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Design and Simulation of a Planar Micro-Optic Free-Space Receiver

July 12, 2017

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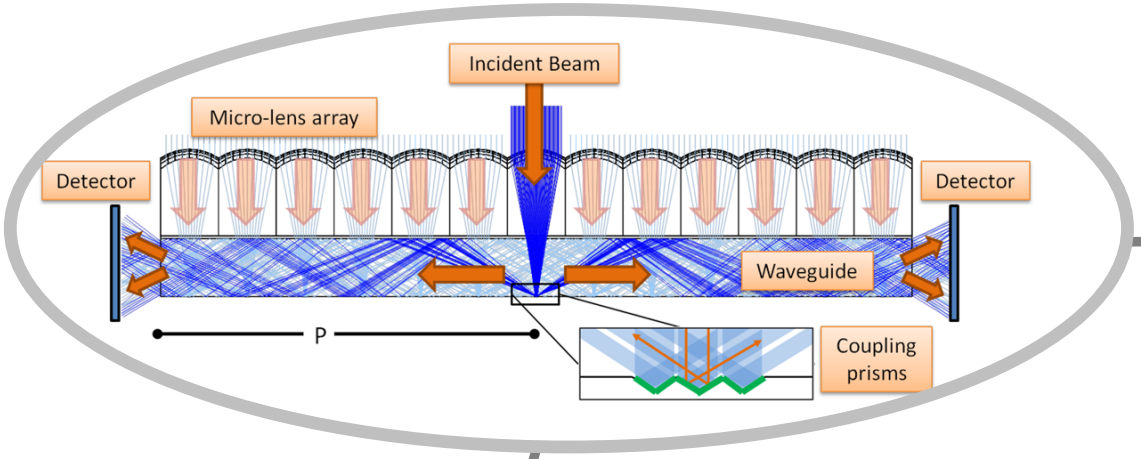

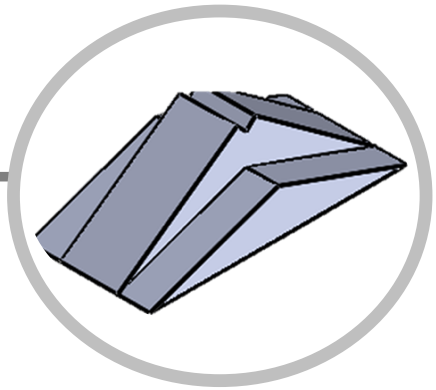

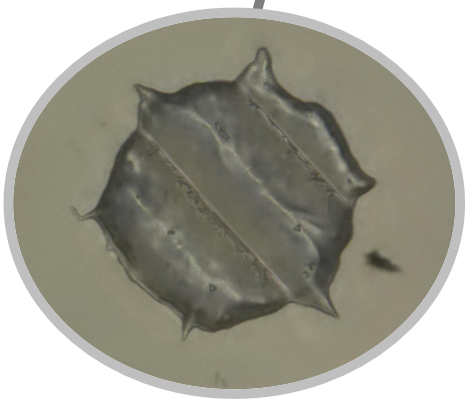

Design Concept: free-space receiver, large aperture, planar, coupling prisms

Design Objectives: 2.5GHz bandwidth (video), reduced costs and complexity, scalability, source tracking or user selectable source

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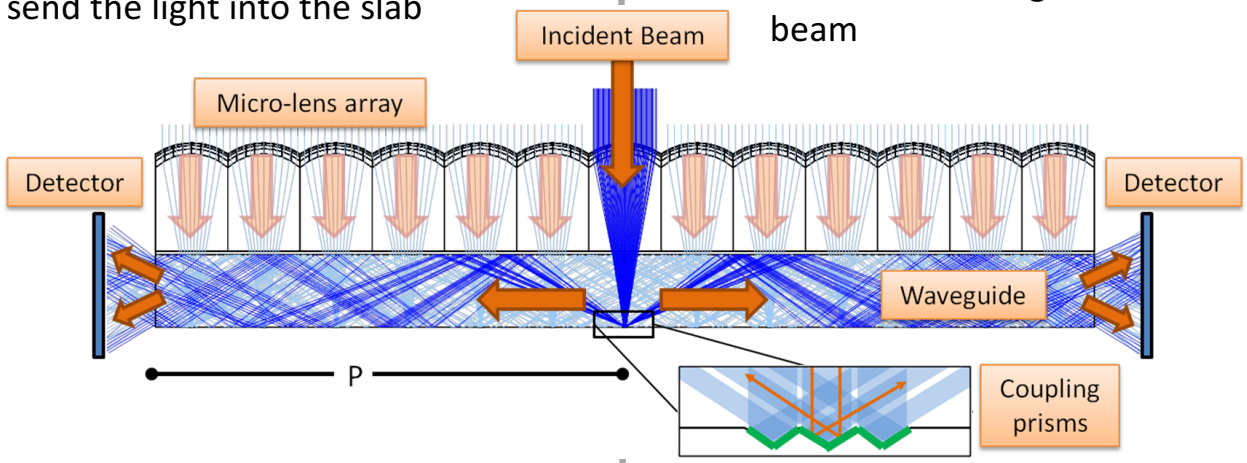
Planar receiver leverages concentrator tech

