Novel Aplanatic Designs for LED Concentration

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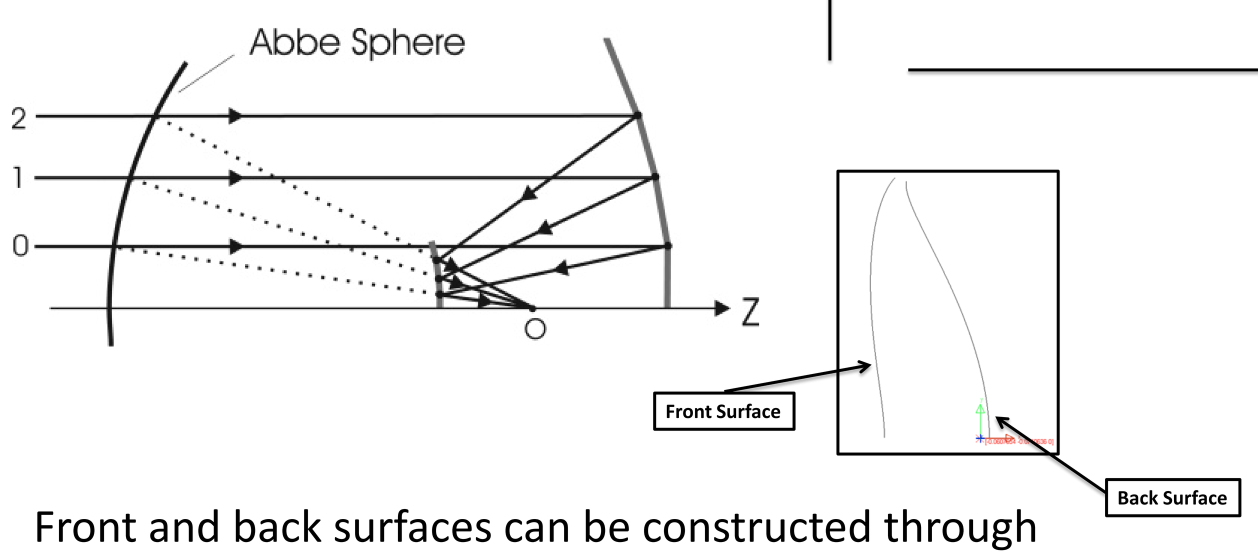
Abstract:
Aplanats make great concentrators because of their near perfect imaging. Aplanatic conditions can be satisfied using two surface curves that are then rotated into a 3D shape. For concentration purposes, having a two mirror system would be impossible because the front mirror would block the incoming light. "The Jellyfish" design uses a one way mirror for the front surface, with a small reflective coating in the middle. In this way, TIR can be utilized. Initial prototype designs obtained efficiencies near 70%. For this work, we optimize the current design using both manufacturer specifications and parameters that improve the efficiencies.

Background:

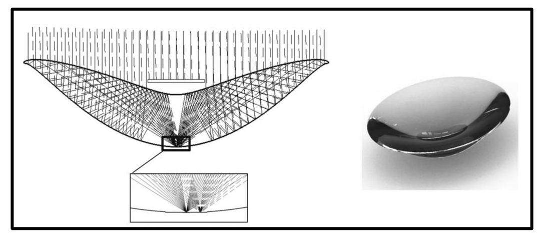
Aplanats make great concentrators – near perfect imaging

