University of Colorado Boulder

Team/Contributors

Karl G. Linden
R. Scott Summers
Al Weimer
Al Lewandowski
Rita Klees
Cori Oversby
Ryan Mahoney
Tesfa Yacob
Richard Fisher
Lauren Hafford
Dragan Mejic
Dana Hauschulz
Sara Beck
Josh Kearns
Barbara Ward
Garrett Sprouse
Kate Stetina
Alyssa Ruiz

Sol-Char Toilet

Richard (Chip) Fisher & Ryan B. Mahoney
Department s of Chemical and Biological Engineering & Environmental Engineering

Innovation in toilet designs and waste treatment technologies
Webinar #4

Key Technology Components

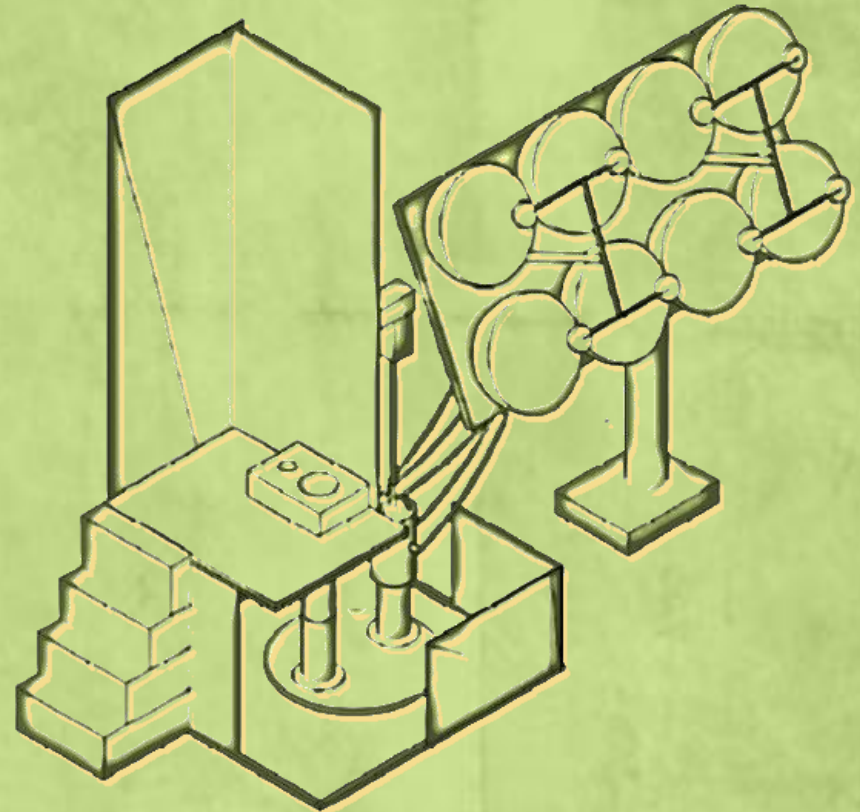Parabolic dishes concentrate solar energy

Fiber optics transmit energy to a pyrolysis reactor

Reactor thermally inactivates human waste

Useful end products are created

Proof-of-Concept Prototype: The Sol-Char Toilet

Sustainable and Renewable Energy

CSP transmitted through fiber optic bundle

- Parabolic mirrors most efficient solar concentrators

- High temperature solar process requires high solar concentration
  - ≈2000 suns

- Expect to see up to 500W – 1000W delivered power

Pyrolysis Reactor & Urine Heat Treatment

- Reactor has two positions: Collection and Reaction
- Automatically dumps char product
- Urine circulated around solar hood and heated (target ~70°C for 30 min)

Collection   Treatment   Sanitized urine storage

- Prototype module still under development
- Simulated lab disinfection experiments at 60⁰C showed complete disinfection of *E. Coli* and virus surrogate (MS2 bacteriophage) in minutes

