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Fluorescence enhancement with metamaterial mirrors

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Abstract. We experimentally demonstrate the strongly enhanced photoluminescence of the fluorescent molecules on the metamaterial mirror. The matematerial mirror can optimize the reflection phase to provide a large electric field for the 20-nm-thick active layer. Compared with the smooth gold plate, the experimental result shows a nearly 45 times enhancement.

1. Introduction

Metal enhanced fluorescence is to study the metal-assisted enhanced interaction between fluorophore molecules and light. By directly placing the active layers on varied metal structures, the fluorescence intensity can be enhanced and the fluorescence lifetime can be shortened. Research in this area includes designing suitable metal nanostructures, choosing proper exciting light and wavelength-matched fluorophore molecules or quantum dots and obtaining metal materials with better qualities. Many metallic nanostructures for enhanced fluorescence have been reported, such as the bowtie structures[1], metal-insulator-metal absorber structures[2,3] and the synthesis monocrystal gold nanoplates[4].
Using metamaterial mirror [5] to design the planar optoelectronic device is a kind of simple and outstanding technology. By changing the reflection phase among zero and π in a period, metamaterial mirror can control the spatial distribution of electric field in the thin active layers. In this study, we fabricate metamaterial mirror to obtain an enhanced electric field intensity in the 20-nm-thin active layer with fluorescent molecules. Compared with the smooth gold plate, the experimental result shows a nearly 45 times enhancement.

2. Materials preparation and sample fabrication

First thermolysis process is adopted to obtain monocrystal gold nanoplates. And then metamaterial mirror is fabricated on the monocrystal gold substrates by using focused ion beam. The groove depth is 85 nm and the width is 50 nm. The period is 150 nm. Then the ATTO633 dye(1μmol/L) and the PMMA solution with the 1:1 proportion is mixed. Finally the mixture is spin-coated on the samples and solidified by heating. The thickness of the active layer is 20 nm thickness. The SEM image of the device is provided in Figure 1.

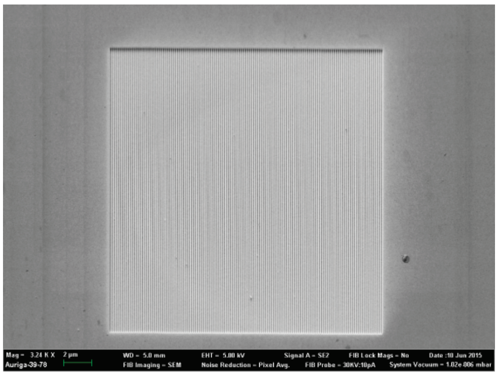

Figure 1. SEM image of the metamaterial mirrors.

3. Experiments and discussion

He-Ne laser (632nm) is used to excite the sample. The fluorescence is measured by spectroscopy via the dark-field microscope. The reflected exciting light is cut off by a 650 nm filter. The emission wavelength of fluorescence is 652 nm. From figure 2, we can see bright fluorescence of the sample under dark-field microscope.

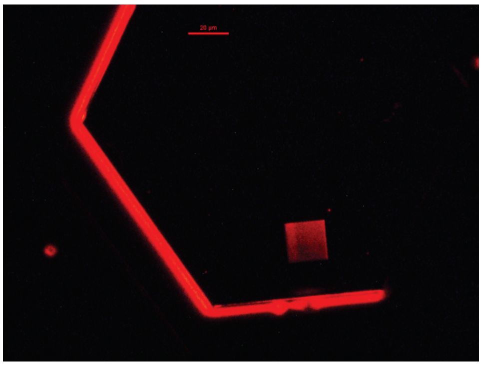

Figure 2. Fluorescence image under dark-field microscope.

The spectroscopy of the metamaterial part and the smooth mirror part are shown in Figure 3. The red line shows the fluorescence spectrum on the smooth gold film surface. And it just represents the background (BG). The black line is the fluorescence signal (SA) on the metamaterial mirror. It is obvious that the fluorescence is greatly enhanced by around 44.8 times using the metamaterial mirror.

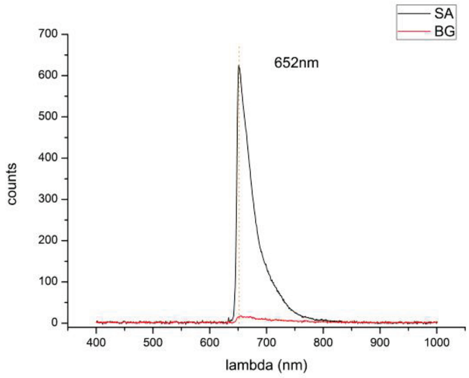

Figure 3 Experimental spectroscopy. The red line is the fluorescence on the smooth gold film and the black one is the result on the metamaterial mirror.

4. Conclusion

In summary, based on the metamaterial mirror, distribution of electric field above the metal surface can be engineered to greatly enhance the fluorescence. Compared with the smooth gold plate, the experimental result shows a nearly 45 times enhancement here. This enhanced light-mater interaction has tremendous potential in nanoscale emitter.

References

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