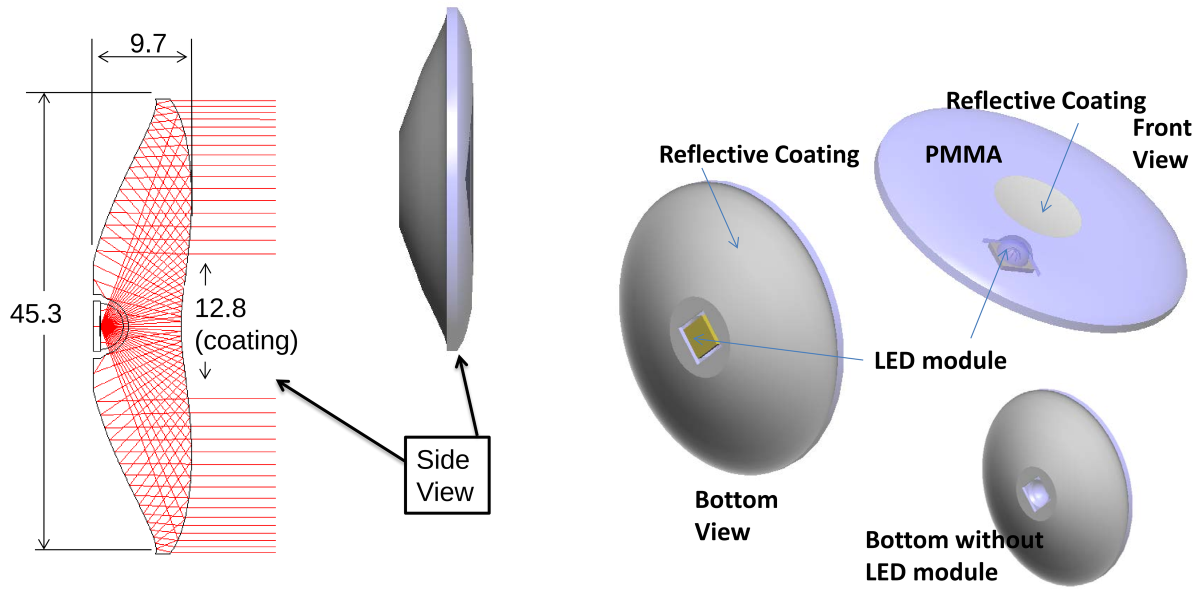


- Front and back surfaces can be constructed through successive approximation, adjusting the slopes such that they properly satisfy the aplanatic condition.
- Rays parallel to the axis intersect rays converging to the focus.

"The Jellyfish"

- This aplanat is a concentrator that works in both forwards and reverse, for both solar concentration and LED illumination.
- We will be using it for LED illumination





- A reflective coating is given to the back, and the top center.
- The material has an index of n = 1.49 (PMMA) allowing the top surface to act as a "One-way mirror" taking advantage of TIR properties.
- An LED is placed in the back.

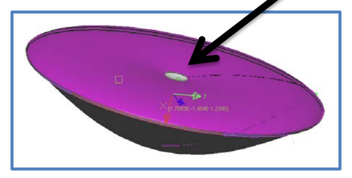
Initial prototype efficiency: ~70%

Our goal here – improve the efficiency by adjusting various parameters to optimize the jellyfish model.

Concentration and Illumination

→ *Efficiency* = 1 – 0.07 = 1 – 0.07 =93%

Based on the prototype model:
JF radius = 22.5 mm
Front reflective coating radius = 6.4 mm

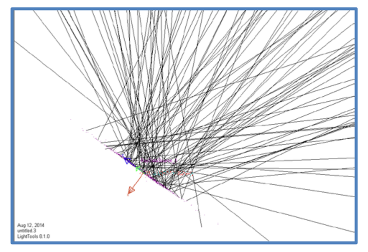


- Decreasing the coating on the JF will increase the efficiency of the JF model.
- Where is the light going in the illumination problem?

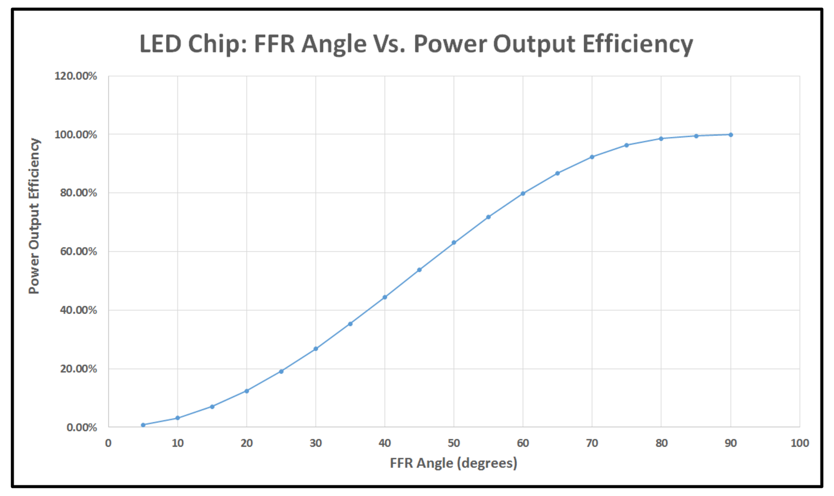
Goal: Decrease the coating on the Jellyfish

