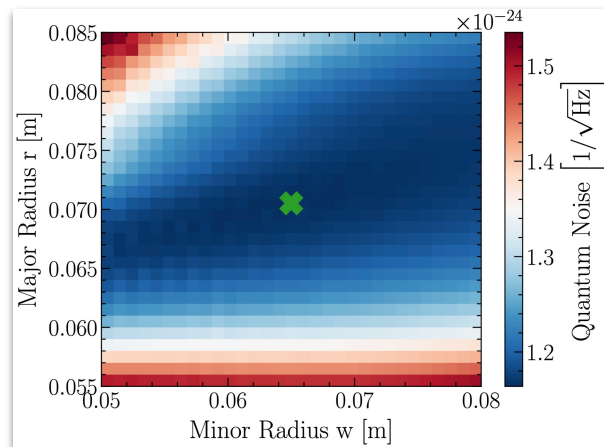


# **Multi-Ring FROSTI with Grid Search**

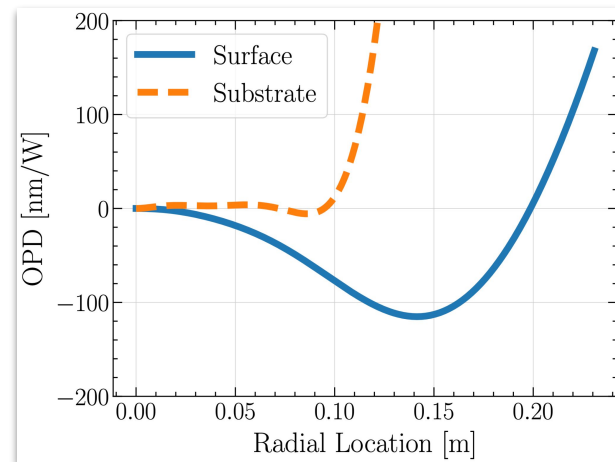
|                   | Lower Bound | Upper Bound | Steps |
|-------------------|-------------|-------------|-------|
| Major Radius [cm] | 5.5         | 8.5         | 30    |
| Minor Radius [cm] | 5           | 8           | 30    |
| FROSTI Power [W]  | 10          | 40          | 30    |



Optimal quantum noise at 1.5 MW

The RH power is optimized to completely remove the quadratic component the substrate OPD

In total, there are  $30 \times 30 \times 30 = 27000$  cases, which takes ~20 hrs over 45 cores.



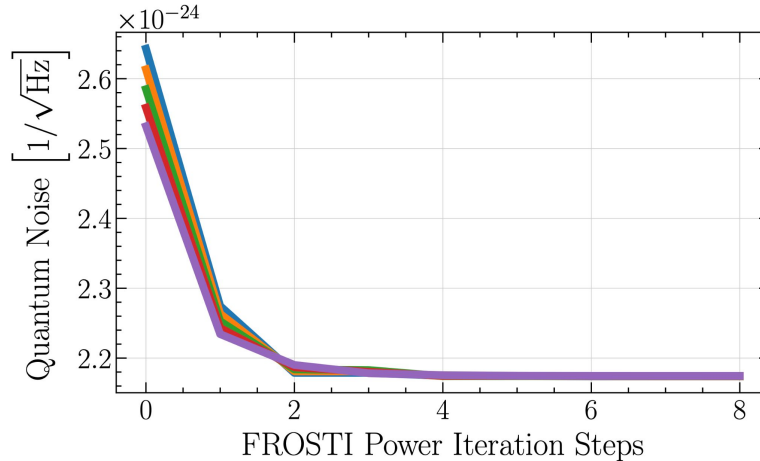
Large Residual Wavefront RMS Error

# **Grid-Search Study for FROSTI A+**

## Grid Search over Single Component FROSTI Parameters

|                   | Lower Bound | Upper Bound | Steps |
|-------------------|-------------|-------------|-------|
| Major Radius [cm] | 5.5         | 8.5         | 45    |
| Minor Radius [cm] | 5           | 8           | 45    |

