Spectral Invisibility Cloaking

In the last decade, numerous approaches have emerged for "invisibility cloaking"—concealing objects by preventing light from interacting with them.[1] Solutions have been demonstrated over different regions of the electromagnetic spectrum, and even for waves of very different nature, including acoustic and thermal waves. But while effective invisibility solutions have been demonstrated for single-frequency illumination waves, realistic operation requires cloaks capable of concealing objects from broadband illumination. Recently, we have demonstrated an approach to such broadband cloaking, which we call spectral invisibility cloaking.[2]

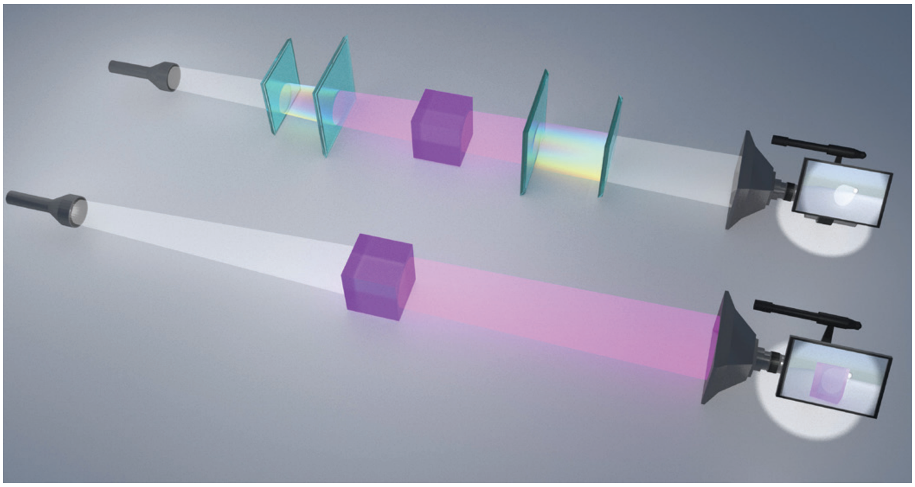
An ideal cloak must restore the exact amplitude and phase distributions of the illumination wave—the full field—at its output.[1] But current invisibility strategies alter the propagation path of the wave around the object to be concealed, which introduces undesired phase variations among the different frequency components of a broadband illumination wave and thus necessarily distorts the wave's temporal profile.[3] Phase-sensitive or temporal detection renders these cloaking solutions vulnerable to phase-coherent broadband illumination.

In our approach, an object's presence is concealed from an observer under broadband illumination in a very different way: by altering the spectrum of the probe wave through reversible transformations of its temporal and spectral phase profiles. Specifically, the illumination wave's energy spectrum is first redistributed towards frequency regions where the object to be concealed is transparent, and the wave is subsequently restored to its exact original state once it has cleared the object. This way, the illumination wave can propagate through the object, entirely unaltered, while avoiding any interaction between object and wave.

Our particular demonstration of this general concept used a set of phase transformations derived from the theory of the Talbot effect.[4] First, the spectrum of a coherent broadband wave was redistributed into a periodic set of frequency gaps (regions of the wave's spectrum stripped of energy), through a combination of group velocity dispersion and electro-optical phase modulation. The frequencies of such gaps were chosen to match the interaction spectrum of the object to be concealed, namely, an optical filter consisting of a periodic set of phase-shifted wide absorption bands, in the reported experiments.

The spectrally redistributed wave propagated then through the filter without interacting with it, and the applied transformations were reversed at the output of the filter, recovering both the spectral and temporal profiles of the original wave. When the cloak transformations were not applied, the action of the filter (its signature) was clearly observed in both the frequency and time domains.

We believe that the spectral energy redistribution concept, by preserving the full-field profile of the illumination wave, paves the way toward development of practical broadband invisibility cloaks. OPN



Spectral invisibility cloaking (top) conceals the signature of an object from observation, otherwise detectable by broadband-wave illumination (bottom). This is done by redistributing the wave's energy spectrum toward frequencies where the object is transparent, and then reversing those changes after the light has been transmitted through the object.

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REFERENCES

1. G. Gbur. Prog. Opt. **58**, 65 (2013).
2. L. Romero Cortés et al. Optica **5**, 779 (2018).
3. F. Monticone and A. Alù. Optica **3**, 718 (2016).
4. L. Romero Cortés et al. Opt. Lett. **41**, 340 (2016).

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