- Micro-lenses focus beam on coupling prisms attached to the backside of the slab
- Reflections send the light into the slab

- TIR propagates beam to the edge of waveguide
- Detectors are edge-mounted to capture beam



- Distance (P) from incident beam to waveguide edge is used to calculate modal dispersion

- Losses occur when focal spot does not mirror prism size and when TIR conditions are not met
- Design objective considered lens & waveguide geometries and prism shape

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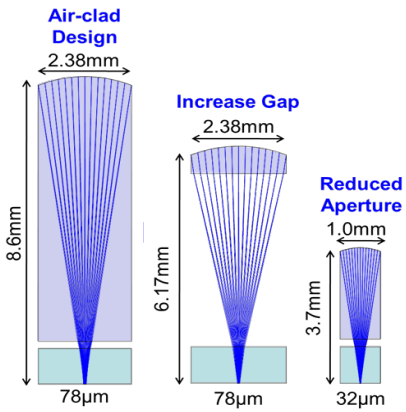
Design space to address optical and geometric loss



(Karp, 2010)

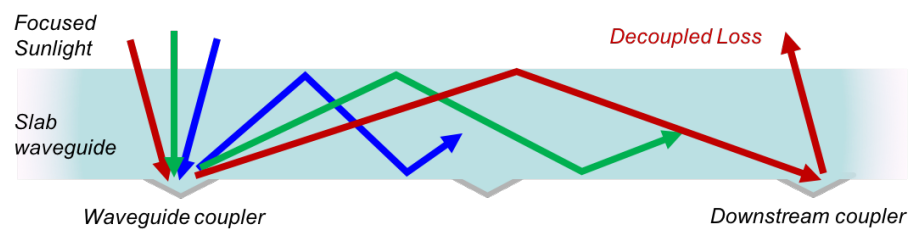
Equivalent Designs

- Identical lens f-numbers
- Same optical efficiency

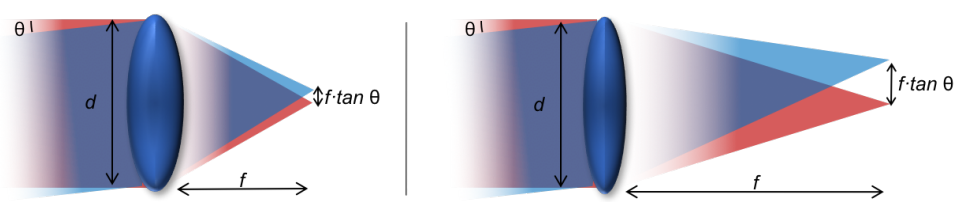
Application-Directed Design

- Waveguide materials, lens array f-number
- Angular acceptance vs. optical efficiency

- Propagation Efficiency
  - Subsequent coupler interaction decouples as loss
  - Inherent loss mechanism due to planar waveguiding



- Focal ratio (f/#): focal length / diameter
- Acceptance angle and focal length define coupling area: 2f·tanθ
- Influences ray angles and propagation efficiency



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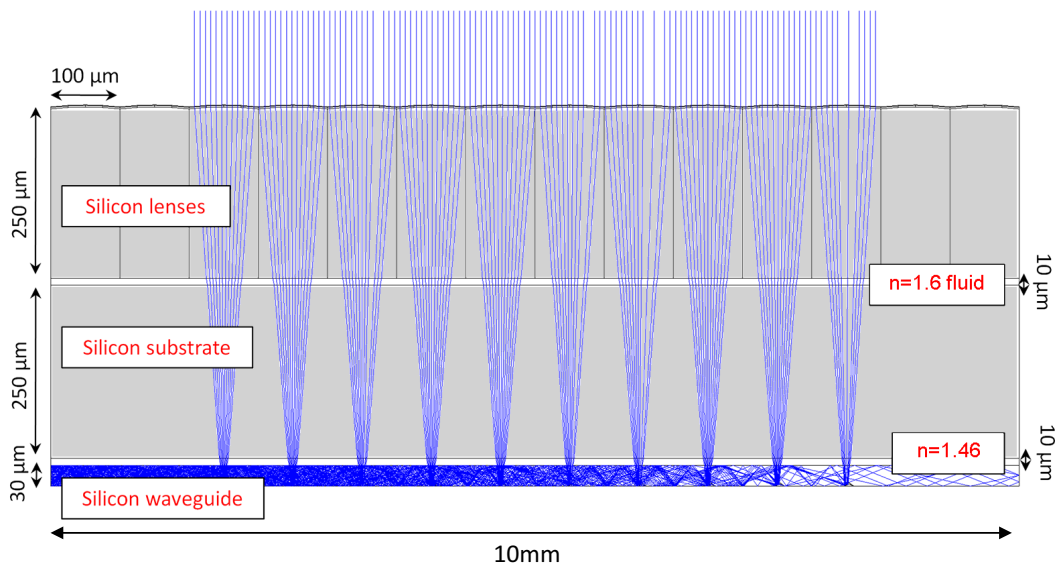
Simulation geometries and material selection

