ND*nano* Undergraduate Research Fellowship (NURF)
2015 Project Summary

1. Student name: Luis Enrique Cortés Herrera

2. Faculty mentor name: Anthony Hoffman

3. Project title: Engineering the linear stability of ray trajectories in highly compact chaotic multipass cells

4. Briefly describe any new skills you acquired during your summer research:
   - I developed a deep comprehension of the foundations of geometrical optics, particularly in its formulation as a Hamiltonian dynamical system.
   - I studied both theoretically and numerically the linear stability of trajectories due to the iteration of a symplectic map.
   - I learned to study the differential geometry of explicit surfaces embedded in a three-dimensional Euclidean space and to characterize such surfaces in terms of curvature.
   - I studied theoretically and numerically the behavior of a Hamiltonian system as integrability is lost and it transitions to chaos.
   - I engineered the parameters of a dynamical system with the objective of optimizing the suitability of particular trajectories for a practical application (optical sensing).

5. Briefly share a practical application/end use of your research:
The results of my research will be useful for the fabrication of robust and compact optical multipass cells, enabling more practical implementations of optical sensing for security applications such as the detection of explosives in airports.

Begin two-paragraph project summary here (~ one type-written page) to describe problem and project goal and your activities / results:

The detection sensitivity of an optical sensor based on light absorption can be improved by increasing the interaction length of the optical beam and the gas under test. Multipass cells achieve long optical path lengths by reflecting light off of mirrors. For mobile or handheld sensors, it is desirable to have a multipass cell with a long optical path length and a small cell volume. Conventional multipass cells have two limitations in their design: first, they consist of multiple reflecting surfaces, making their alignment nontrivial, and second, their performance is limited by approximations used to simplify their design. To bypass these limitations, multipass cells consisting of a single, closed, reflecting surface with rotational asymmetry and chaotic ray dynamics were developed.

This summer, I studied the linear stability of the ray dynamics inside rotationally asymmetric multipass cells and related the stability to the geometry of the reflecting surface. I explored the relationship between the curvature of the multipass cell and the focusing of the rays while varying the initial conditions and deformation of the surface defining the cell. In this way,

we tested the stability limits in the symmetry-breaking deformations to understand the resulting propagation of chaos in the ray dynamics. This analysis enables more efficient and effective engineering of rotationally asymmetric multipass cells that exhibit ray focusing and are robust to errors in the fabrication process.

Publications (papers/posters/presentations):
- I gave an introductory talk about this work as part of a series of oral presentations of NURF recipients about their summer research.
- I will co-author a paper with fellow group member of Prof. Anthony Hoffman's group, Galen Harden discussing a numerical method to engineer long and stable trajectories in asymmetric optical multipass cells. The manuscript is in preparation and will be submitted in August 2015.
- I will be the first author of another paper discussing the linear stability of ray trajectories in asymmetric optical multipass cells and how this entity can be studied and interpreted to engineer said ray trajectories. The manuscript is in preparation and will be submitted in August 2015.