Sustainable Sanitation

- Sol-Char uses renewable energy from the sun to treat human waste
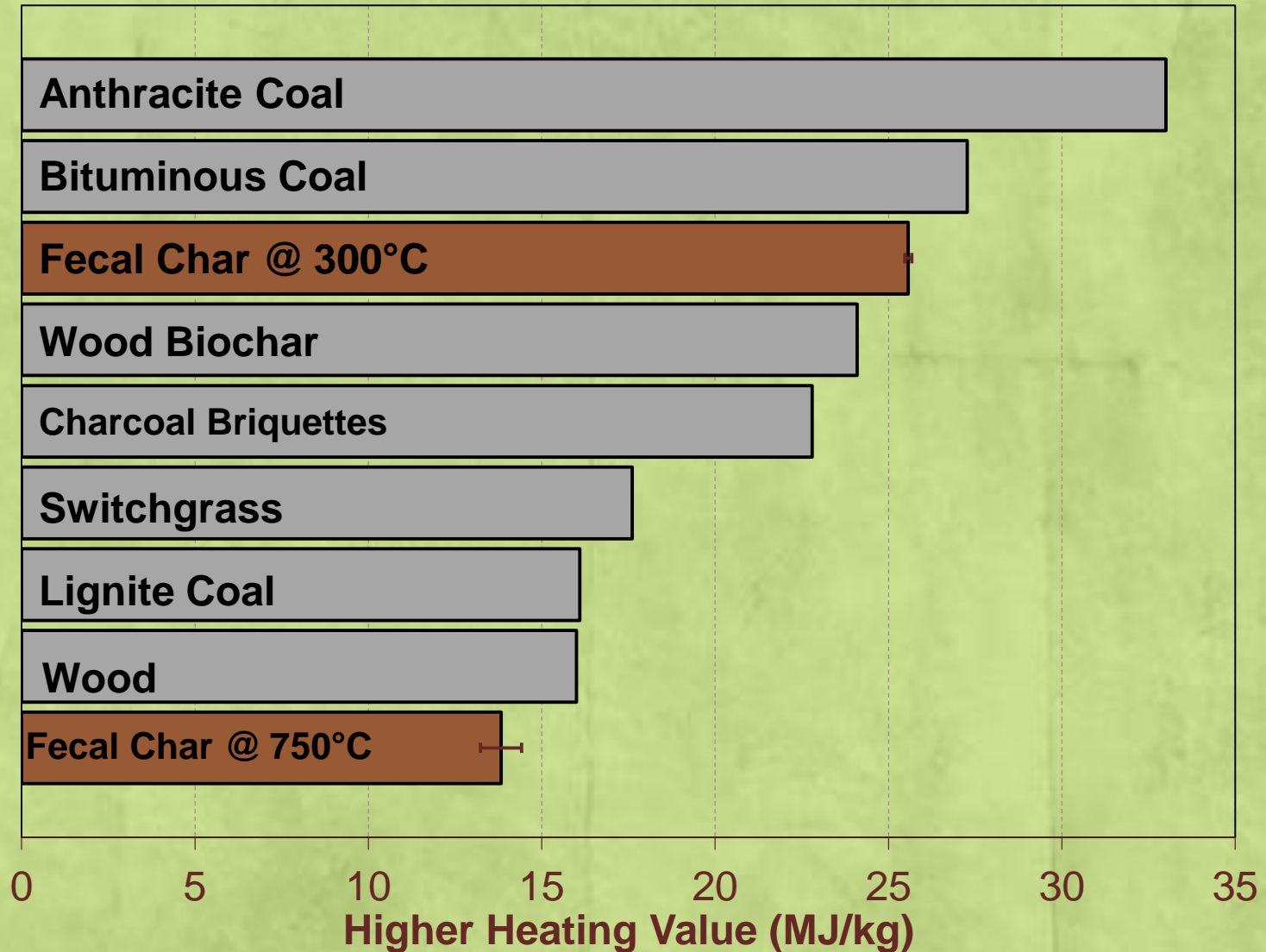
Designed to process

2 kg of feces

4 kg of urine

in 4 hours

➢No added water, no added grid-power, no chemicals

➢Value-added biochar and sterilized-urine fertilizer

Char as a Fuel Source*

Bar chart showing Higher Heating Value (MJ/kg) for various fuel sources:

- Anthracite Coal — ~33
- Bituminous Coal — ~27
- Fecal Char @ 300°C — ~25.5
- Wood Biochar — ~24
- Charcoal Briquettes — ~23
- Switchgrass — ~17.5
- Lignite Coal — ~16
- Wood — ~16
- Fecal Char @ 750°C — ~14

X-axis: Higher Heating Value (MJ/kg), scale 0 to 35

Char as a Soil Amendment & Adsorbent

Preliminary Results

- Biochars made with real and synthetic fecal sludge in laboratory furnace
  - Compared/contrasted results

