IS THAT AN INVISIBLE CLOAK? —

Easy-to-make thermal chameleon fades into the background

New cloak not so much Harry Potter as emperor's new clothes.

CHRIS LEE - 6/30/2019, 9:00 PM

Renee Grayson / Flickr

Enlarge / This story isn't really about this kind of chameleon. Sorry.

Chameleons, unlike bow ties, are cool. The chameleon is most famous for its ability to blend with its surroundings (I'm just as impressed with the acrobatic tongue), something we'd often like to do ourselves. Doing something similar with heat would be exciting. Imagine a camouflage suit that blended in with its background in both the visible and the infrared.

Three researchers suggest they've done exactly that in a recent paper on a thermal cloaking demonstration. Unfortunately, their cloak doesn't so much blend with the surroundings as become completely transparent. This is still remarkable, and, at least when cloaking in two dimensions, it's surprisingly simple to make.

Hiding in plain sight

Before we get to how the cloak works, let me take you through what the thermal chameleon is trying to hide. Let's imagine that I have a long cylinder. At one end, I heat the cylinder to 50°; and at the other end, I cool it to 10°. If I measure the temperature along the length of the cylinder, it will decrease steadily between the hot end and the cold end.

Now imagine that I place a small sphere of a different material in the cylinder. Because of the material differences, the sphere has a different thermal conductivity from the cylinder. This distorts the temperature profile, not just in the sphere, but also to either side of it. If I were to thermally image the hot end of the cylinder from the cold end, the presence of the sphere would distort the picture of the hot end.

In this case, the problem is that the thermal conductivity of the sphere is different from the background thermal conductivity of the cylinder. To make the sphere invisible, the temperature profile should appear undistorted to either side, which requires that the thermal conductivity of the sphere be the same as the cylinder.

That is the aim of the research: create a layer that, no matter what, matches the thermal conductivity of whatever is behind it.

To investigate the idea, the researchers consider a ring of material. That ring has to match the thermal conductivity of whatever is inside it. The researchers show that thermal conductivities (as measured from outside) match when the thermal conductivity *around* the ring is much worse than the thermal conductivity *through* the ring. In 2D, the way to do this is to put a copper ring on some glass or plastic, then mill slots in the ring so that it is made up of thin stripes that all point to the center of the ring. Heat traveling into or out of the ring can travel along the copper, which has a high thermal conductivity. Heat that travels around the ring has to go through the glass and air, which has poor thermal conductivity.

The proof is in a laser-cut copper sheet

To test their idea experimentally, the researchers used a perforated copper sheet as a base material (the holes reduce the thermal conductivity of the copper sheet). Then, in the middle of the sheet, they carved out a ring with lots of slots in it. Finally, they heated up one end of the copper and cooled the other end. If their calculations were correct, the thermal map on either side of the ring should show no evidence of the ring. The researchers used a thermal camera to obtain temperature profiles of the sheet. They showed that, while the temperature profile inside the ring was distorted, the ring prevented those distortions from showing on the outside of the ring. In other words, the ring itself appears to be invisible.

What that result means is a little less clear. For instance, if the material in the center of the ring is different from the material outside the ring, or is hotter or colder than the surroundings, it will still show up by distorting the thermal image. It is only the ring that is invisible, so you're not actually cloaking anything. Or, since the researchers like the chameleon analogy—this cloak is more like the emperor's new clothes: so fine you can't tell it's there.

I still like the research, though. Essentially, the researchers have reinvented impedance matching, which is the physics that provides anti-reflection coatings on glasses, for instance. I am quite convinced that almost every physics and engineering problem comes down to solving an impedance-matching issue. So, I have high hopes for this being useful. On the other hand, I have spent quite a bit of time trying to envision how you would use this for camo and cannot actually come up with any ideas at all. Luckily, there are plenty of smarter people who can do that for me.

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