Designable timbre is realized in a meta-silencer

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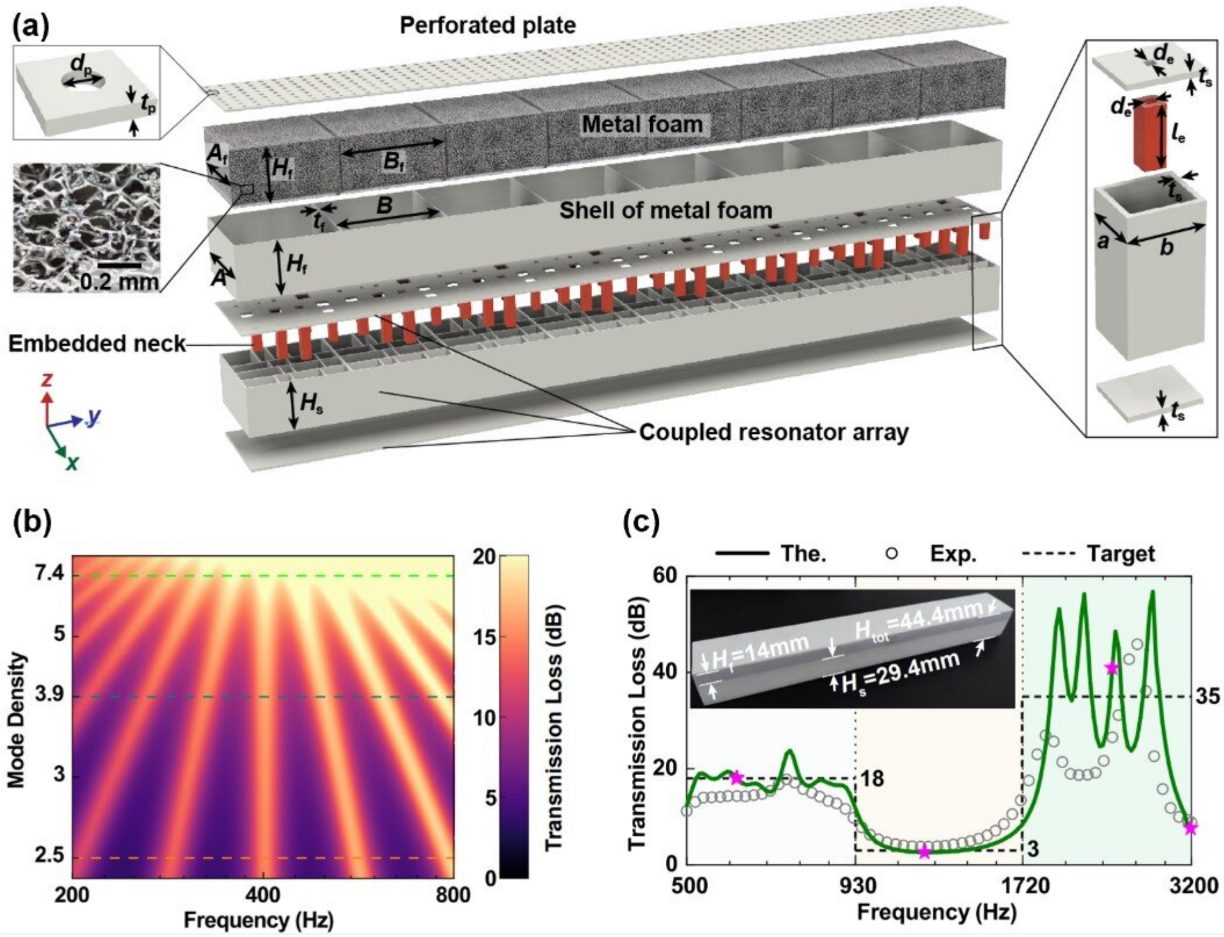

(a) Meta-silencer's configuration and manufacturing. (b) Schematic diagram of transmission loss (TL) property as a function of mode density and frequency. (c) Designable timbre via a meta-silencer. Credit: *International Journal of Extreme Manufacturing* (2023). DOI: 10.1088/2631-7990/acbd6d

Publishing in the *International Journal of Extreme Manufacturing*, a team led by researchers based at the Institute of Acoustics of Tongji University presents a meta-silencer supporting intensive mode density as well as highly tunable intrinsic loss and offering a fresh pathway for designable timbre in broadband. The designed meta-silencers featuring deep subwavelength thickness (~5cm) and can achieve high-efficiency and efficiency-controlled sound attenuation as well as designable timbre in the broad frequency range of 500-3200Hz.

One of the lead researchers, Professor Yong Li, commented, "Timbre, as one of the essential acoustical elements, plays an important role in determining sound properties, whereas its manipulation has [remained] challenging for passive mechanical systems due to the intrinsic dispersion nature of resonances."

"Recent advances in acoustic metamaterials have greatly enriched the methods of wave manipulation through enhanced performances and under compressed sizes. [Additionally], the construction of metamaterial-based acoustic devices has become more feasible due to the development of additive manufacturing techniques. All of these offer the possibility for addressing this above-mentioned challenge."

First author doctoral student Nengyin Wang said, "Timbre operation puts forward higher requirements for frequency selectivity and fine modulation of broadband resonance. In order to realize the designable timbre, we first establish a theoretical model to analyze the overall coupling effect, and to study sound transmission loss of the meta-silencer based on the coupled mode theory and mode matching method."

"Then, by analyzing the relationship between transmission loss and mode density and frequency, it is found that increasing mode density can strengthen the global coupling effect between resonant elements, so as to effectively suppress the TL curve oscillation caused by the resonance dispersion characteristics. Finally, the designed meta-silencer successfully adjusts the timbre by alleviating the fundamental-frequency sound, relatively highlighting the first overtone and muting the second overtone."

This work opens up a fundamental avenue to manipulate the timbre with passive resonances-controlled acoustic metamaterials and may inspire the development of novel multifunctional devices in noise-control engineering, impedance engineering, and architectural acoustics.

Professor Yong Li said, "This work offers fresh insights into the modulation of global coupling for suppressing resonance dispersion, and presents versatile and efficient ways to manipulate the mode density distribution, coupling effects and intrinsic loss via an acoustic meta-silencer."

"The presented design concept can also be employed to construct reflection-typed meta-structures for a wider range of applications in room acoustics. These results would benefit the development of multifunctional and efficient acoustic silencers for aero-engine and ventilation systems, and open up an avenue for the study of designable timbre."

More information: Nengyin Wang et al, Meta-silencer with designable timbre, *International Journal of Extreme Manufacturing* (2023). DOI: 10.1088/2631-7990/acbd6d

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