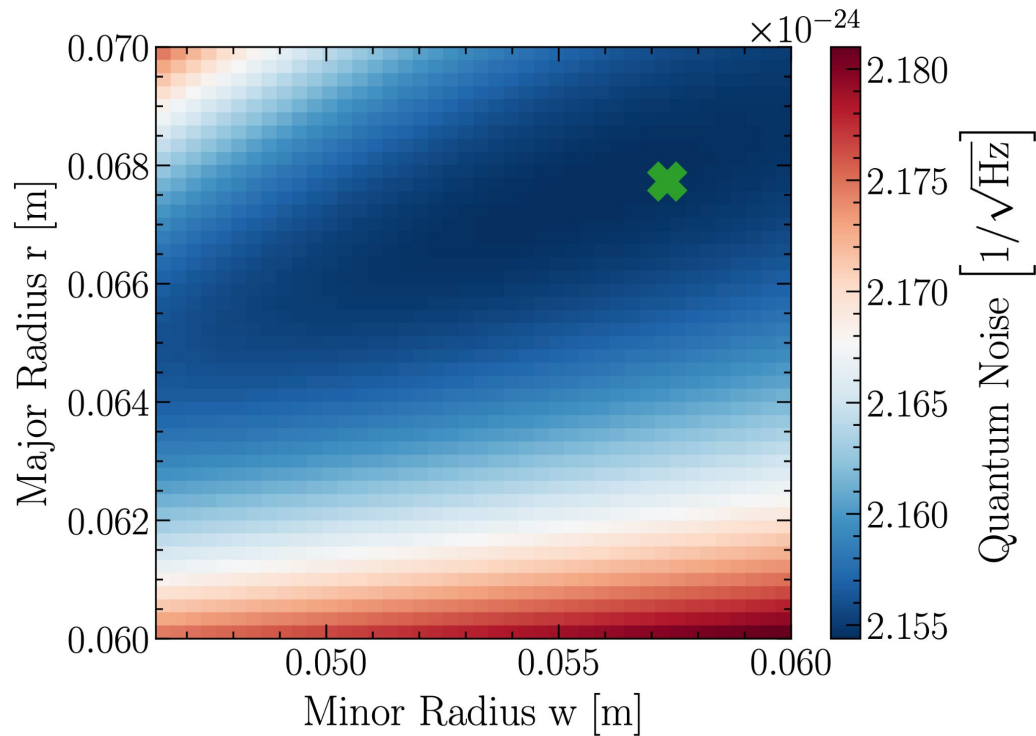
Example  
convergence  
over FROSTI  
power  
optimization



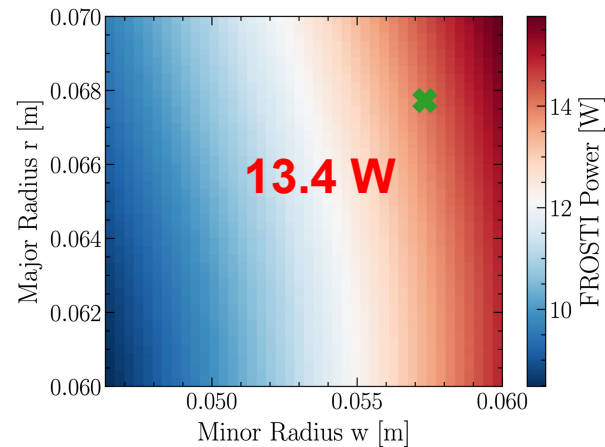
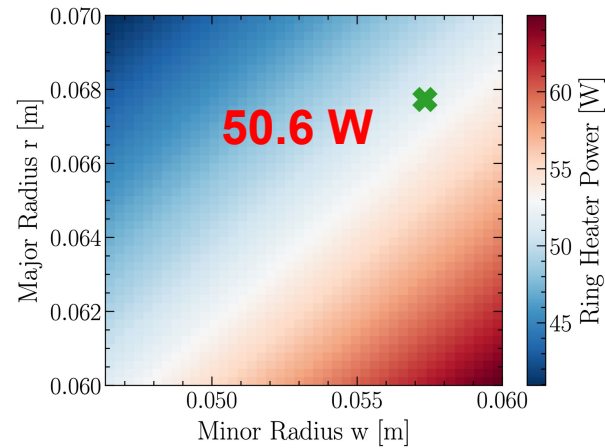
The RH power is optimized to completely remove the quadratic component the substrate OPD

The FROSTI power is optimized based on the quantum noise (8 steps max)