Adjustable Optomization Parameters

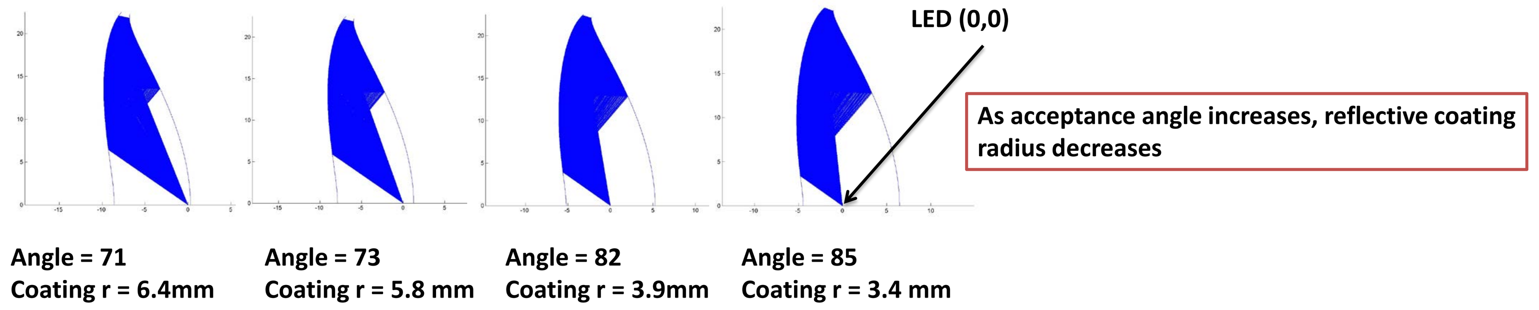
1. LED Acceptance Angle

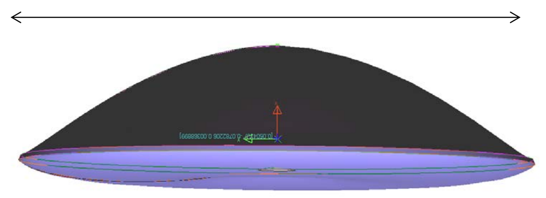


Seoul Semiconductor LED chip Acceptance angle



- The first adjustable parameter in the JF is the acceptance angle we use for the LED.
- LED source ray distribution can be analyzed w.r.t. Far Field receiver (FFR) angle.
- We see 100% peak near an angle of 85 degrees, which we will choose to be our LED acceptance angle input.



