A photonic crystal flat lens at optical frequencies

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Abstract

We report here the direct observation of light refocalisation through a photonic crystal superlens operating at optical frequencies. The superlens is etched in a III-V semiconductor slab and we directly visualize the propagation of the electromagnetic waves by using a Scanning Near-field Optical Microscope (SNOM). We directly evidence spatially, as well as spectrally, the refocalisation operating regime of the lens. At last, in light of the experimental SNOM pictures, we estimate the subwavelength resolution of the reported lens to almost $0.8\lambda_0$.

1. Introduction

Metamaterials can bend light in a direction opposite to that one predicted by the classical refraction laws and operate in a so-called negative refraction regime [[i]]. Under the stringent opto-geometrical conditions that permit to match this regime, a perfect lens that enables to break through the Rayleigh criterion of classical optics could be fabricated [[ii]]. However, if the feasibility of perfect lenses with centrimetic sizes was demonstrated at the microwaves frequencies since few years [[iii]], achieving this phenomenon at optical frequencies is a challenging task. As a matter of fact, reducing the operating wavelength of the perfect lens down to the visible range requires a miniaturization of the metamaterials at the nanometer scale as well as drastic improvements of the instrumentation tools.

In this work, we first face the miniaturization of the perfect lens by taking benefits from a photonic crystal [[iv]] etched in a III-V semiconductor and then challenges the direct visualization of the operating perfect lens by using a Scanning Near-field Optical Microscopy (SNOM) technique.

2. Direct observation of light refocalisation

We show on Fig.1a the Scanning Electron Microscope view of the fabricated photonic crystal lens which was preliminary designed to operate at λ=1.55µm and for the widest range of angle. A rib waveguide etched at its very end is used to mimic a point source emitting light inside the optical near-field of the lens and as depicted by the ray tracing on the figure (for a refractive index of the lens rigorously equal to -1), an image of the point source is expected on the other side of the lens. Next, we scan a near-field probe that consists in a tapered fiber optical at a few nanometer heights above the whole nanostructure in order to directly visualize the light propagation from the point source to the other end of the lens. The recorded near-field map is plotted on Fig.1b.

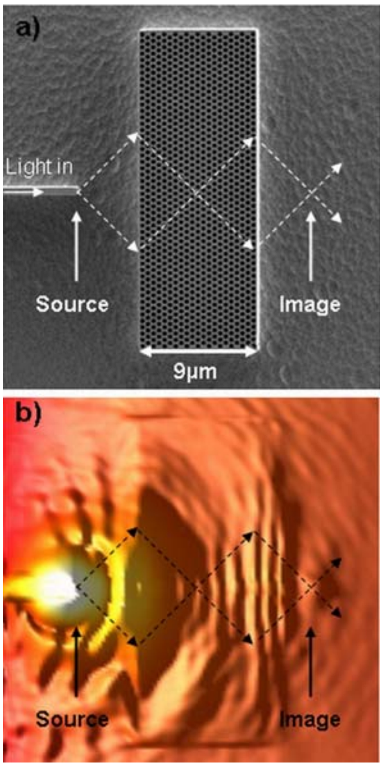

Figure 1: (a) Scanning Electronic Microscope picture of the fabricated photonic crystal lens and the input waveguide that mimics a source point in the vicinity of the lens. (b) Scanning Near-field Optical Microscope picture of the lens recorded for an input wavelength of λ=1525nm. For a better visualization of the small amplitude signals that evidence the electromagnetic waves propagation inside the nanostructure, an illuminated picture is plotted.

From left to right, one can observe the end of the waveguide that mimic a punctual light source radiating a cylindrical wave, the light propagation through the lens that leads to the interference fringes visible above the lens and finally on the other side of the lens a punctual bright spot. Finally, we estimate the lateral size of the focused to 0.8 λ_0 demonstrating the ability of the reported lens to produce sub-wavelength spots.

5. Conclusion

The reported result is an unambiguous demonstration of the focalisation of light by a photonic crystal flat lens at optical frequencies and is a significant step towards novel imaging systems and may open the route to new functionalities in integrated optics components.

6. Acknowledgments

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7. References

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