Optimizing the Tinytol pupil using Genetic and Hill climbing algorithms

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Briefing:

- The task given to me was to find optimizations that could be made to the current iteration of the Tinytol pupil (figure 1)
- The value chosen to optimize was the max power delivered to any pixel across the array in the focal plane
- By Finding the pupil that minimized this we hoped to spread the power across all the fringes in the array
- No constraints were placed on either the amount of power contained within the 6λ/D region or the power gradient on the detector

Approach:

- Starting from this base pupil (fig 1) - the code used to generate the pupil was modified such that it took in a list of Boolean values that is used to encode the different spirals
  - Each entry in this list corresponds to some section of the spiral that can either be ‘on’ or ’off’ (\pi or 0 phase)”
  - The hole in the middle of the pupil was widened in order to reduce computation time so that not too much time was spend making small changes to the spiral in the central regions of the pupil.
- These lists were then permutated both through Genetic and Hill climbing algorithms in order to find optimize the pupil design

Starting point

- Note: the Heuristic used has arbitrary units and is only a relative measure
- Note: that 6λ/D converts to circle on the detector of with a radius of ~30 pixels. All images shown are a 120x120 pixel central region of the array
- Note: These simulations were run on an aperture size of 15mm

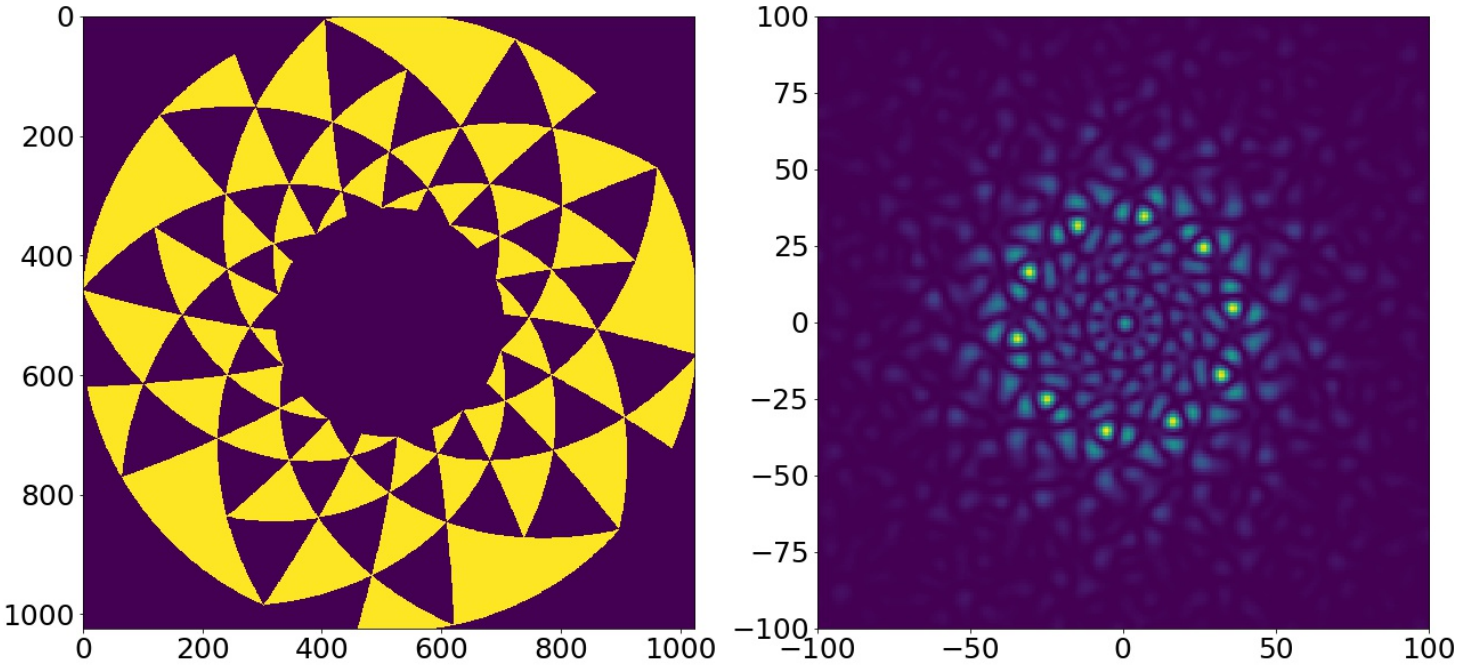

Figure 1. Left, Initial pupil design. Right: Formed image
H = 92

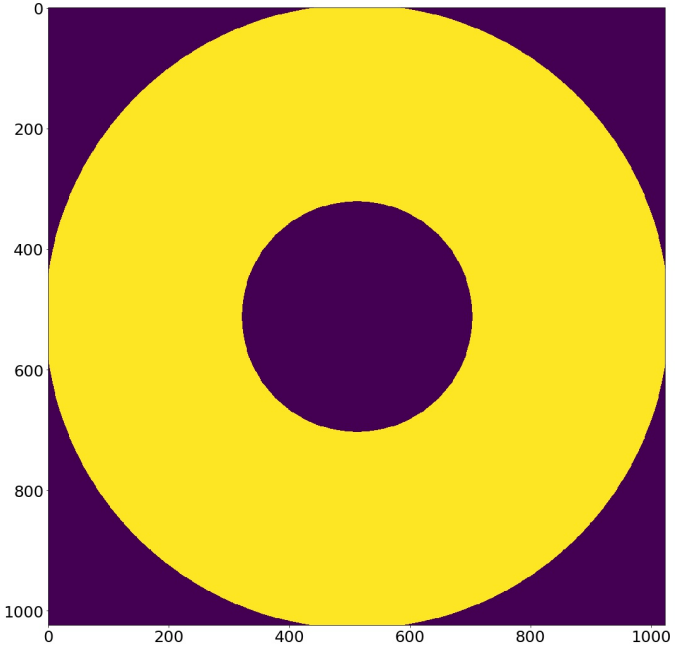

Figure 2. Power delivered to the pupil

Whole Pupils and Half Pupils

- Two different kinds of pupils were searched for, dubbed “half” and “whole” pupils.
- Whole pupils refer to permutations of the original pupil that try flipping ‘whole triangle’ regions in the pupil
  - These pupils were found to have a lower-bound heuristic value of ~50
- Half pupils refer to permutations of the original pupil that have had each triangle cut into two smaller triangles, each of which can be flipped independently
  - These pupils were found to have a lower-bound heuristic value of ~30