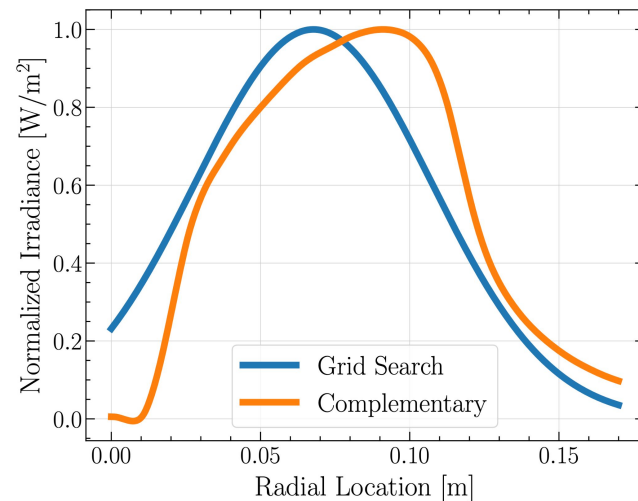
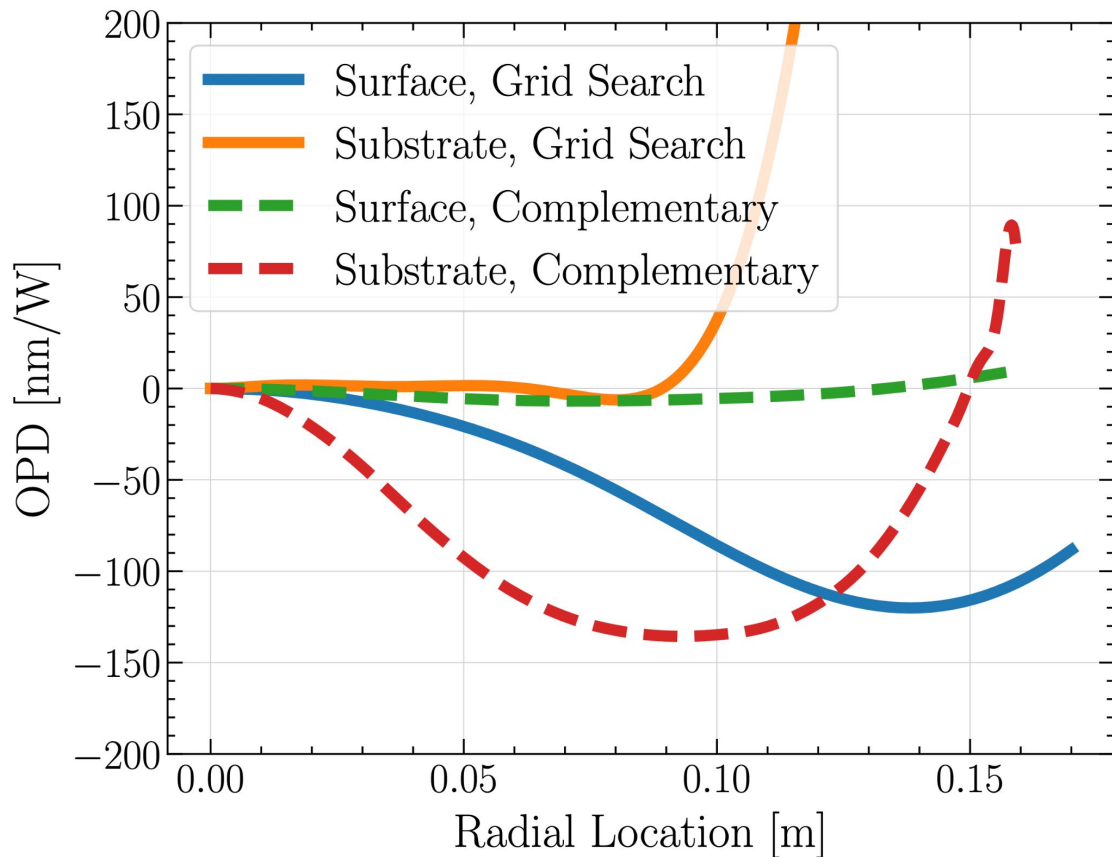
In total, there are  $45 \times 45 = 2025$  cases, which takes ~40 hrs over 45 cores.



