Enhanced design strategy for Mesoscopic Self-Collimation

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Mesoscopic photonic crystals (MPhC) are composed of alternating photonic crystal slabs (PhC) and homogeneous material. MPhC structures combine PhC dispersive properties (self-collimation and slow light, among others) with reflectivity control (Bragg mirrors). One of the most studied properties of MPhC is mesoscopic self-collimation (MSC). MSC occurs when PhC dispersion properties compensate the natural divergence of light in homogeneous material [1]. However, MSC is only visible if the energy properly propagates throughout the structure, it is thus crucial to control undesirable reflections at each interface. Different methods, relying on complex Fourier modal analysis [2], allow reflectivity control using an impedance-based approach such as half-holes or comet-like holes between each interface. These methods have fabrication limitations (not circular holes) and may need long and complex calculations. We propose a method based on a fast and simple multiscale approach. In constrast to [3] we prioritize perfect antireflection at the different interfaces, instead of perfect self-collimation. At the μm-scale, we first model the MPhC as a multilayer Bragg structure. By solving simple Bragg equations we determine a first set of parameters ensuring perfect antireflection. At the nm-scale, we then take into account the PhC dispersion properties to search for MSC solutions within the first set of parameters. With this approach, we obtain a complete set of MPhC geometries that ensures reflectivity control and correct MSC (i.e. low beam divergence), without the need for long numerical simulations. To validate our model, we use FDTD [4] simulations to study light propagation through the previously determined MPhC (Figures 1b, 1c, 1d).

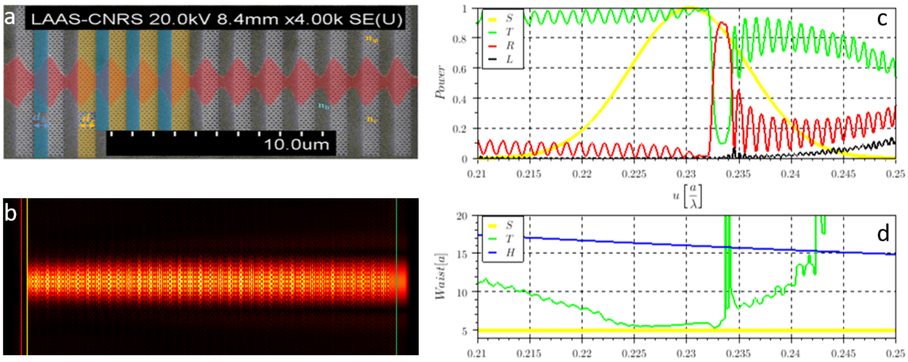

Figure 1: **(a)** SEM image of a MPhC suspended membrane: homogeneous slabs (blue), PhC slabs (yellow) and an artistic view of MSC (red). **(b)** Magnetic field energy in the structure at the frequency of design: respectively in red, yellow, and green: the reflection, source, and transmission planes. **(c)** Transmission (green) and reflection (red) spectra; source spectrum (yellow) and lateral losses spectrum (black). **(d)** Waist evolution at the transmission plane (green) and the homogeneous waist (blue) as a function of frequency, the initial source waist in yellow.

Figure 1c shows the transmission (green) and reflection (red) spectra of a MPhC ensuring MSC with parasitic reflections below 1% in the range $u \in [0.231, 0.232]$, which corresponds to our model prevision. Figure 1d shows the waist evolution at the transmission plane (green). In the frequency range of interest this waist is 3 times smaller than for propagation through a homogeneous medium (blue), and only 1.2 times bigger than the initial waist (yellow). Figure 1b shows the magnetic field spatial distribution at the frequency $u = 0.231$. The beam profile remains unchanged along the axis of propagation and no important lateral spread of the beam is noticed. Rather surprisingly, multiple structures ensuring correct MSC are effectively designed; which show that correct MSC is easily achieved by priorizing perfect antireflection at the different interfaces.

References

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