spectra. With a point of giving opened up signals for progressed strategies like surface-enhanced Raman scattering (SERS), tip-enhanced fluorescence (TEF), and other single particle fluorescence strategies, this apparatus has demonstrated its ubiquity [3-6] As talked about prior, the whole wonder of plasmon-enhanced fluorescence is based on the crucial guideline of the improvement of the electromagnetic field, owing to the coupling of the occurrence light recurrence with the recurrence of the surface plasmons, and it has an exceptionally solid reliance on the shape, estimate, and interparticle division separate in the metal nanostructures [7, 8]. In spite of plasmon as useful metal based surface waves, there is another metasurfaces based on dielectric nano layers which utilized for ohmic lossless optical components [9, 10], head of new generation biosensors [11, 12], sun oriented cells and photodetectors [13, 14]. These metasurfaces has picked up expanding consideration due to their less difficult manufacture utilizing common procedures, such as photolithography and electron-beam lithography, and on-chip and on-fiber collecting. A MS is an ultra-lean planar optical component composed of reverberating components that shows the capacity to control light at the nanoscale [15- 22].

Based on above mentioned categories, there are several reports on highly enhancement exceeding of LIF based on metallic metasurfaces names as plasmon induced florescence and there are no enough papers onto the dielectric metasurface usage in this useful field. Unless using photonic crystal slabs [23], semiconductor quantum dots [24], silicon based two dimensional structure [25] and so on.

Hence, there is an opportunity to explore highly LIF enhancement and also tuning based on all dielectric metasurfaces to discover ohmic loss and easy way building process. In this report, we use soft nanolithography to produce two dimensional metastructure and based on surface lattice resonance in these structures, investigate the LIF and the ability of tuning and controlling process.

## 2. Experimental part

To obtain the metasurface enhanced LIF, we create two flexible samples, S1 and S2, the difference between them was in dimensional of grating as shown in figure 2. S1 and S2 are two dimensional (2D) structures by soft nano imprint lithography technique onto polydimethylsiloxane (PDMS) [26].

After preparation of PDMS based mold, it coated with a thin layer of $MgF_2$ (15 nm) and Rh6G using a sputtering machine and spin-coating device in the last step in two samples. When the samples dry, we record LIF by using the second harmonic of the Nd: YAG laser, and at an angle of 90°, the fluorescence is recorded via a spectrometer covering all visible spectra with four different excitation energies from 0.13 to 1.95 mJ (Figure 1).