- High concentrations & large acceptance angles ==> high index lenses and waveguide materials
- Si (n = 3.48) transparent to 1550nm source
- Lens substrate separated from substrate by air or fluid (optical coupling fluid, n = 1.6)
- Substrate to waveguide separated by optical coupling fluid, n = 1.46, with SiO_2 beads for TIR guiding and structural support.



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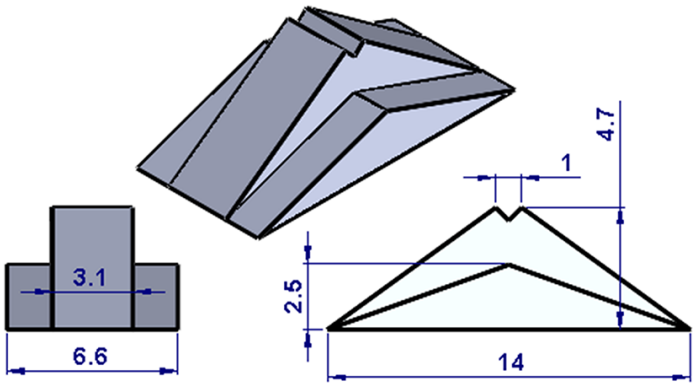
Prism features optimized in software

- Merit function based on total output power coupled to detector
- Variables under consideration:
  - Lenslet array: radius, conic, and aspheric terms
  - Injection elements: position, width, and height
- Polarization was allowed
- Transmission coatings with efficiencies listed at 99.99% used on surfaces not requiring TIR.
- Various waveguide footprints (length and width) optimized for maximum output power
- Peak of the symmetric ramps of the prism elements inverted, creating the folded injection feature
- Improved efficiency compared to a uniform 60°or 45°prism.



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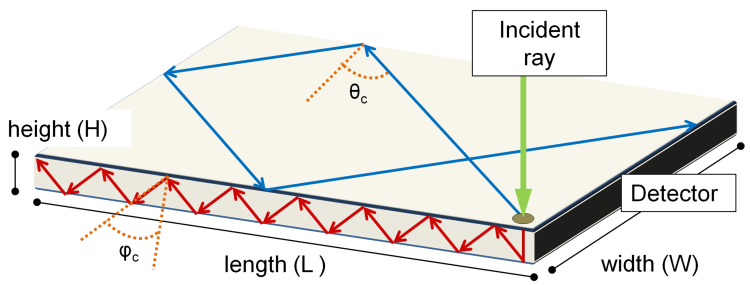
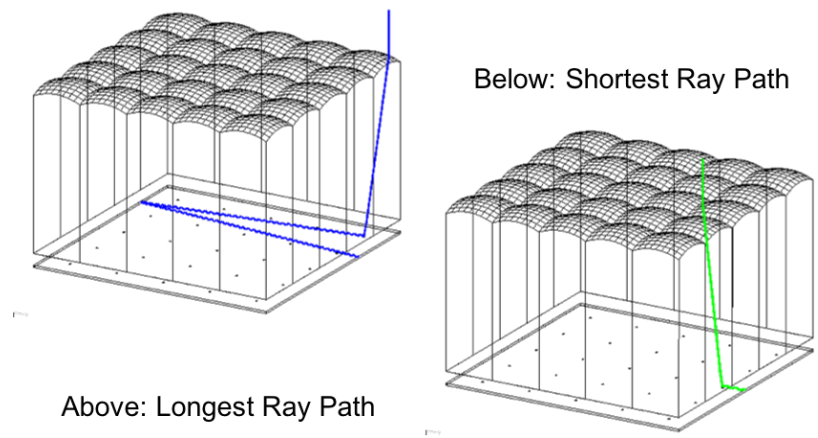
Path dependent delays