- Found fecal sludge char is able to sequester carbon, increase CEC and alter soil pH

- High temperature (greater than 500°C) only worthwhile for adsorption uses
  - Odorous compounds (H_2S, ect...)
  - Ammonia nutrient adsorption

Preliminary Property Results
1. Longevity in soils
2. Cation Exchange Capacity (CEC)
3. pH / Liming Effect
4. Structure
5. Nutrient content

Achievements to date:

- Ability to dewater waste in only a few hours and achieve charring temperatures above 600°C

- Improved solar tracking accuracy 10x with cheap analog controls

- Overcome high heat flux burning/damaging fiber optic cables through fusing process

- Quantified fuel value in resulting char product

- Worked with partners to learn about markets for products (dried fecal sludge, carbonized briquettes)
  - Household cookstove-scale
  - Retail heating and cooking fuel (hotels/
  - Industrial fuels for kilns/boilers

- Completed urine disinfection and regrowth experiments

Thank You

Like us on facebook!:
http://www.facebook.com/SolarBiochar

Human Waste Drying Odor Removal

pH = 10.3 - Dose vs. Removal

% Captured in Biochar vs. Carbon Dose (g/L)

Bamboo 350
TLUD Pine 900
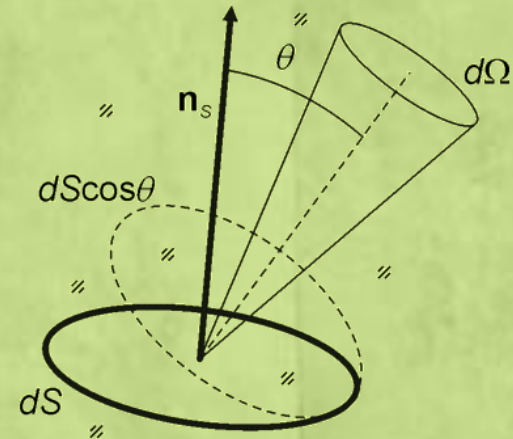Bamboo 900
Fecal Sludge 300
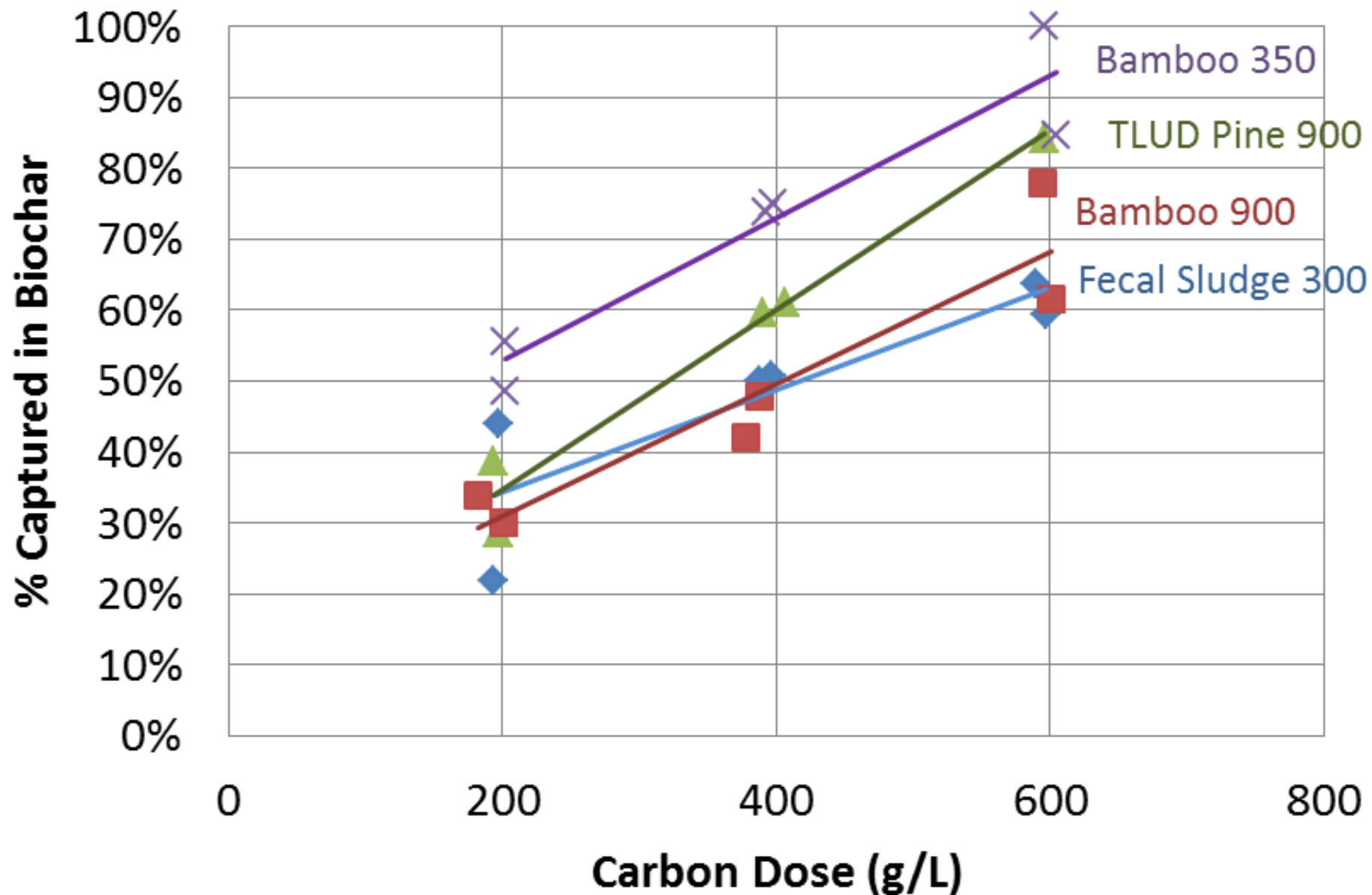
Sun Tracking Required

