Tunable graphene-coated spiral dielectric lens as a circular polarization analyzer

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Abstract-We propose a tunable circular polarization analyzer based on a graphene-coated spiral dielectric lens. Owing to the geometric phase effect, the analyzer focuses circular polarization with opposite chirality while defocusing that with same chirality, producing spatially separated solid dot or donut shape fields, respectively. Moreover, distinct from the narrow working bandwidth of a traditional circular polarization analyzer, the focusing and defocusing effects in the analyzer are independent of the chemical potential of graphene, and depend only on the dielectric permittivity and the grating occupation ratio. Combined with the strong tunability of graphene plasmons, the operation wavelength of analyzer can be tuned by adjusting the graphene chemical potential without degrading the performance. The proposed analyzer could be used in applications in chemistry or biology, such as analyzing the physiological properties of chiral molecules using different circularly polarized waves.

Fig. 1. (a). Schematic view of the left-handed graphene-coated spiral dielectric lens. (b). The circular polarization extinction ratio of the spiral lens with respect to incident wavelength under various chemical potentials. The sensor length is $a=20$ nm.

The proposed tunable circular polarization analyzer based on graphene-coated spiral dielectric lens is shown in Fig.1(a). When a circularly polarized beam is focused onto axially symmetric plasmonic structure, the entire beam is transverse magnetic (TM) polarized with respect to the interface, enabling surface plasmon excitation.
from all directions and homogeneous plasmon focusing through interferences of these plasmon waves. A strongly confined solid spot will be obtained when the geometric phase produced by the spiral dielectric gratings cancels out the vortex wavefront of circularly polarized illumination (spiral structure and incident light owe opposite chirality) [1]. Conversely, an electric field with donut shape emerges due to the superposition of geometric phase and the vortex wavefront (spiral structure and incident light have the same chirality).

To simultaneously satisfy the phase matching condition in the excitation procedure and the constructive interferences condition in the focusing process, the relationship between the propagation constants of graphene plasmons on the dielectric gratings \( \beta_1 \) and on the dielectric substrate \( \beta_2 \) can be defined as,

\[
\frac{\beta_1}{\beta_2} = \frac{f \varepsilon_d + (2-f)\varepsilon_i}{\varepsilon_d + \varepsilon_i} = \frac{1}{2n+1}
\]

where the permittivities \( \varepsilon_d=1 \) and \( \varepsilon_i=11 \) correspond to the one of upper layer (air) and dielectric substrate. It can be seen that the focusing or defocusing effect only depends on the dielectric permittivity and grating occupation ratio \( f \), leading to the possibility of tuning operation wavelength by the graphene chemical potential without degrading the performance.

The differences of field profiles caused by the geometric phase effect of plasmonic lens for the illumination of light with chirality leads to its potential application as circular polarization analyzer [1-3]. If a detector with a fixed length \( a \) is placed in the vicinity of the focus, the detected signal can be distinct for RHC (Right-Hand Circularized) and LHC (Left-Hand Circularized) polarizations. In Fig.1(b) we illustrate the extinction ratios as functions of incident wavelengths with different chemical potentials (i.e. \( \mu_c=0.5 \text{ eV}, 0.6 \text{ eV} \) and 0.7 eV). The sensor length is fixed at \( a=20 \text{ nm} \).

The curves clearly show that for the plasmonic spiral lens circular polarization analyzer, the performance varies with the incident wavelength due to its intrinsic working mechanism based on constructive interference. For instance, at the chemical potential \( \mu_c=0.6 \text{ eV} \), the extinction ratio can be as high as 60 at \( \lambda=7.2 \text{ \mu m} \) with 3dB bandwidth is only 0.7 \( \mu m \) (from 6.9 \( \mu m \) to 7.6 \( \mu m \)). The intrinsic narrow bandwidth restricts the application of circular polarization analyzer, while it can be solved by applying various chemical potentials on graphene sheet. As rendered in Fig 1(b), the peak in extinction ratio spectrum can be shifted from 6.7 \( \mu m \) to 8 \( \mu m \) with almost constant values, giving rise to the great potential of analyzing chirality illumination with various frequencies.

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**REFERENCES**