Investigating disordered media with water waves

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Abstract

Coastal erosion is one of the biggest problems we face today. To protect coastal areas, there exists several coastal defenses such as submerged or emerged breakwaters, dunes and dikes (1,2). We aim to tackle this problem with a different approach and implement disordered structures, such as hyperuniform media to control water waves.
A hyperuniform medium is a form of correlated disorder where large scale density fluctuations are suppressed (3). This characteristic reduces scattering at low wave numbers, increasing the scattering mean free path (compared to that of a medium with the same density and type of scatterers) and making the medium transparent. With reduced scattering, absorption can be maximized when the medium's size exceeds the attenuation length (4).

At a laboratory scale, we implemented a hyperuniform medium in a deep-water tank (150cm x 50cm x 7cm) where we generate water waves ranging from 4Hz to 10Hz (fig. 1.a). We can continuously image the elevation of the surface water waves in real time up to a micrometric precision, enabling precise analysis of multiple scattering phenomena. This enables us to study a single scatterer consisting of a vertical cylindrical pillar placed in the water tank. We are able to measure its scattering cross section by suppressing the incident field. We also investigate other types of scatterers and resonators (e.g., floating and Helmholtz types) to be able to finely tune the scattering cross-sections.

The set-up is versatile as we can measure the wave field in various media (of size 40 cm x 60 cm) with up to 300 cylindrical scatterers, each 1 cm in (fig. 1.b). Fig. 1.c shows the wave field the transparency region of a hyperuniform medium. We can study random, hyperuniform, and crystalline structures, and understand how each affects wave absorption and extinction mean free paths. We first want to illustrate the transition between the transparency and scattering regimes in hyperuniform media. We then want to highlight their superior absorption.

We intend to explore different regimes depending on how the absorption mean free path compares to the size of the scattering medium and address scalability issues to real-world oceanic environments. Another type of medium with enhanced absorption we would like to investigate is the fractal structure, which has been shown to efficiently absorb acoustic waves (5).

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