- To achieve 2.5GHz transmission, new waveguide design incorporates F/3 lenses
- Modal Dispersion
  - Receiver bandwidth limited by path delays
  - Receiver theoretical bandwidth of 7.05GHz determined by path difference between the longest and shortest rays





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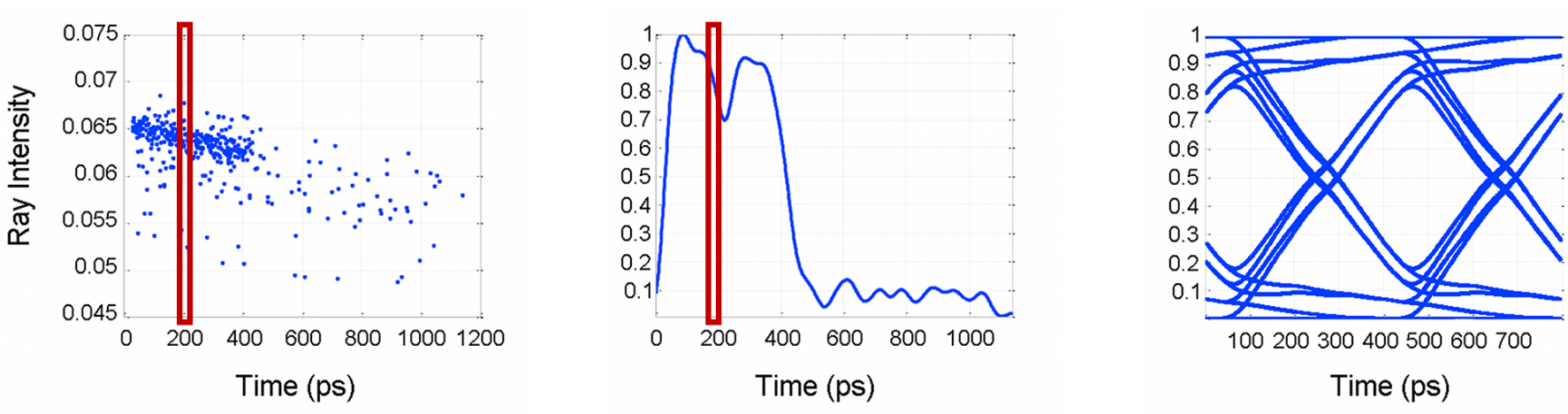
Waveguide response with ideal detectors

- On-axis incident rays time stamped with intensity at detector
- Compiled into intensity-based impulse response of waveguide as function of time
- Convolved impulse response with 10-bit PRBS signal at 2.5 GHz to yield simulated system eye diagram



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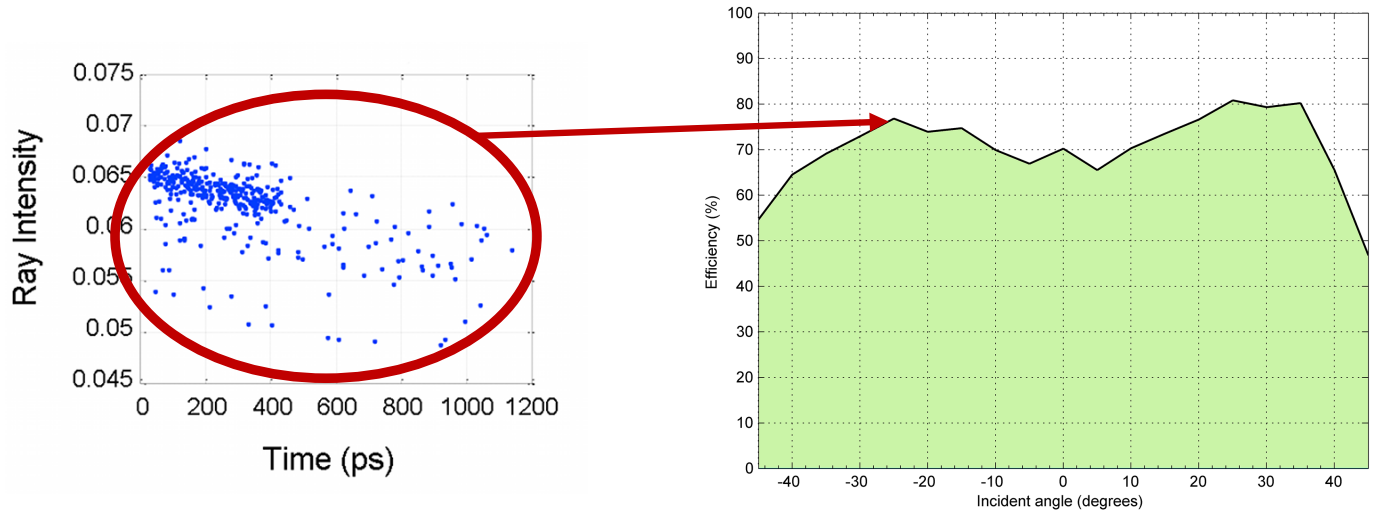
Waveguide response with ideal detectors

- Varied light source over incident angles in a range from -45° to 45° to determine the efficiency of the waveguide at different tracking positions.
- Waveguide design with L=10mm, variation in signal loss between ±40° less than 1.84dB.



