A Plasma State of Mind

BY CHRIS YOUNG

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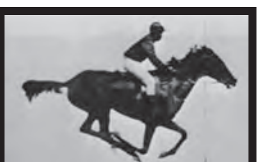
My first undergraduate research experience was right out of a science fiction movie. I had 10 weeks to build a plasma thruster. What I knew at the time about space propulsion came from the *Star Wars* trilogy, but my advisor was confident, and soon a bright purple glow emanated from a soup-can-sized device.

What I find fascinating about plasmas (not the blood kind but the fourth state of matter) is that they aren't really part of your daily experience on Earth. Sure, the sun is a plasma, and lightning is a plasma, but you can't interact with those things like you can with, say, a glass of water. Everything that's intuitive about earthly solids, liquids and gases won't help you know what plasma is and does. It's a hidden part of the universe that comes to life on Earth only in exceptional circumstances. In my case, it takes a vacuum chamber pumped down to a billionth of atmospheric pressure just to turn on the thruster.

Although improving the design of space propulsion devices is important for lowering satellite costs, the real value of studying these thrusters comes from what we learn about the plasma inside them and how we might use this knowledge to manipulate plasmas usefully. I'm working on a fundamental plasma physics problem that, besides helping determine how well the thruster runs, will generally apply to plasma devices.

Specifically, I study plasma sheaths: little electrical layers that form between plasmas and any surface they touch. Most every manmade plasma must be contained by something, and the plasma will probably touch that container in some way. Where this contact occurs, the sheath forms, so they're quite common in the world of plasmas.



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We plasma physicists must worry about electrical layers because plasmas are full of tiny charged particles intermixed with all the other molecules that make up regular gases. This is why plasmas get that fancy designation as a separate state of matter. You can make a plasma from just about anything if you add enough energy to it – by heating it or running an electric current through it – so that some electrons that used to be happily attached to their parent atoms are free to roam. These newly independent electrons leave behind oppositely charged ions that are now short of a full electron set. With all these free charges flying around, a host of new physics and several new ways to make the plasma do what we want come into play. When charged particles abruptly slam into the container wall the plasma adjusts and forms the sheath, preventing its otherwise uninhibited journey through a given device.

Sheaths are found everywhere in today's plasma applications. In some cases, like using plasma to etch patterns in semiconductors, we want it to contact a surface in a precise and controlled way. You can bet there's a sheath on the semiconductor surface that must be taken into account. In other cases, like fusion reactors in which we want to create the hottest and densest plasma possible, allowing it to reach the wall can be a serious detriment. The more we understand about how sheaths work, the better we can use them to our advantage in such applications.

Plasmas could transform society.

A recent summer at Lawrence Livermore National Laboratory gave me new perspectives on how plasma physics researchers are applying their findings to critical energy and stewardship science problems. Plasmas form the heart of fusion energy research, where the challenge is getting them to stick around long enough to extract more energy than spent producing them. They also are found in nuclear explosions and are integral in determining what happens during and after detonation. Facilities like Livermore's National Ignition Facility allow unprecedented access to these extreme conditions and we are learning much about the physics at play.

Plasmas could transform society, especially in renewable energy. This is why I consider continuing research into them to be vital. I was hooked from day one in the space propulsion lab, and I plan to build a career around learning as much as possible about this intangible part of our universe.

This page samples experiences of Stewardship Science Graduate Fellowship recipients. The author, winner of this year's SSGF Essay Slam, is a second-year fellow at Stanford University.