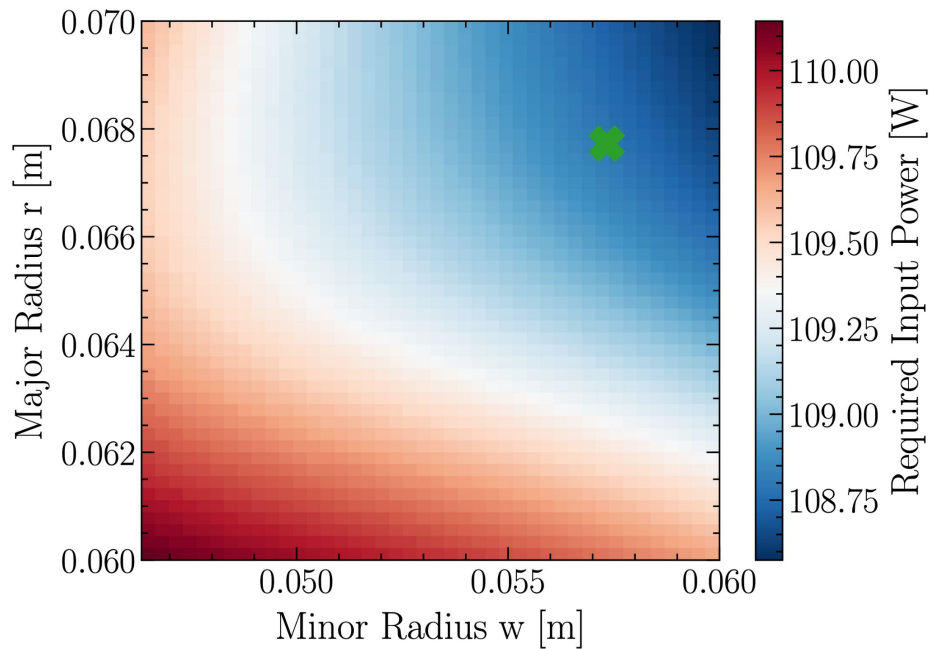
|                               | Optimal QN<br>(green cross) | Cold State         |
|-------------------------------|-----------------------------|--------------------|
| QN $[1/\text{rt}(\text{Hz})]$ | $2.154\text{e-}24$          | $2.148\text{e-}24$ |



## Grid search vs. complementary for A+

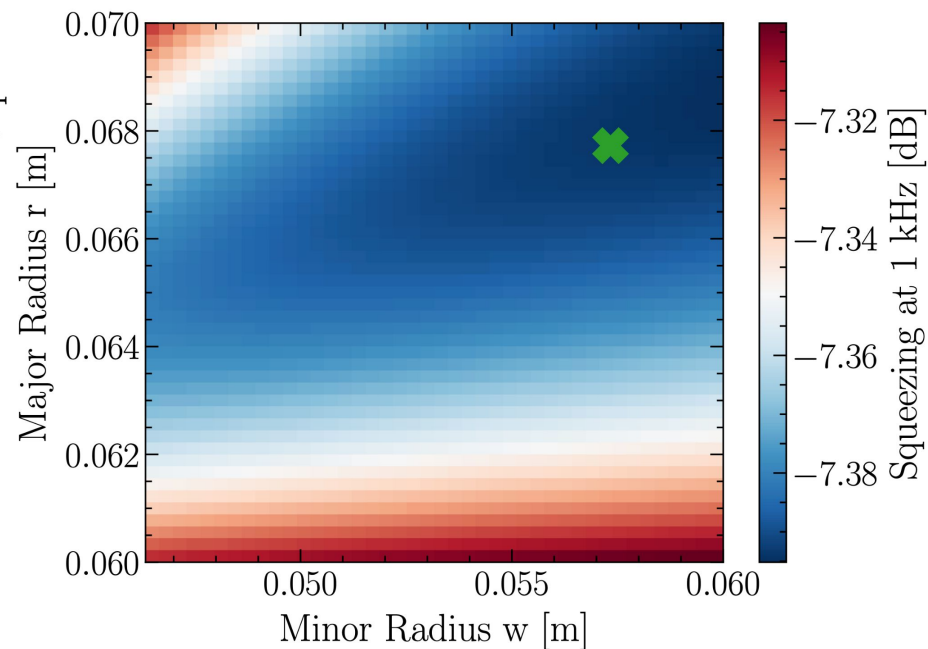


1. Grid search has flat substrate OPD near the center but larger at outside and surface OPD
2. Complementary case has flat surface but larger substrate OPD
3. Optimal profiles are similar