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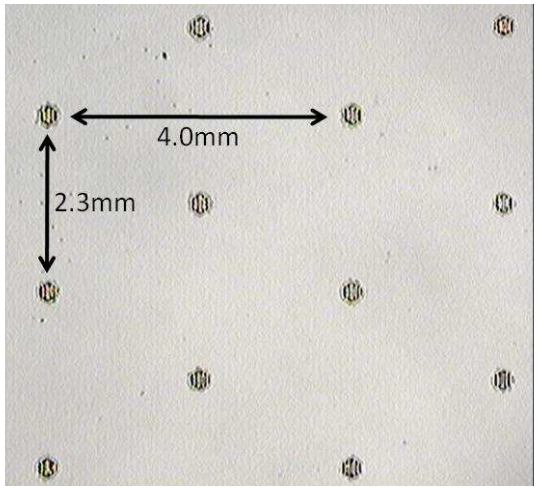
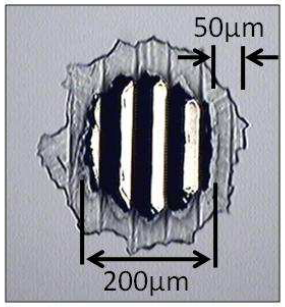
From simulation to prototype realization

- Injection prisms: SU8 self-aligned lithographic technique
- Self-aligning process uses lens array focal spot to cure prism features
- Prototype shown offers 32.43% efficiency (η) over visible and IR but designed for solar collection rather than communications
- 50µm pitch 120°coupling prisms coated with 90nm aluminum layer





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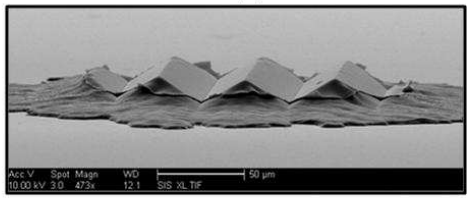
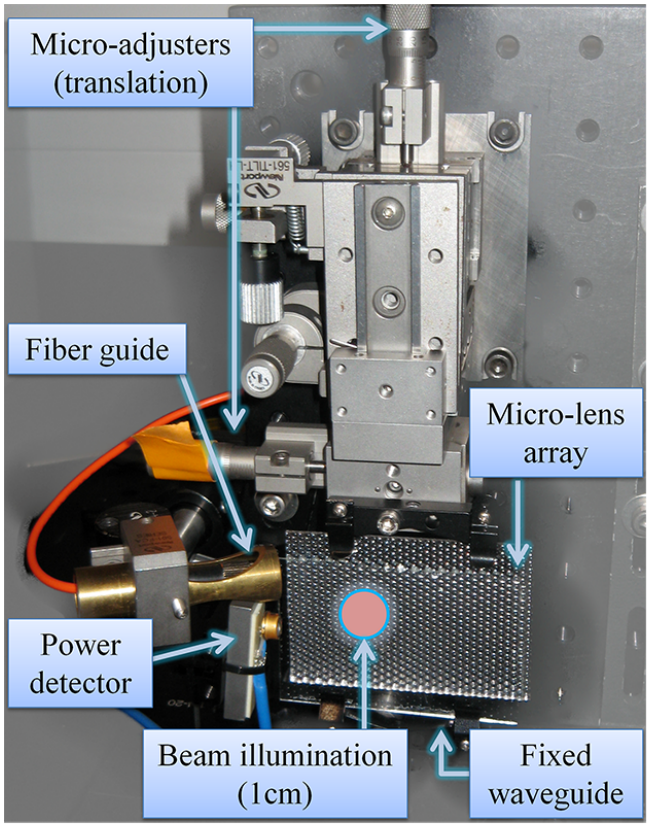


Experimental setup aids off-axis investigation

- PMMA lenslet array (η=1.481) and BK7 glass (η=1.501) waveguide
- Concentrator optics efficiency of 34% for the IR (λ=1.55μm) wavelength
- BK-7 glass waveguide 75mm long by 50mm wide and 5mm thick
- Lenslet array (75mm x 50mm) with 2.3mm diameter F/1.1 plano-convex lenses of 86.3% fill factor