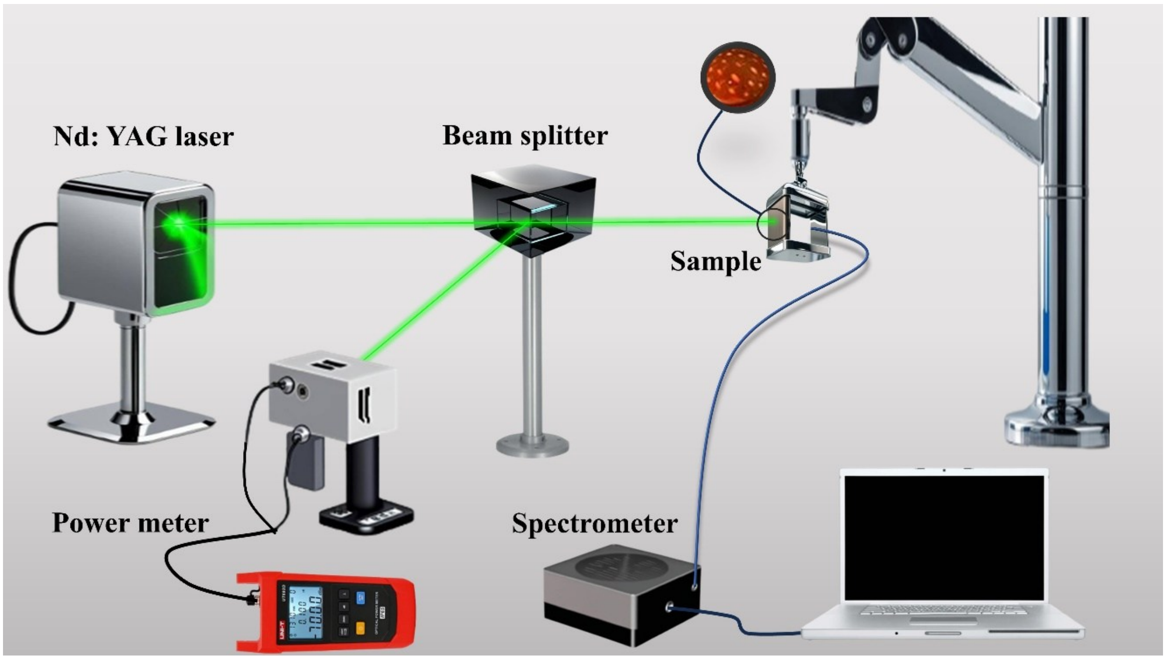


**Figure 1.** The schematic diagram of LIF recording setup from two dimensional $MgF_2$ sample

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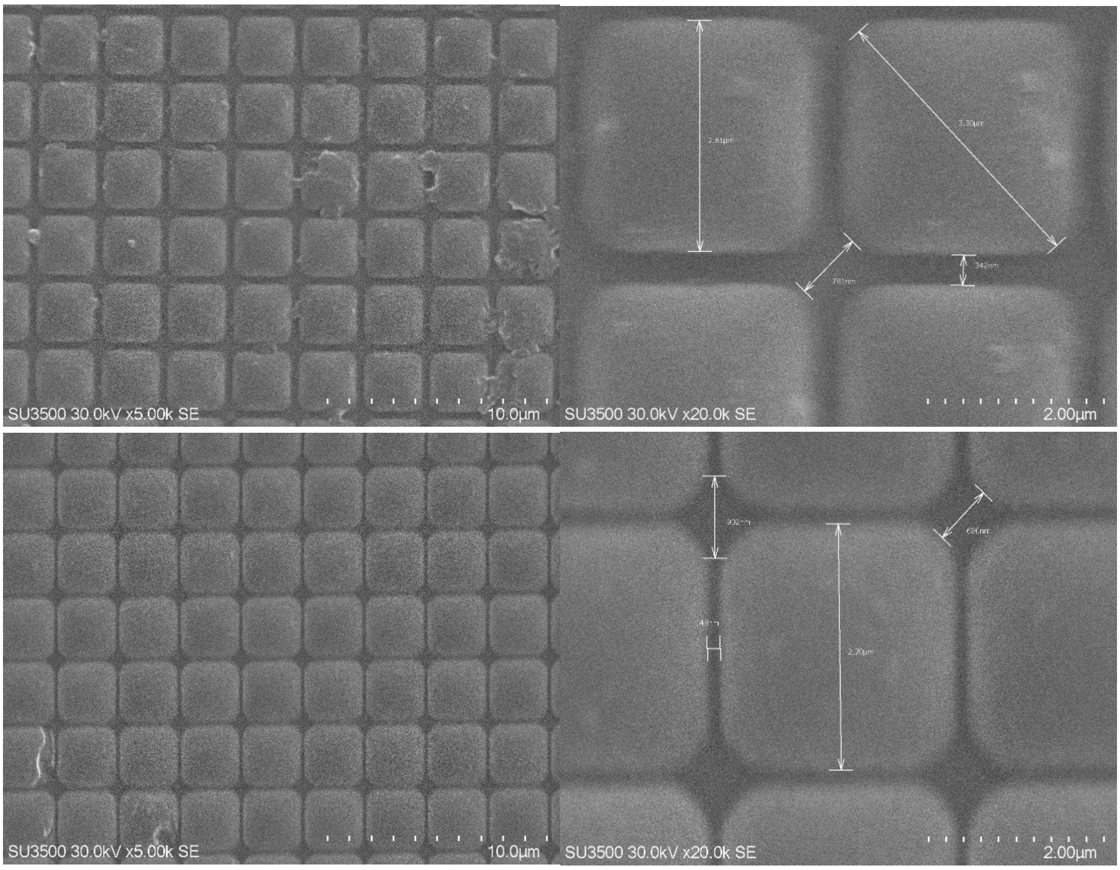


