Sensing Figures of Merit for Terahertz Photonic Light Cages

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Terahertz technology is a rapidly developing field, particularly for sensing and telecom applications. We recently presented and characterized 3D printed photonic terahertz light cage (THzLC) modules [1], shown in Fig. 1(a): they consist of free-standing dielectric strands that guide light inside a central hollow core, providing immediate access to the environment. We fabricated and experimentally characterized several flexible and temperature-resistant modules: the propagation losses were ∼1 dB/cm, and largely independent of the strand material. Measured near-field output profiles showed excellent agreement with numerical modelling, as shown in Fig. 1(b). However, the discussions of light cages' Figures of Merit (FOMs) have so far been limited to comparisons of gas diffusion rates in the core of equivalent enclosed photonic crystal fibers [2], whereas THz gas sensing applications typically use free space beams [3]. We discuss in detail the appropriate Figures of Merit for quantifying the performance of light cage guidance with respect to free space propagation. The potential advantages of light cages over gaussian beams are: (1) a slower decay of intensity with propagation length for narrow beams, and (2) a reduced sensing volume. For example, Fig. 1(c) shows the minimum gas volume (normalized to λ^3) needed to obtain a phase shift ϕ (in units of 2π rad) in any gaussian beam, compared to the THzLCs presented here. The FOM (inset) points to the potential of THzLCs for improving the phase sensing capabilities of free-space. We believe that THzLCs are a useful addition to the rich library of terahertz waveguides.

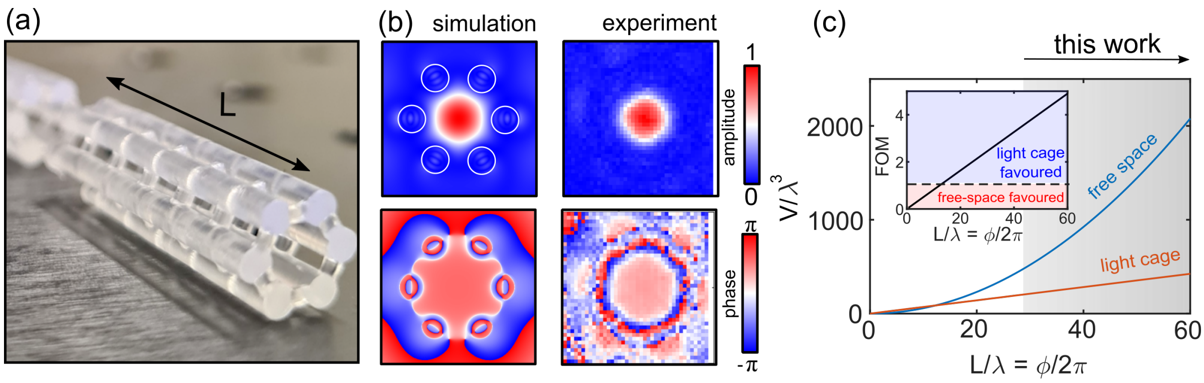

Figure 1: (a) 3D printed THzLC of length $L = 3\,\text{cm}$ (b) Simulated and measured near field amplitude and phase. (c) Volume Figure of Merit comparing free space beams with THzLCs.

[1] A. Stefani *et al.*, *ACS Photonics* **9**, 2128 (2022).

[2] C. Jain *et al.*, *ACS Photonics* **6**, 649 (2018).

[3] D. M. Mittelman *et al.*, Applied Physics B **67**, 379 (1998).