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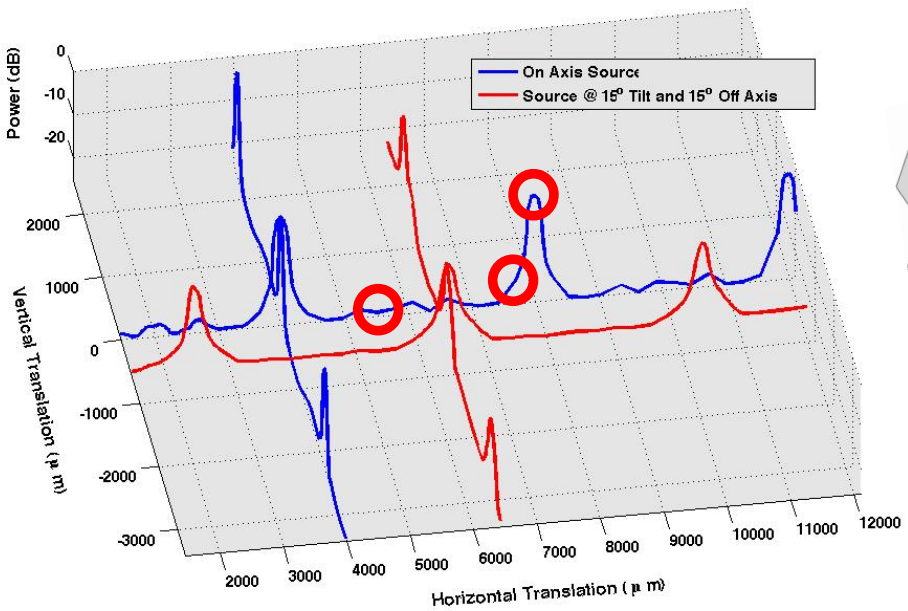
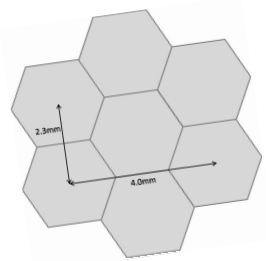
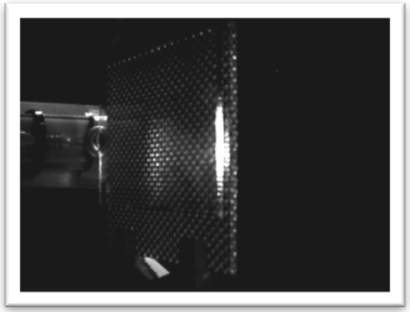
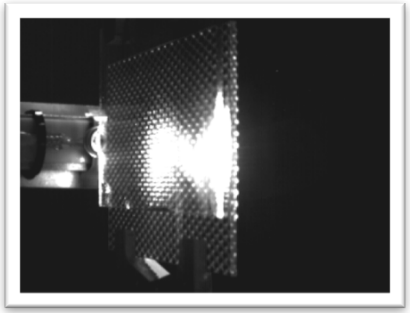
On-axis power tracking

1. Misalignment evident when lost signal passes through and edge appears dark.
2. During translation more light is coupled appearing as increased intensity.
3. Peak light capture observed as edge of waveguide appears bright and more uniform in intensity.









