A Phase–Change Metamaterial–Based Dynamic Beam Steering Device

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Abstract. The use of Phase–Change materials combined with metasurfaces is presented as a way to create novel reconfigurable beam shaping and beam steering devices working in the optical telecommunication regime (λ=1.55μm).

Introduction

The exploitation of the crystalline/amorphous electro–optical contrast of phase–change materials (PCM) for the provision of non–volatile memories is now well established [1]. On the other hand, metamaterials –or engineered structures having subwavelength inclusions of common materials– have shown the ability of manipulating light in a desired manner [2]. More recently, the combination of PCM materials with metasurfaces has been proposed to deliver novel reconfigurable photonic devices such as “perfect” absorbers, or infrared light modulators [3]. In this work, we have combined the phase–change material GST225 with metasurfaces to create an ultrafast dynamic beam steering device working in the optical telecommunication band. Our design is inspired by the reflectarray antenna technology in the micro–wave regime. The simplicity of our structure has allowed to successfully fabricate the device, and the first experimental look promising.

Reflectarray design and analysis:

Our reflectarray consists of periodically spaced antennas/light scatterers. Figure 1–A shows a diagram of the unit cell, where each antenna is made of a thin GST layer with a continuous metal layer underneath, and a metal patch antenna on the top. The working principle of the device is based on the fact that the phase response of an antenna can vary significantly across a resonance. When the GST layer is amorphous, a constant phase gradient can be imposed along the surface by varying the size of the metal patches (Figure 1–C). As shown in Figure 2–A, light reflected from the surface will therefore interfere constructively in a direction different from specular reflection. This phenomenon is known as anomalous reflection, and the resulting angle is given by [3]:

$$\sin \alpha = \frac{\Delta \phi \lambda}{2\pi d}$$

After crystallization, the GST layer becomes highly reflective and the resonant behaviour of the device elements is cancelled. As a result light is reflected according to specular reflection laws (Figure 2–B).

![Figure 2. Scattered electric field showing anomalous reflection when the GST layer is amorphous (A), and specular when the GST layer is crystalline (B).](Image)

Characterization (amorphous)

First experimental results reveal that:

- Specular reflection decreases and anomalous reflection (~36°) increases around λ=1500nm.

- The device is therefore working as expected in the amorphous phase.

![Figure 1. A) 3D sketch of a single antenna element (or unit cell). B) Phase response of a single antenna as a function of size of the metal patch, for both amorphous and crystalline states. C) Super-cell of the device (top), and final device (bottom).](Image)

Fabrication

The device was successfully fabricated using thin film deposition and E–beam lithography techniques. The image on the right shows the top patterned metal layer under the optical microscope

Conclusions

We have successfully designed a dynamic beam steering device by combining GST with metasurfaces. The PCM is protected against oxidation, and the simplicity of our design has allowed to successfully fabricate the device. First experimental results has shown that the device is behaving as expected when the GST layer is amorphous, and further work is required to measure the device in the crystalline state.

References

2. Yu et al., Science334 (6054): 331–332
3. T. Cao, OSA 6, p1580–1585 (2013)