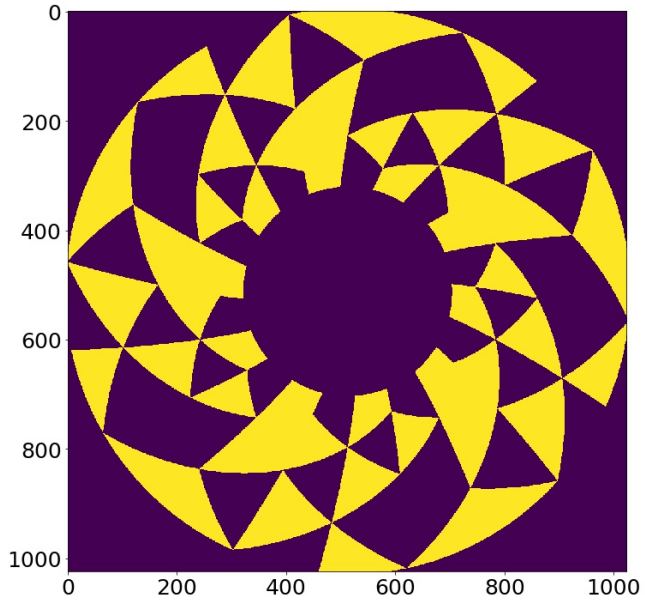

Figure 3. Example whole pupil

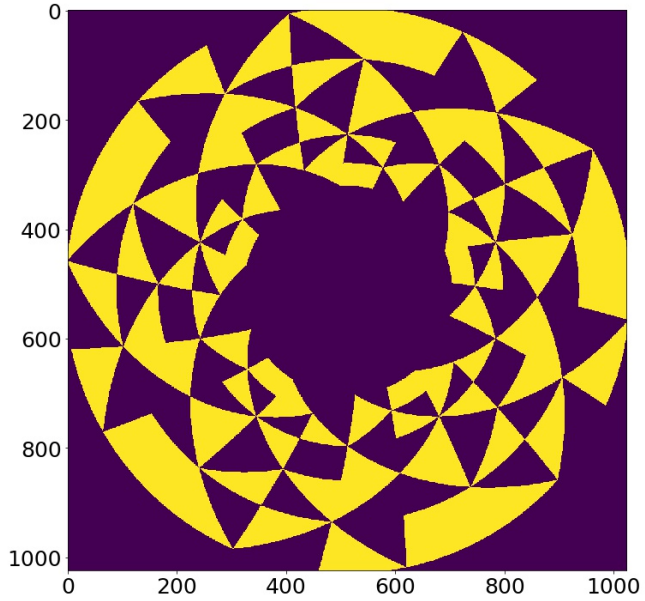

Figure 4. Example half pupil

Whole Pupil designs

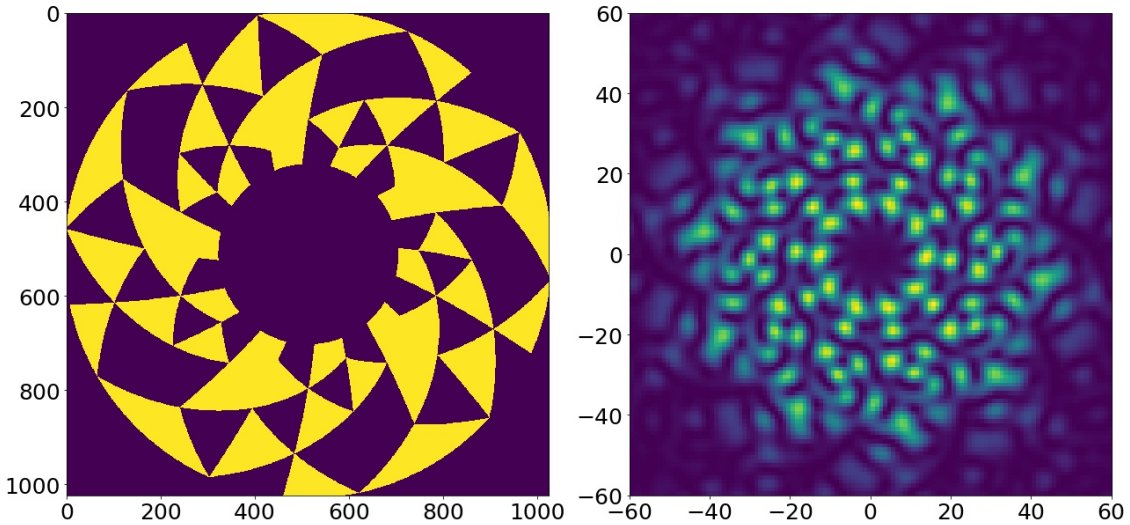

Figure 5. Heuristic value of 52

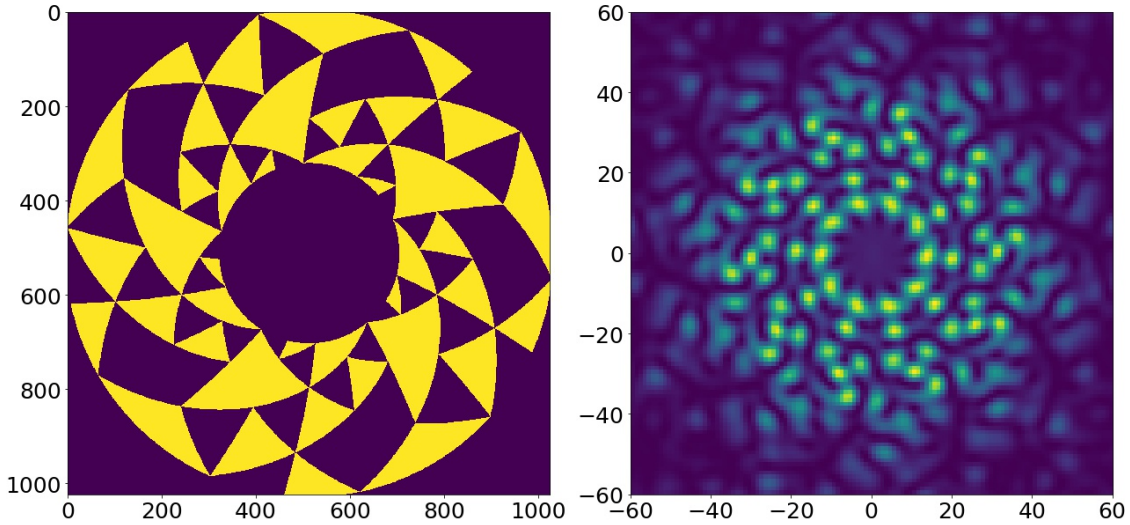

Figure 6. Heuristic value of 52

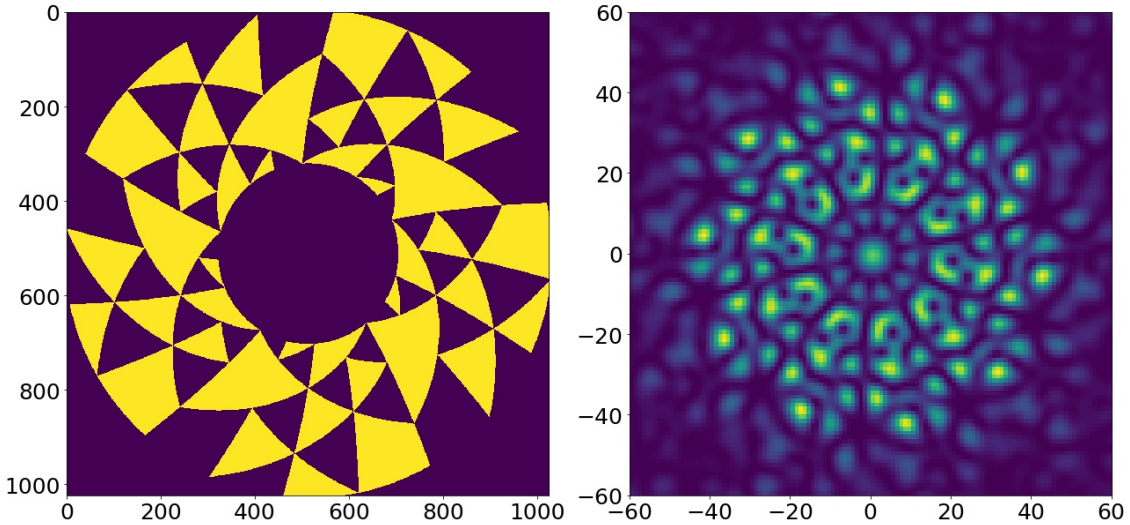

Figure 7. Heuristic value of 54

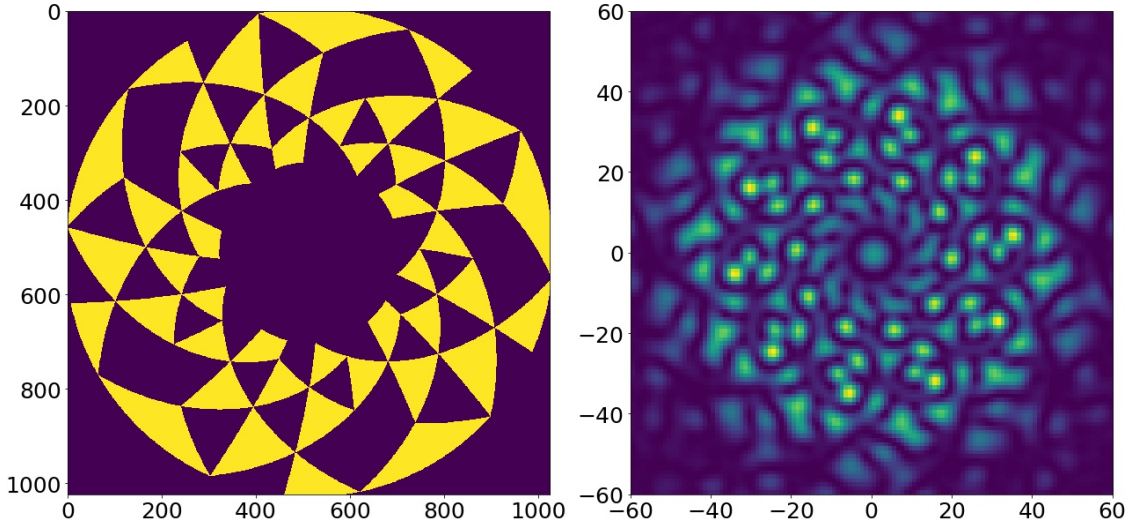

Figure 8. Heuristic value of 53

Half Pupil designs

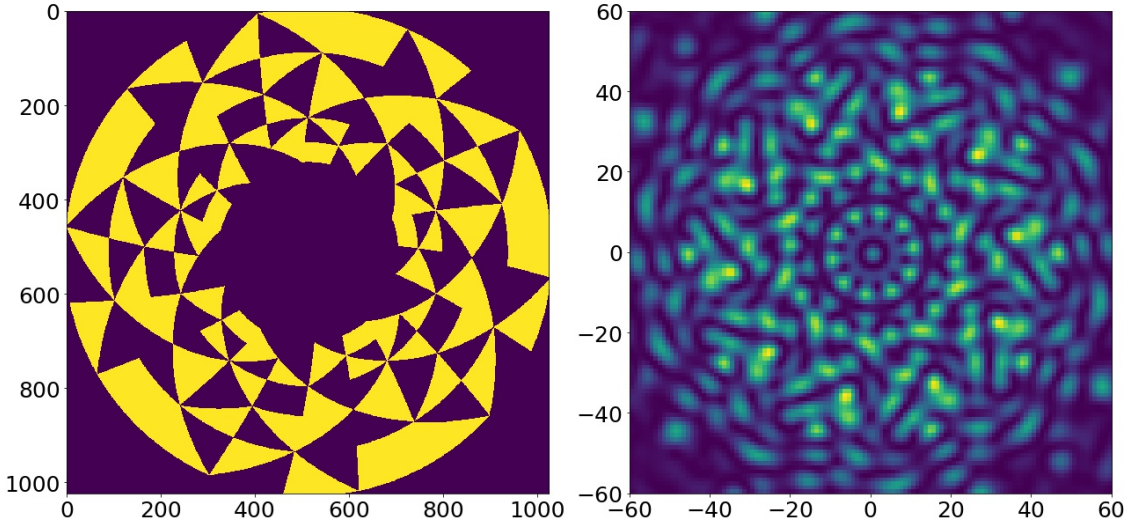

Figure 9. Heuristic value of 34