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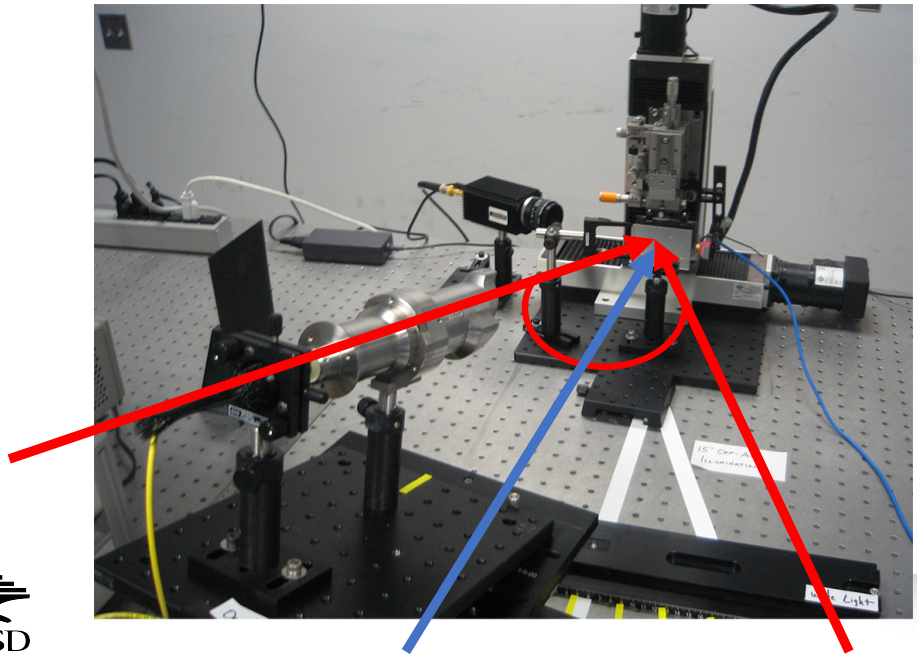
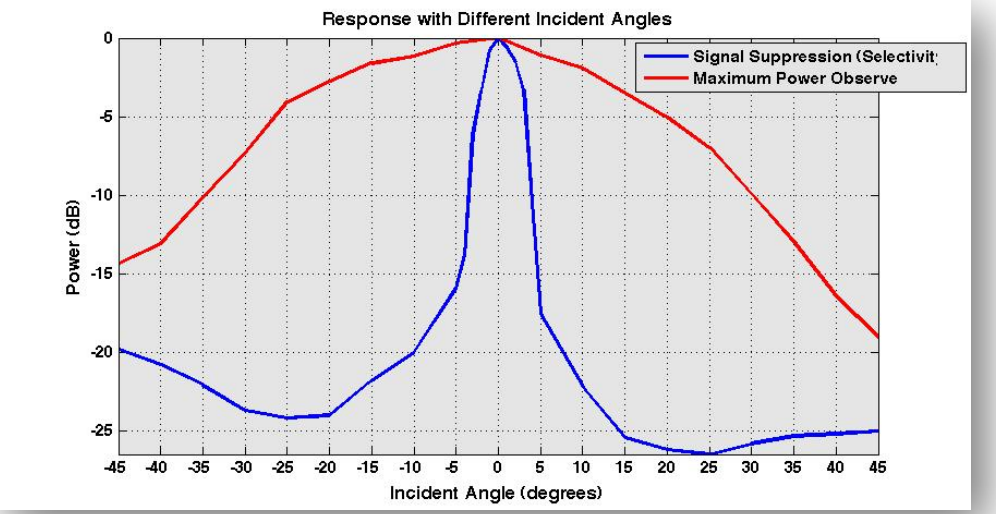
Peak power and angular suppression

- Off-axis sources show decreased light capture measured as a function of angle (red line).
- Second measurement (blue) shows signal suppression when angle observed without waveguide translation and tracking.





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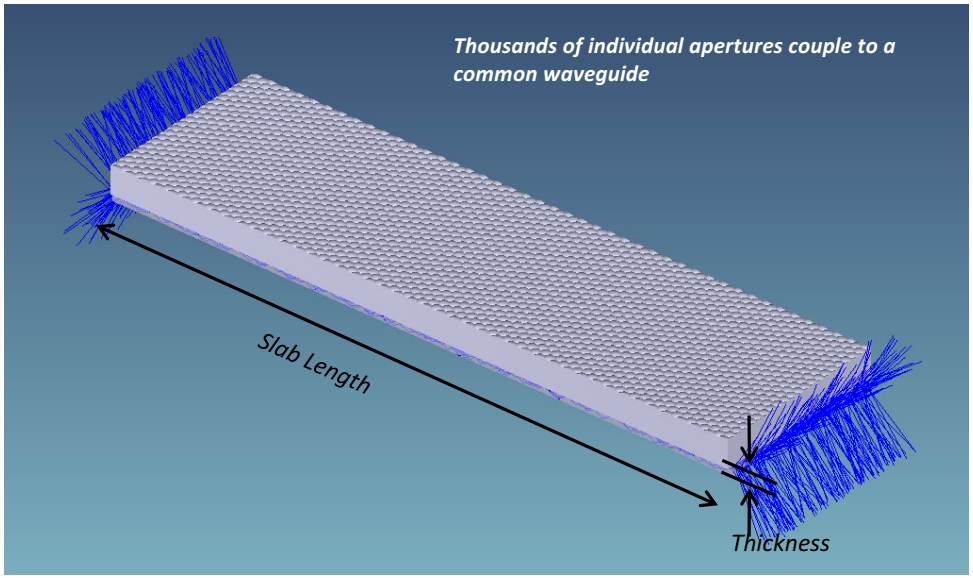
Final thoughts on receiver cookies?