Direct +Diffuse Irradiance

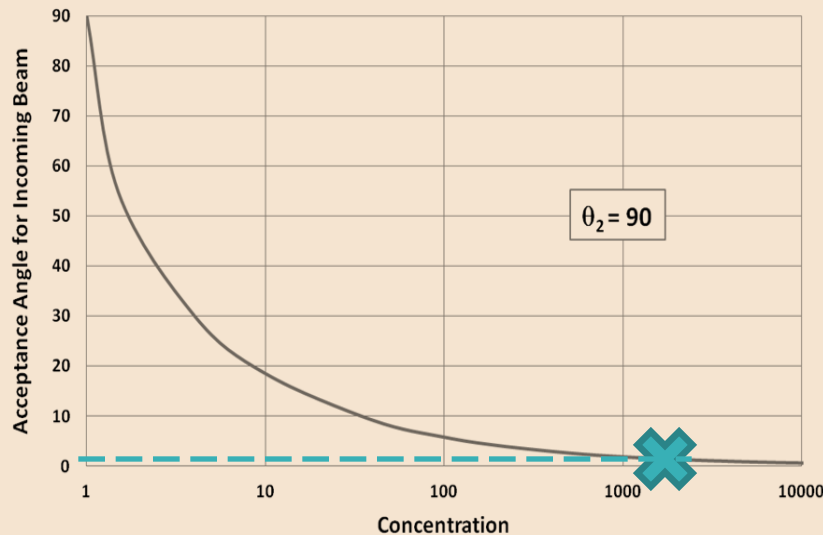- Low concentration systems do not require tracking
  - Heliotropic plants, flat plate PV, solar water heaters