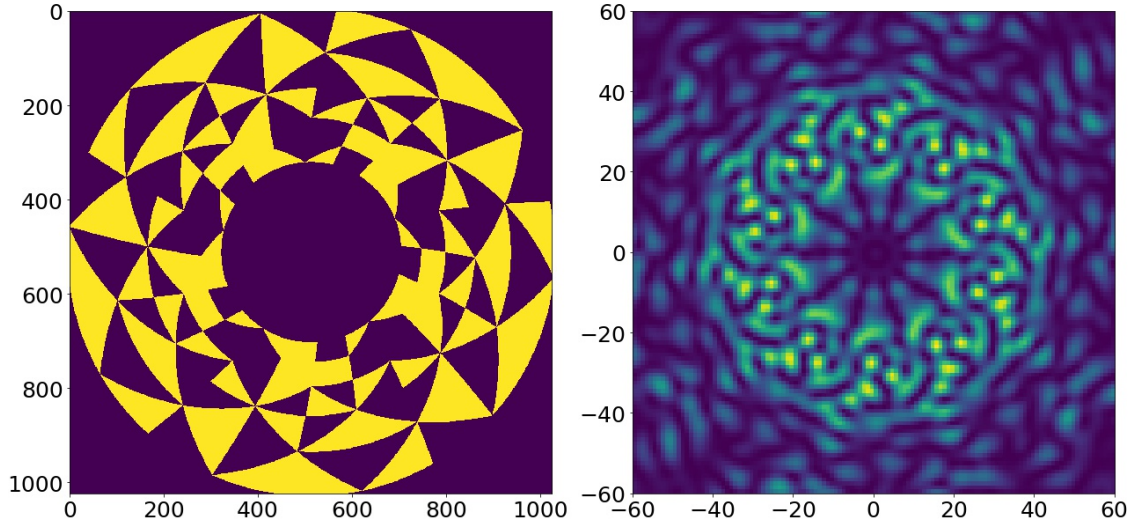

Figure 10. Heuristic value of 36

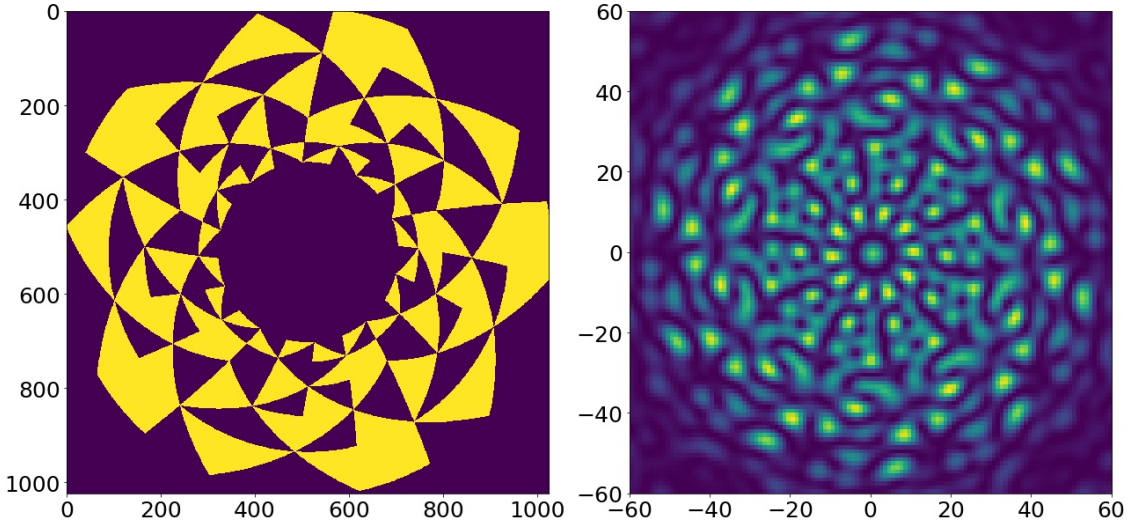

Figure 11. Heuristic value of 37

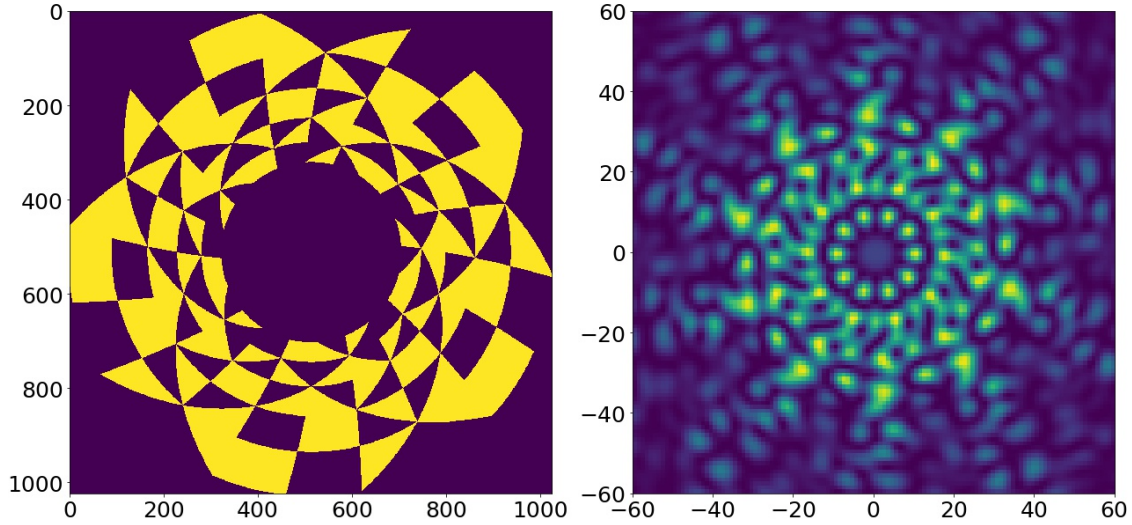

Figure 12. Heuristic value of 37

Results and Discussion

- Results:
  - The best pupils were found to have a heuristics value of 52 and 34 for the half and whole pupil respectively.
  - Using the given heuristic this reflects a large improvement (92 -> 34), showing that there is potentially a great deal more ideal pupils that haven’t been found.