(quoteimg.com
, 2017)



Thank You

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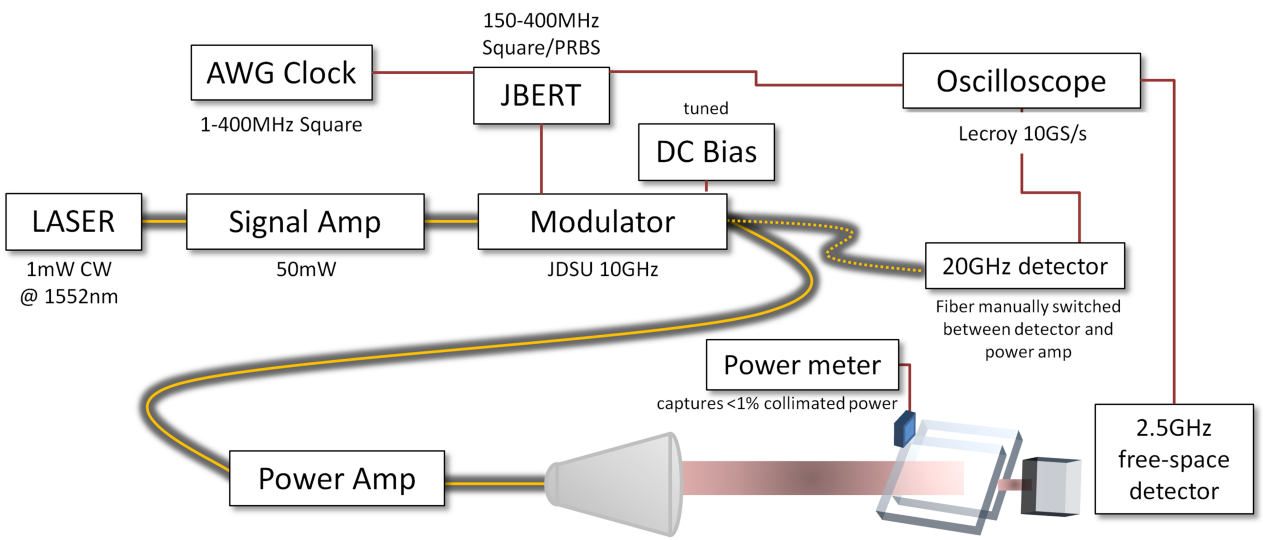
Backup image



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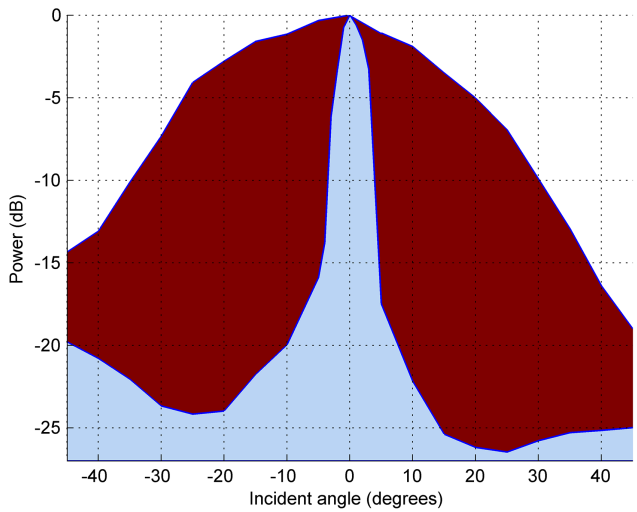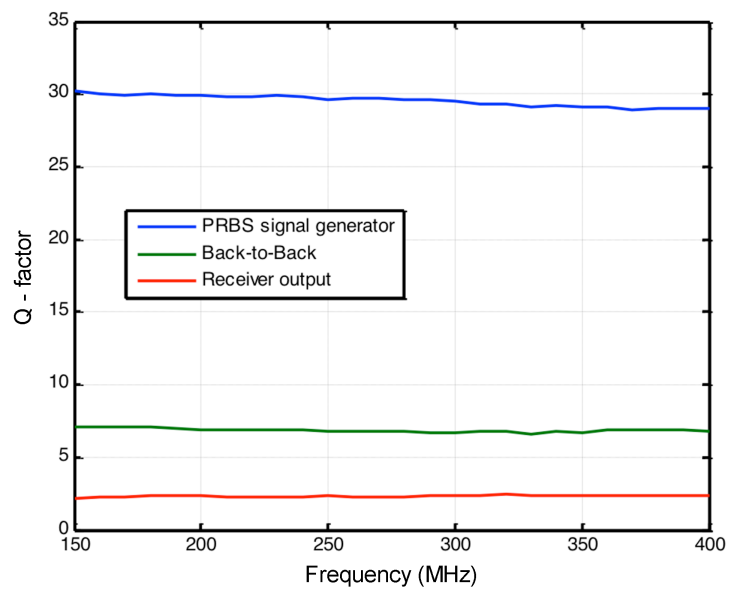
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