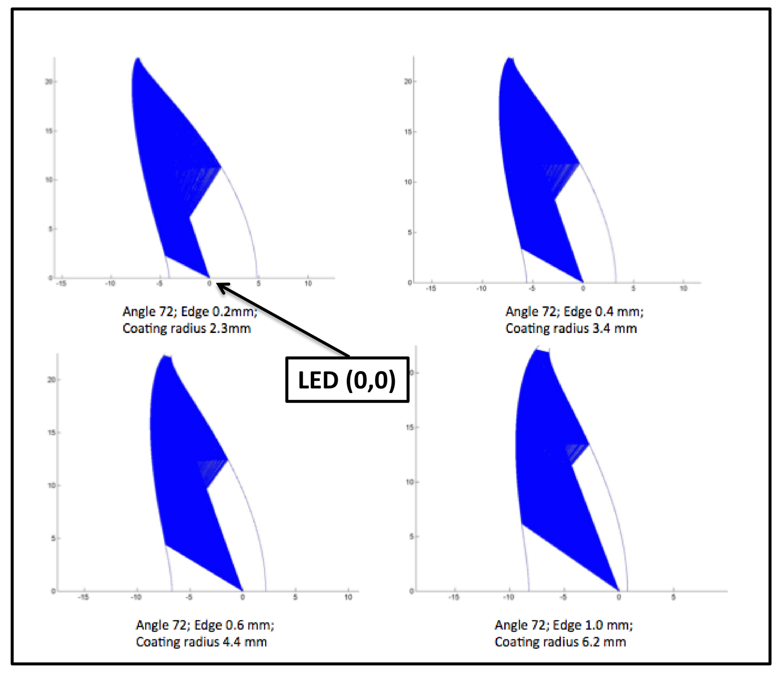


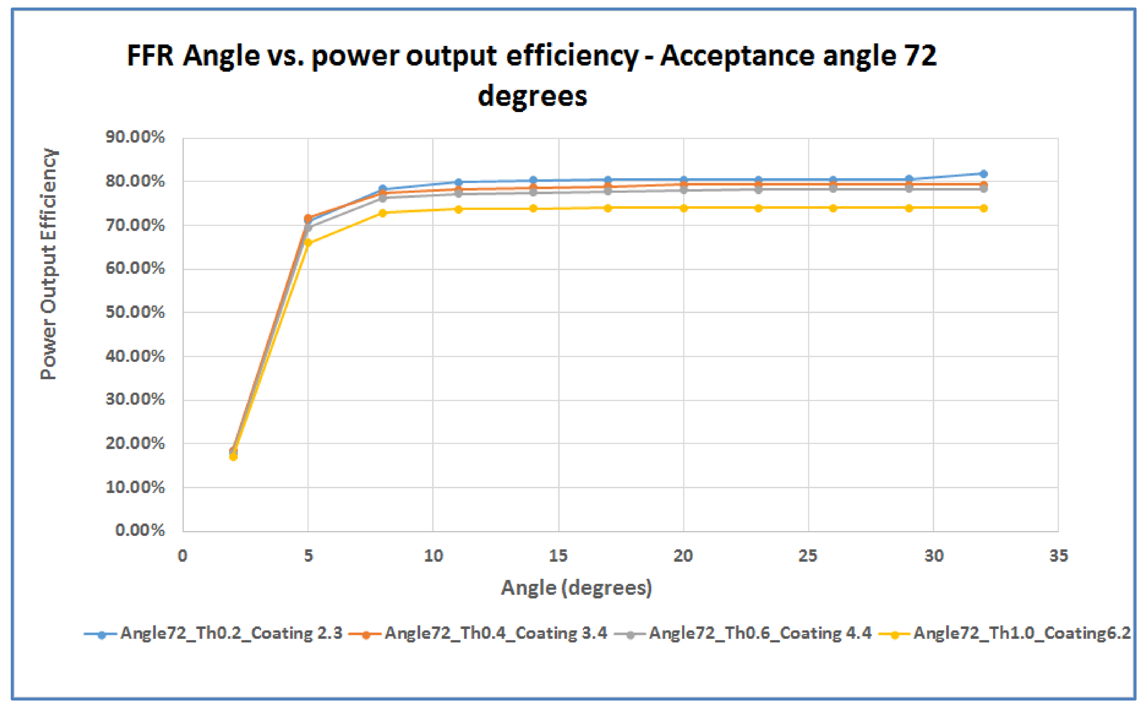
2. Radius of the Jellyfish

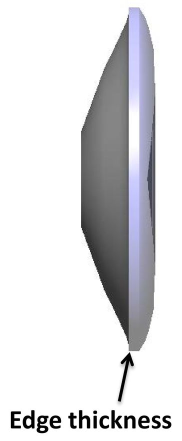
Though adjusting the radius does influence the overall efficiency, we are limited by the practical considerations where we would like a 45mm diameter Jellyfish.

3. Edge thickness of the Jellyfish

- As the edge thickness increases towards 1.0 mm, the LED location becomes farther back from the front surface
- The further back the LED moves from the front surface, the greater the coating radius must be.
- As shown before, moving the LED back to increase the coating radius will reduce the concentrator efficiency.



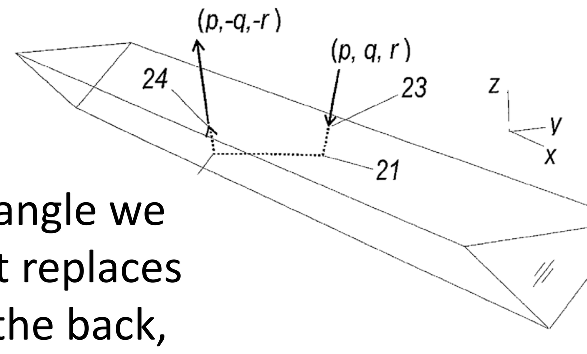




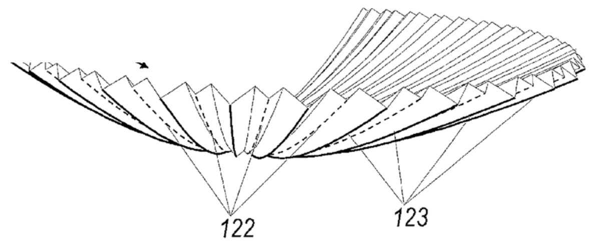
Edge thickness dictates reflective coating size, and thus efficiency. Thinner edges yield a smaller coating radius and greater efficiency.

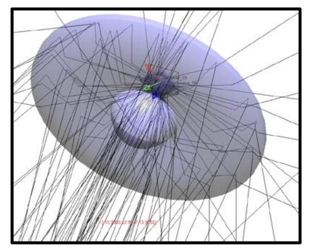
Final Efficiency: 87%

Future Work



Using wedges with a 90° angle we will design a TIR back that replaces the reflective coating on the back, decreasing the cost to manufacture





We will also look at replacing the reflective coating with a Cartesian oval.

References:

- Winston, Roland, and Weiya Zhang. "Novel Aplanatic Designs." Optics Letters 34.19 (2009)
- US Patent No.: US 8,238,050 B2

Acknowledgements

- UC Solar group
- UC Light
- Dr. Roland Winston
- Lun Jiang
- InteLED

UC Solar