  - These results could be improved upon given further computation time as these results were found just doing an initial exploration of the parameter space
- Discussion:
  - More specialized pupils can be found using this method given a tighter set of design constraints
  - From these tight constraints we could construct a more rigorous heuristic that allows us to hone in on a design that is much more suited to what we want

Further work

- It seems that the other teams working on this pupil have gone a different route in terms of their optimization methods. The method I have used in limited in the sense that it can only make modifications to a pre-designed base pupil and optimize from there
- Re-defining our heuristic to better match the tight constraints could be done in order to find a new base pupil,. This could then be further optimized using the ‘table top’ algorithm described by Kieran
- Hopefully these different designs can be incorporated in some manner that further idealizes the pupil
- As mentioned earlier a better heuristic function is the starting point of any further optimization among all the teams

Potential Heuristic functions

- A potentially more ideal heuristic function could include some combination of the following:
  - Maximum power delivered to any pixel on the array P, minimize
  - Percentage of total power that falls within the 6λ/D radial region C, maximize
  - Standard deviation within the 6λ/D radial region S, minimize
    - This is proposed as a method to measure the power gradient and give us more defined (less blurred) power peaks
- Potential maximizing heuristic:
  - $H = C/(P * S)$
- Potential minimizing heuristic:
  - $H = (P * S)/H$