**Figure 2.** SEM image of (a) $S_1$ and (b) $S_2$ sample

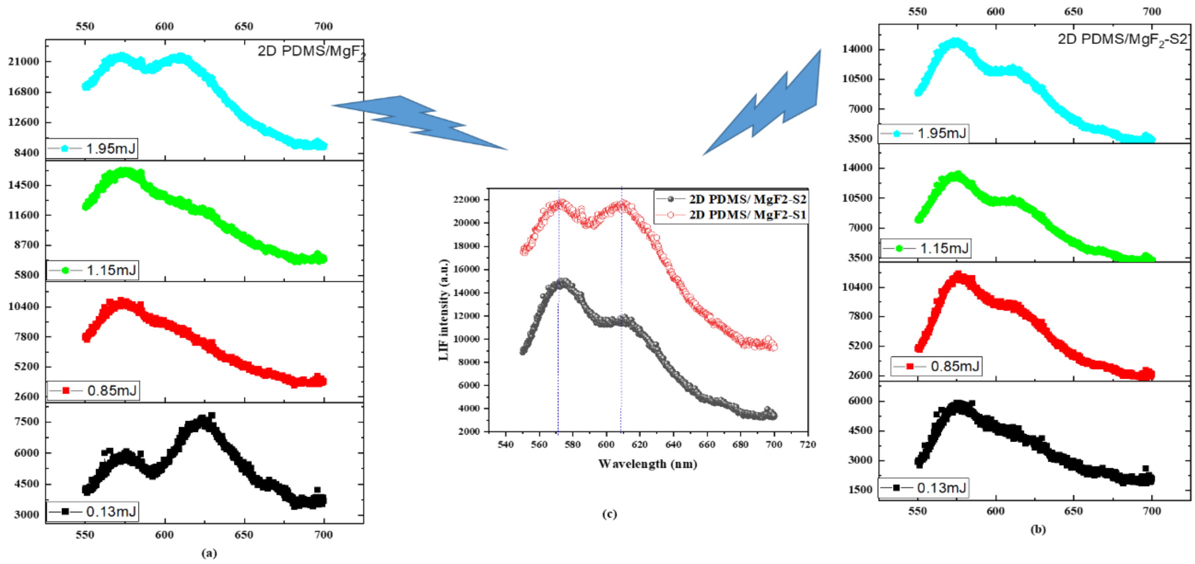


**Figure3.** Spectrum of the recorder fluorescence at 90 degree for different incidence energies for (a) S1, (b) S2 and (c) comparison between two samples at 1.95 mJ excitation power

## 3. Results and discussion

Scanning electron microscopy image of samples has been shown in Figure 2. As shown in this figure, we have a smaller size in the first sample which it means that that we must have better electrical and magnetic dipoles as ED and MD excitation.

In the foremost LIF window, we can see two prominent peaks in the spectrum which can be comes from the coupling of electric dipole (ED) and magnetic dipole (MD) of each nano rhombus in the unit cell with diffraction order of the periodic array. The ED and MD localization in the first and second resonance wavelength is dramatically supporting this fact as we show previously in [26].

10.57647/jtap.2026.2002.18

In these all dielectric samples, due to metasurfaces, we have ED and MD resonant modes which can enhance the optical field intensity at two SLR wavelengths in 570 and 610 nm. Now when we change the substrate and thus change the size of each nano rhombus, we must have difference in excitation wavelengths and coupling of them as well. The coupling in the first sample due to more matches of incidence wavelength to the size in any motif, is prominent and any ones can see resonance correspond to the ED appears in all of incidence energies and MD modes in higher wavelengths show red shifts in second sample.

## 4. Conclusion

In sum, all dielectric two dimensional structures as PDMS/$MgF_2$/Rh6G multilayer with different unit cells as the main substrates for LIF signal in the visible region. Our results show two peaks in 570 and 610 nm in the fluorescence spectrum due to the ED and MD modes in both samples and more efficient results in the sample with smaller motif and unit cell size due to better coupling. It means that all-dielectric metasurfaces can enhance the optical field intensity contribution when the incident and resonance wavelengths adjusted together which supports LIF enhancement in two mainly wavelengths.

**Authors Contribution**
Noor D. Abdulameer produces the samples and write the main text, Lazem Hassan Aboud and N. S. Shnan supervised and advised the project.

**Availability of data and materials**
Data were available by request from the corresponding author.

**Conflict of interests**
There is no any conflict of interest.

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