Two Axis Tracking Requirements

Direct Normal Irradiance

- Medium to high concentrating systems require tracking

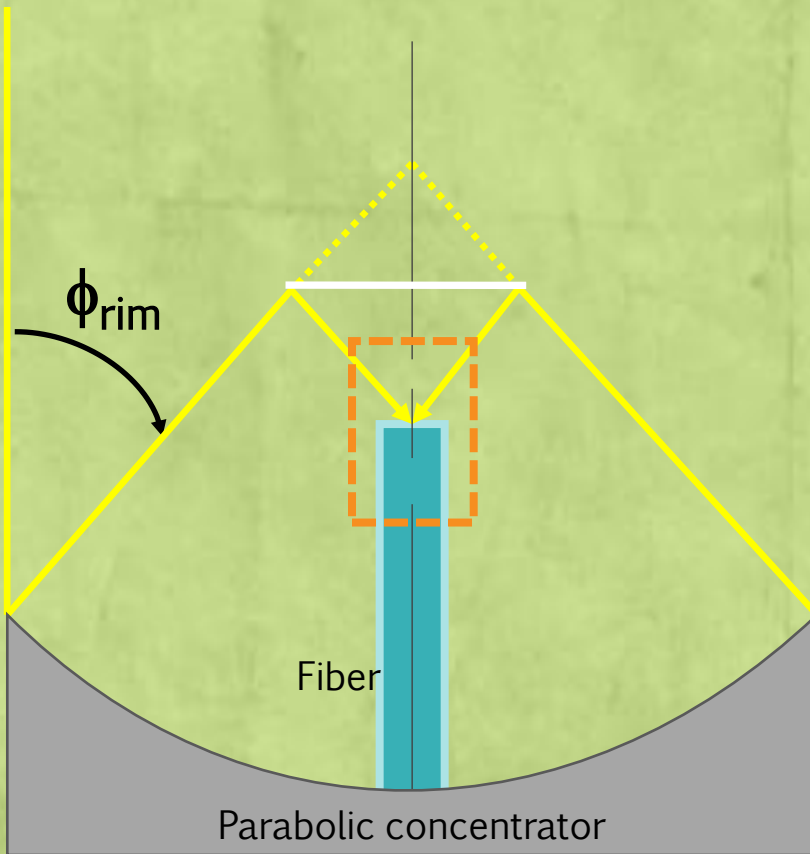$$C = \frac{S_1}{S_2} = \frac{\sin^2 \theta_2}{\sin^2 \theta_1}$$

