Surface plasmon optics: from polarization control to negative refraction

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Abstract

We will show recent experimental results that demonstrate this link through structure designs and surface plasmon manipulations. In particular, the control of polarization states together with the generation of specific optical modes will be discussed. We will also show results that convey efficiently concepts from photonic crystals into surface plasmon optics.

1. Introduction

Surface plasmon optics is a continuously expanding field of research. Tailoring surface plasmons by controlling the design of metal surfaces at the nanometer scale has allowed addressing the intimate relation between structures and optical properties of coupled light [1,2]. There is currently a particular interest in the polarization properties of sub-wavelength transmitting structures, for possible implementation at the level of optical local addressing. For polarization imaging [3] or ultra-fast optomagnetic data storage for e.g., integrated optical systems capable of displaying specific states of polarization are looked for.

2. Plasmonic wave plate, chiral polarizer

In this context, we have developed plasmonic devices which show interesting polarization properties in the visible range. Two representative examples are the plasmonic optical wave plate and the chiral polarizer. The former resonant device is a single circular aperture surrounded by an elliptical grating that acts like a quarter wave plate, able to fully convert and tailor the state of polarization of the light. Experimental results and theoretical analysis show that the general procedure used does not influence the optical coherence of the polarization state and allows us to explore the surface of the unit Poincaré sphere by changing only the shape of the elliptical grating [4]. The chiral polarizer consists in a twisted plasmonic device –see Fig.1- which reveals, for the first time in the visible domain, that structural chirality can have a different optical manifestation than usual optical activity. Here, our analysis demonstrate how surface plasmons, which are lossy bidimensional electromagnetic waves propagating on top of the structure, can delocalize light information in the just precise way for giving rise to this subtle effect [5].

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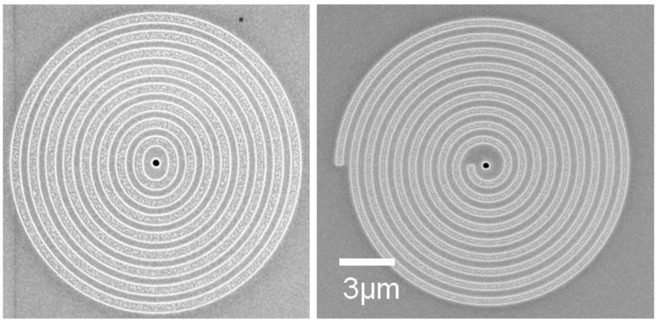

Fig 1: Plasmonic wave-plate (left panel) and chiral polarizer (right panel). The structures are fabricated on opaque Au film. The holes have a diameter smaller than 300nm.

3. Non-diffractive and helical beams

The polarization properties of our elements have been characterized by measuring the associated Stokes parameters. The fact that the light is transmitted only through a single sub-wavelength central aperture keeps the polarization coherence for transmitted light, allowing us to retrieve effective Jones polarization matrices.

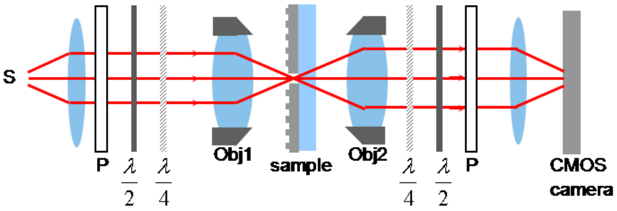

Fig 2:Sketch of the polarization measurement set-up. P, λ/2 and λ/4 correspond respectively to linear polarizer, half- and quarter wave-plates located in the input and output beams. The structures are placed within the telescope (objectives 1 and 2) and the signal is measured by a CMOS camera. The source S is a laser diode emitting at 785 nm.

In this polarization context, we demonstrate experimentally a simple method for preparing nondiffractive vectorial optical beams that can display wave-front helicity. This method is based on space-variant modifications of the polarization of an optical beam transmitted through subwavelength annular rings perforating opaque metal films where the vectorial character of the polarization must be accounted for. We show how these properties can be controlled by straightforward sequences of preparation and analysis of polarization states [6].

3. Surface plasmon beam steering and negative refraction

Finally, the discussion can be extended in the near-field. We analyze the propagation of surface plasmon beams through singly and doubly periodic metallic gratings both in real and Fourier spaces using high-resolution leakage radiation microscopy (LRM) –see Fig.3. Large beam steering effects are experimentally revealed by probing the isofrequency surfaces (IFS) related to propagating plasmonic Bloch waves inside the gratings. In particular, negative refraction is demonstrated close to the Bragg condition. We finally analyze how the local structure of the IFS can amplify the sensitivity of SP-based sensors [7].

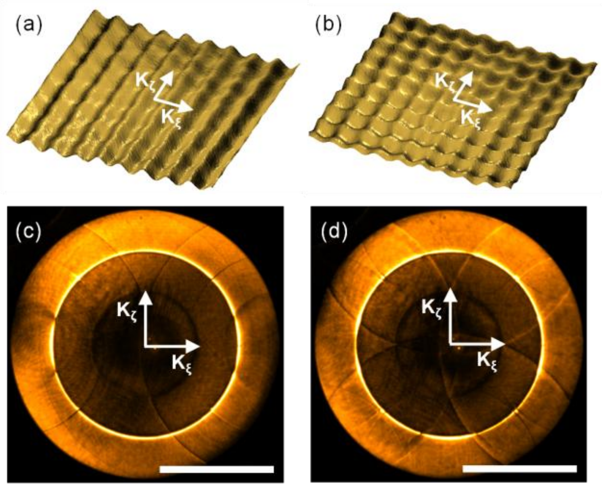

Fig 3: (a)+(b) Atomic force microscopy 5 × 5 μm2 images of the one-periodic and doubly-periodic gratings. (c)+(d) Corresponding IFS recorded in the Fourier plane of a LRM.

Our results show the possibility for controlling light both in the far- and near-fields through surface plasmon manipulations in the visible range. This confirms some of the interesting perspectives discussed recently in the field of plasmonics and in particular show that high metallic absorption loss in the visible are not necessarily detrimental for observing and tailoring a specific optical behavior of plasmonic elements.

References

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