Multimodal reflection and bound in the continuum modes in indirectly-patterned hyperbolic media

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The general premise of nanophotonics involves shrinking light to the subwavelength nanometric scale. However, despite immense progress in nanocavity research [1], all current nanocavities exhibit low quality factors, on the order of 10 (see Fig. 1a). An alternative route to plasmonic cavities lies in hyperbolic phonon polaritons (PhPs) [2], but shrinking existing PhP nanocavity designs to the sub200nm scale is seemingly impossible.
Here, we introduce a new class of nanocavities and demonstrate the previously unattainable fusion of high-quality factors (Q>100) in ultrasmall cavity sizes (sub100nm), resulting in mode volume confinement above 10^9. At the extreme, we show that cavities as small as 23×23×3nm still show clear resonant behavior and that slightly larger cavities can attain quality factors in excess of 200. Intriguingly, the performance of our cavities exceeds the theoretical maximum for a single mode (impedance mismatched) cavity, indicating that confinement in our cavities is greatly enhanced by multimodal effects. We then explore and demonstrate a novel mechanism of multimodal reflection mechanism and its relation to a hyperbolic version of a bound in continuum [3] mode. This alliance of hyperbolic dispersion with bound in continuum modes yields a radically novel way to confine light, with far reaching consequences wherever strong optical confinement is used.

References

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Figures

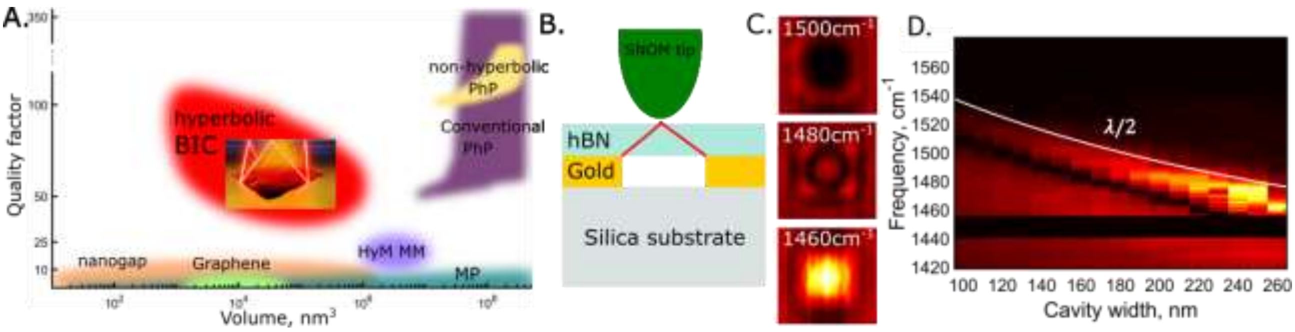

Figure 1: Fig. 1A, Survey of nanocavity quality factors and volumes. Different colors correspond to reported values of different cavity types (HyM MM stands for hyperbolic metamaterial, MP stands for metallic particle) and the red blob represents the values in this work. B, Sketch of system with the red ray representing a multimodal excitation. C, Measured nearfield signal at different excitation wavelengths, showing the passage through a resonance in a 200nm wide cavity D, Spectrum of cavity response as a function of the cavity width. The narrowness of the spectral response is indicative of high quality factors. The weakening of the signal below 100nm size is due to sample drift and detailed measurements show that the quality of the cavity does not diminish. The white line represents the half wavelength of the zero order PhP mode, where the cavity mode is expected.