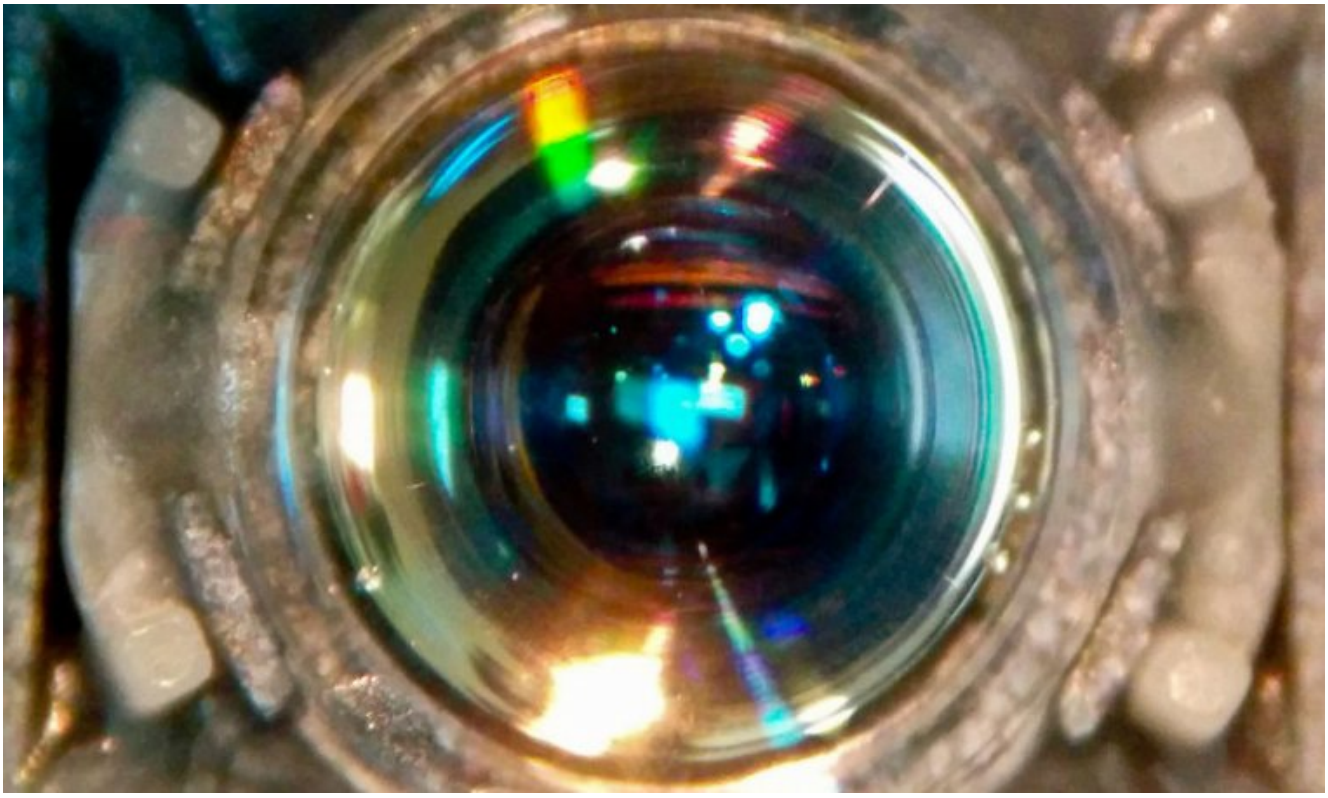
# Gas jets make beautiful lens for light we can’t normally focus



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I try not to write about optics too often because, well, I love optics, but no one else does. Unfortunately for you, I can’t resist the subject.

If you turn over your cell phone, you will find the lens on your camera. This is what lets the camera create a nice image. But for light in the wavelength range of 1-100nm (called the extreme ultraviolet), lenses don’t work. Or, rather, that was the accepted wisdom until now. But that wisdom will change, as researchers have shown how to make a lens for extreme

ultraviolet radiation.

## Lenses don’t work? You need your eyes checked

Lenses are basically a curved surface of a material in which light moves at a different speed. When light hits the material of a glass lens, for example, it slows down (by about 30 percent)—this is the effect of the refractive index of the material. Since the lens is curved, the light at the edge of the lens gets to travel that little bit further before it slows down, putting it ahead of light that is near the center of the lens.

But light is a wave and has to change smoothly in space. To maintain that smooth profile, the light at the edge of the lens has to bend itself toward the center. As a result, the light focuses some distance beyond the lens.

But, what if light didn’t slow down on entering a material? Well, then nothing would happen; the wave continues on as if nothing was in the way. This is almost what happens with extreme ultraviolet light. For these wavelengths, most materials have a refractive index that is just very slightly less than one. This means that the light *speeds up* by about less than one percent on entering material. The difference is just too small to make good optics.

But that’s not the only problem. All materials strongly absorb extreme ultraviolet light. You would lose most of the light, even if a material were to focus it nicely.

To get around this problem, people use mirrors to focus and otherwise manipulate extreme ultraviolet light. Mirrors make life really tough when designing a high-quality optical system. Not only that, these mirrors aren’t all that reflective, so you still lose lots of light.

# Finding refractive index

It turns out that there are ways to get something with a refractive index at extreme ultraviolet wavelengths. The refractive index of a material is generated by the electrons jiggling about in response to the incoming light field. An electron's willingness to jiggle is highly dependent on the combination of its environment and the wavelength of the light causing it to jiggle. If the light is *just about* the right wavelength to cause the electron to jump from one energetic state to another, then the electron can get very jiggly indeed.

A group of researchers has made use of this fact. They shone a beam of extreme ultraviolet light through a jet of helium gas. The wavelengths that were close to the energy required to drive helium's electrons from their normal energy state to a higher energy state were strongly bent. Indeed, the results fit theory very well. Wavelengths that are just a bit shorter than required for excitation are defocused by a gas jet (because the refractive index is just less than one), while wavelengths just a bit longer than required are focused.

In a stroke of good fortune, making a jet using a circular opening produces a gas with a parabolic density profile. That means that the gas jet makes a very good lens.

That said, as cool as this is, it's going to be of limited use. You need to have the right gas to create a lens that works at a specific wavelength. You are really stuck with what nature gives you—if there's no gas for the wavelength you want, then you're out of luck.

As with glass optics, the shape and density of the optic really matters. But you can't grind a gas to the shape you want. Instead, the gas jet nozzle (or nozzles) has to be very carefully shaped to give exactly the right density profile. This is possible, but it is not a trivial exercise and is

highly sensitive to small changes in environmental conditions.

Still, I’ve been wrong about the utility of this sort of stuff before, and I hope I am again.

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