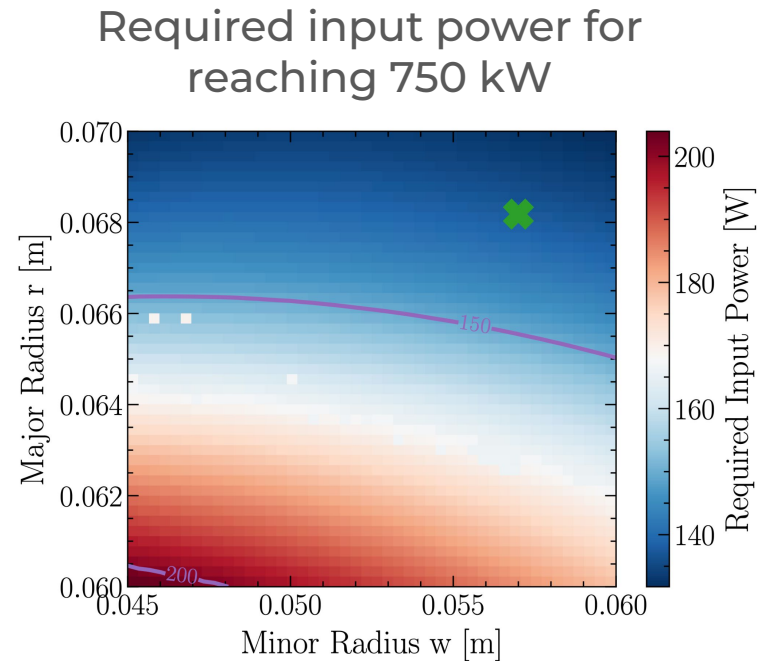
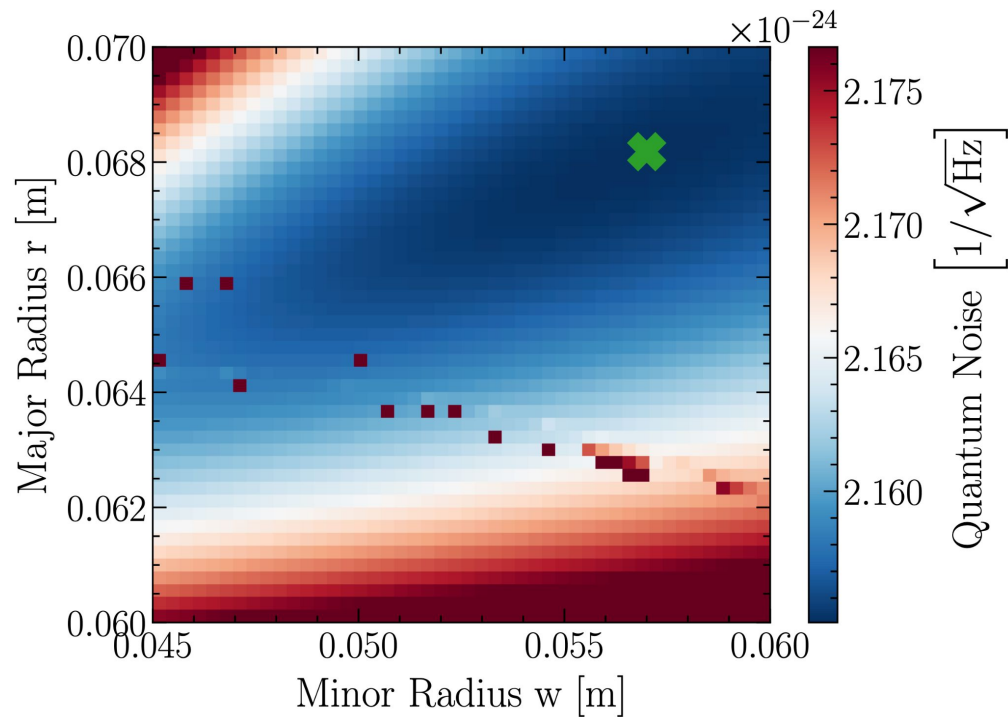
Required input power for  
reaching 750 kW