- Conservation of étendue
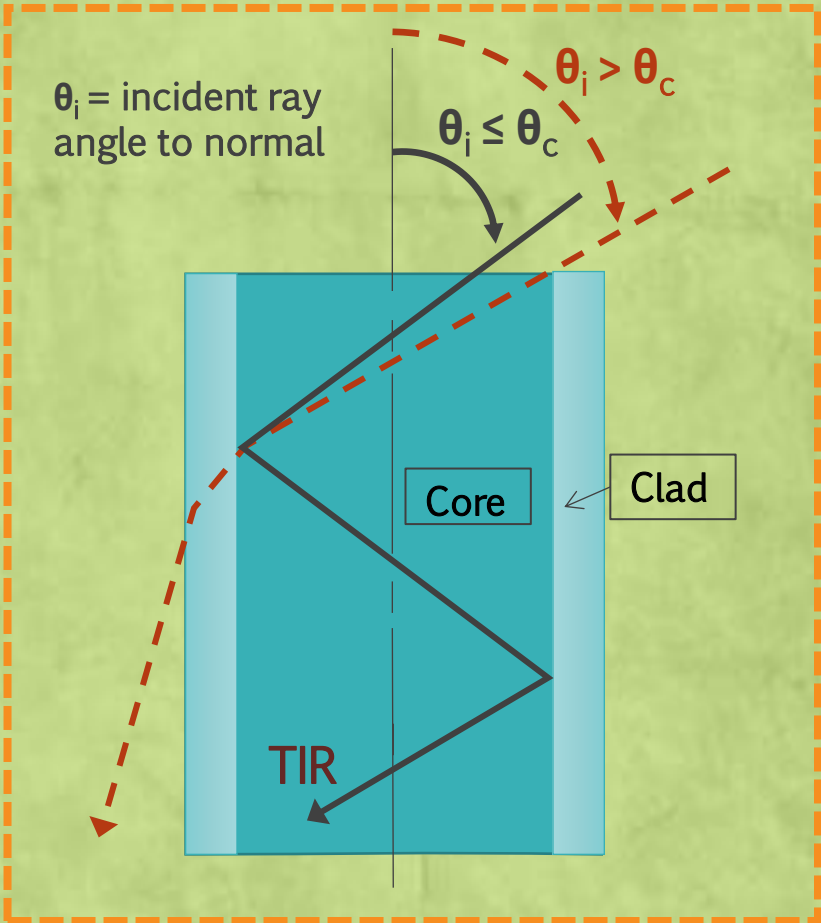
CSP Basics

$$\phi_{rim} = \theta_{i,max}$$

Best optical efficiency if
$$\phi_{rim} \leq \theta_c$$

ϕ_{rim}

Fiber

Parabolic concentrator

θ_i = incident ray angle to normal

$\theta_i > \theta_c$

$\theta_i \leq \theta_c$
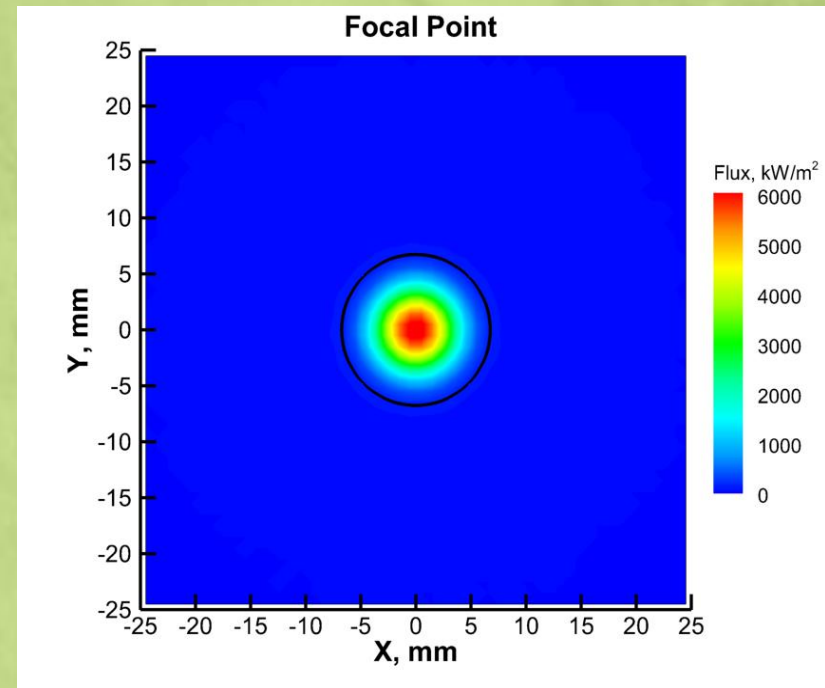
Core

Clad

TIR

CSP Image at Focal Point

Measured
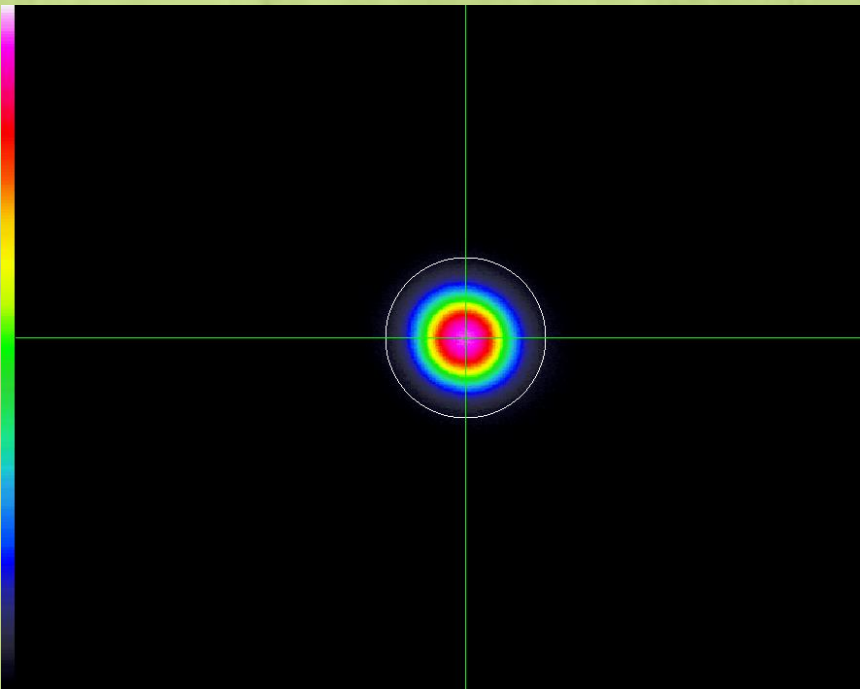
Modeled

- Pink/red color is high energy flux, color scales do not match
- Circle drawn is active fiber diameter of 13.5mm

Fecal Waste Treatment: Pyrolysis

Pyrolyzing fecal sludge

"Glaze" that forms during pyrolysis, considerable amount of tar

Nearly all water removed, 89% mass reduction and sterile/safe to handle

Continuing work on parasitic losses that are affecting heat transfer

800g Synthetic, 690W Power for 4 Hrs