Cornell Solar Ovens Project Team: Fresnel Lens Subteam

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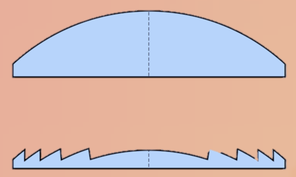
Background

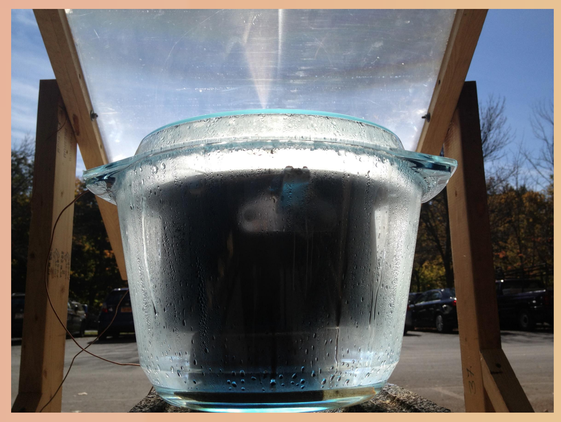
The Solar Cooker team designs, builds, and tests solar cookers, solar fryers and and other solar powered systems. Our mission is to improve and optimize solar oven designs in order to provide cheap, sustainable, easy alternatives to wood fired cooking. We are partnered with Grupo Fenix, an organization at the Universidad Nacional de Ingeneria in Managua, Nicaragua, and Las Mujeres Solares de Totogalpa, a women's collective in Sabana Grande, Nicaragua.

As the Fresnel Lens subteam within the larger group, we began by working on developing ways to focus more light into the cookers than the cooker glazing intercepts on its own using Fresnel lenses. This lens functions by preserving the outer curvature of a conventional lens—where the refractive power is contained—while removing most of the internal material (See below). Because Fresnel lenses can converge light from a large area to a smaller one, one of their most basic applications is in solar concentration. As opposed to conventional lenses, which can be heavy, bulky and fragile, Fresnel lenses are characterized by their flexibility and thinness, making them advantageous for our initial testing.



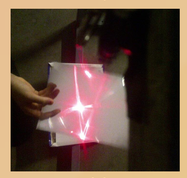
The Fresnel lens, on the bottom left, uses much less material than a conventional lens, top left. The thickness of the lens, then, does not have to increase greatly with size.

Our initial focus was to supplement the existing box cookers with a system to concentrate more light into them. However, as we conducted more experiments, we shifted to using the lenses to accomplish tasks that exceed the capacity of the solar cookers alone. For example, the team working on the small cooker designed for use in Ithaca used the Fresnel lenses to concentrate more light into the small oven. However, traveling to Nicaragua last spring and working with Las Mujeres Solares gave us a new awareness of the limitations of the solar ovens, as well as a greater understanding of the culture and daily practices of the people in Sabana Grande. These insights have shed light on how the lenses can be applied in more pragmatic and relevant ways.



Early Testing

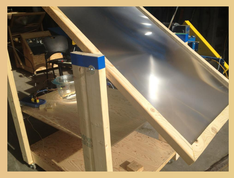
Before investing in the large Fresnel lenses, we purchased several small (8” x 11”) Fresnel lenses to test in order to evaluate if the investment in the larger lenses would be worth it. We then conducted a series of tests using lasers to understand how the lenses focus light. After understanding the basic mechanism for concentrating and redirecting light using the lenses, we came up with a set of tests to experiment with the lenses using natural solar light.



At the end of Fall Semester in 2011, we were able to purchase two larger Fresnel lenses. These were 34”x46”, thicker, and more rigid, and because they concentrated a much larger area of light, they were powerful enough to greatly expand our repertoire of testing. However, initial tests with the larger lenses revealed that safety precautions were necessary when working with the lenses. First, it is necessary to protect your eyes when working with the lenses--looking directly at the focal point is harmful. Second, it is important to be mindful when directing light with the lens so as to prevent fire or explosions, both of which occurred on small scales during testing. During the early testing period, we became more familiar with using the lenses and gained perspective on how we could use them to achieve our objective.

Depicted here are the small Fresnel lenses focused on washers. The primary objective of these tests was to compare temperatures slightly before, directly at, and slightly after the focal point of the lens.

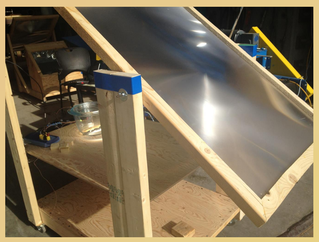
A second test design involved focusing the lenses on small pots. In these tests, we wanted to experiment with heating water using the Fresnel lenses to increase the amount of incident light that the pots intercepted. We were able to heat water by focusing the lens on the outside of the small black pot.



We also conducted tests using the larger lenses, attempting to heat pan surfaces and water within pots. Depicted to the left is the so called “pot-in-pot” setup where we placed a black pot within a glass pot—this insulation made testing on cold days more feasible. Above is a common setup we would use during testing with the stand. Because the larger lenses were so much more powerful, we began having issues with breaking and melting glass and plastic bottles and rapidly starting small fires, so we had to refine our methods for further testing.

Later Testing

This round of testing, which occurred primarily after our return from Nicaragua in 2012, we were able to make more progress towards practical applications of the large lenses. We reevaluated our original goal of supplementing the box cookers and determined that we should go in a different direction. We decided to tackle the process of tortilla making—something which conventional box cookers are not capable of—using light concentrated by the Fresnel lenses. This staple of the Nicaraguan diet is one thing that Las Mujeres Solares still rely on wood-burning stoves to cook.



We spent the first part of the fall semester constructing a stand on which the lens was mounted and adjustable. We designed the stand to have shelf units so that the base would be adjustable to different heights, depending on where the focal point of the lens was.

We then conducted a series of tests on pots and pans. For this sequence of tests, we utilized the new lens stand to focus light on several different sets ups with the primary goal being to heat and boil water. These tests could be used to achieve new methods for solar cooking without using conventional box ovens.

To the right is a picture of one success in cooking tortillas on a pan with the heat created by the lens’ redirection of light. The process is comparable to cooking over a wood fire. Note the thermocouples in the tortillas to measure temperatures.

During our most recent tests, we were able to cook tortillas on a black metal pan. Whether the tortilla was actually in the focal point or off to the side, it cooked thoroughly, demonstrating that the lenses could concentrate a sufficient amount of light to carry this process to completion.

Applications

This year, we had the opportunity to bring a Fresnel lens with us to Nicaragua. We were able to transport it via plane by cutting it into four pieces in the lab with a bandsaw and taping the pieces back together once we got to Nicaragua. We demonstrated how the Fresnel lenses worked for Las Mujeres, and because we were so close to the equator, the lenses were able to function much better than they do in Ithaca. However, this fact also magnified the aforementioned safety concerns.

Both Las Mujeres Solares and Jovenes Pedaleando Hacia El Futuro, a young person’s group that is associated with El Centro Solar, are very open to pursuing experimental methods for improving current technologies used in the community. If these groups have an awareness for the Fresnel lens technology available then their perspective on new ideas for implementing the lenses is vital.

Last year, when we went to Nicaragua, our focus shifted from supplementing the conventional box cookers to trying to tackle something that the box cookers were incapable of. This year, our trip to Nicaragua showed us how many exciting new projects were being started—many of which were aimed at sustainable solutions to problems with a scope beyond what we were expecting. This spirit of trying new experimental methods and widening the range of projects is promising for the future use of Fresnel lens within this Sabana Grande community.

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