Observed squeezing with 7.5  
dB of input squeezing



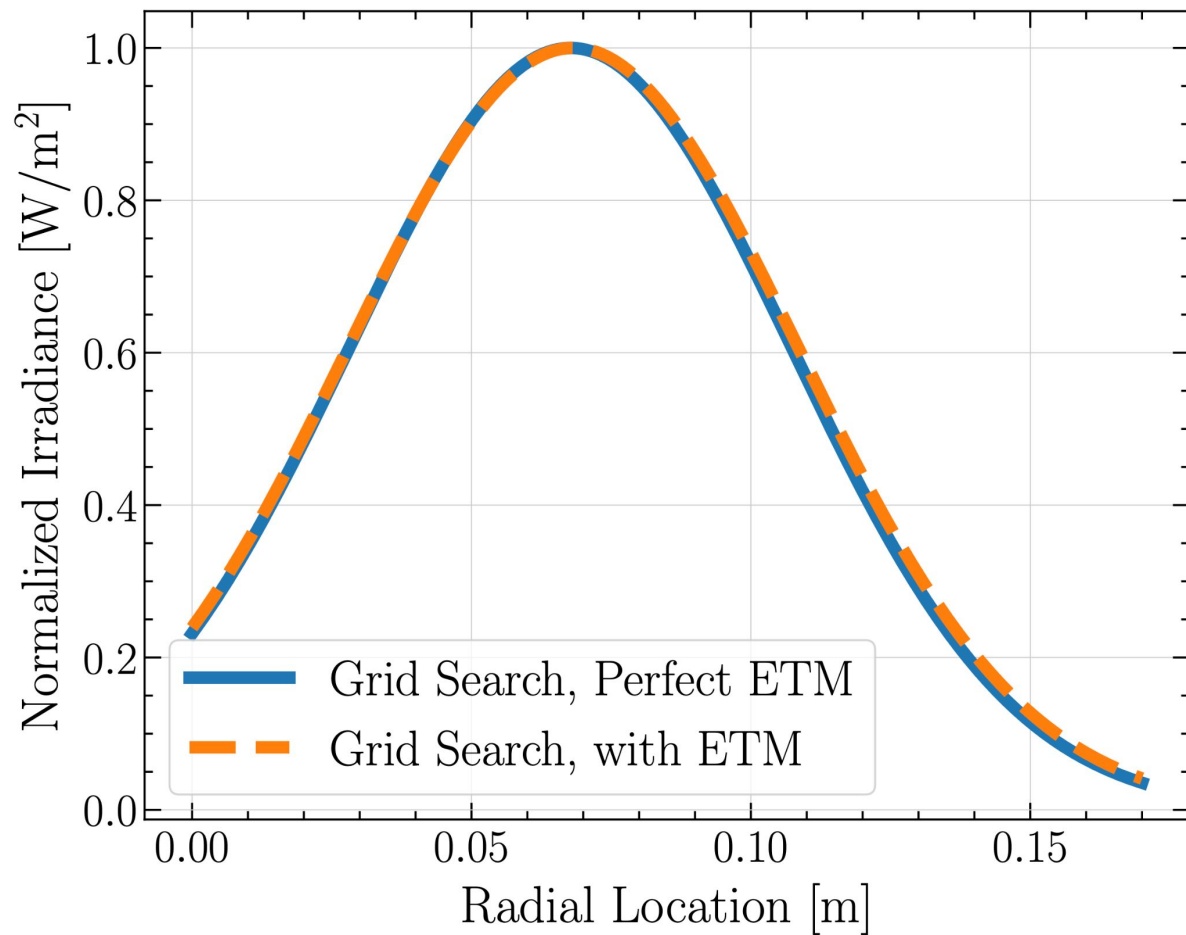
# **Grid-Search Study for FROSTI A+ FROSTI ITM, ETM: SH+RH**





|               | Optimal QN<br>(w/ ETM) | Optimal QN<br>(w/o ETM) | Complementary<br>design |
|---------------|------------------------|-------------------------|-------------------------|
| QN [1/rt(Hz)] | 2.155e-24              | 2.154e-24               | 2.161e-24               |

With thermal aberration on the ETM, the required input power is more sensitive to the design choice. The optimal QN is similar.



Optimal FROSTI ITM parameters ( $r$ ,  $w$ ,  $P$ ) are not sensitive to the ETM:

- With perfect ETM:  
6.77 cm, 5.60 cm,  
13.4 W
- With ETM+ thermal:  
6.82 cm, 5.70 cm,  
13.9 W