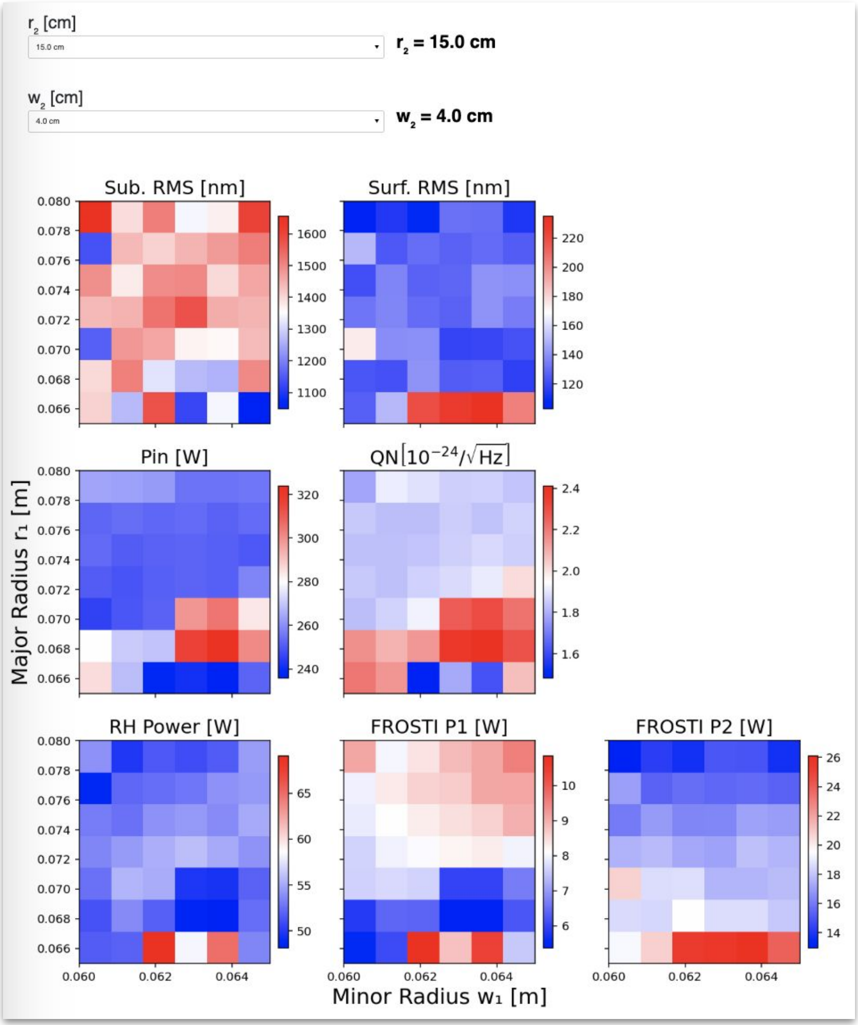
Dimensionality Reduction for Visualization

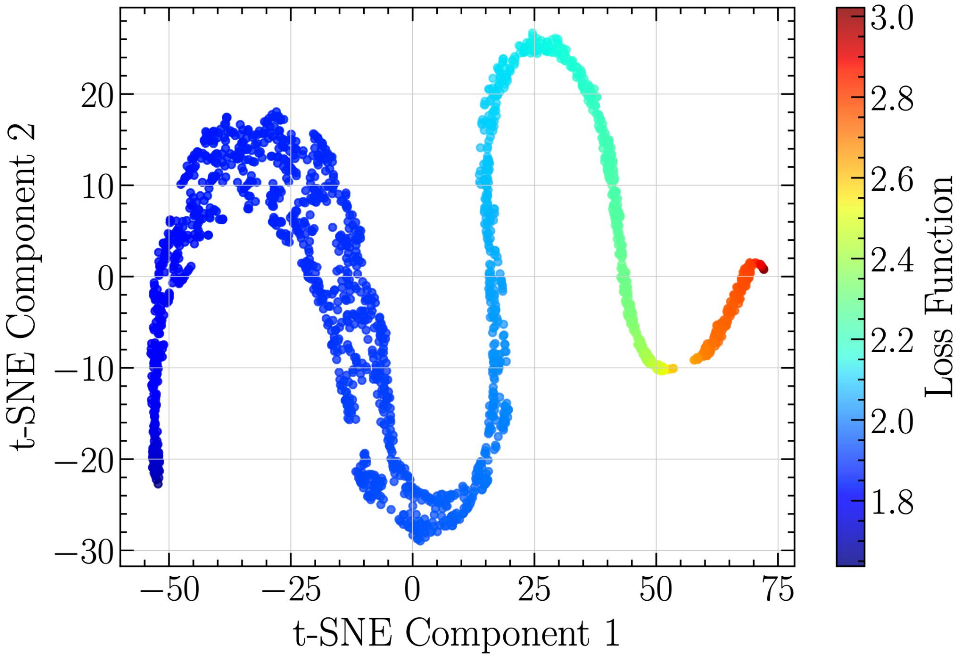
1. High-dimensional (4D) parameter space search for dual-FROSTI ITM design and optimization.

2. Need a better way to visualize the 4D results, and design objective/loss function to help choose the optimal result.

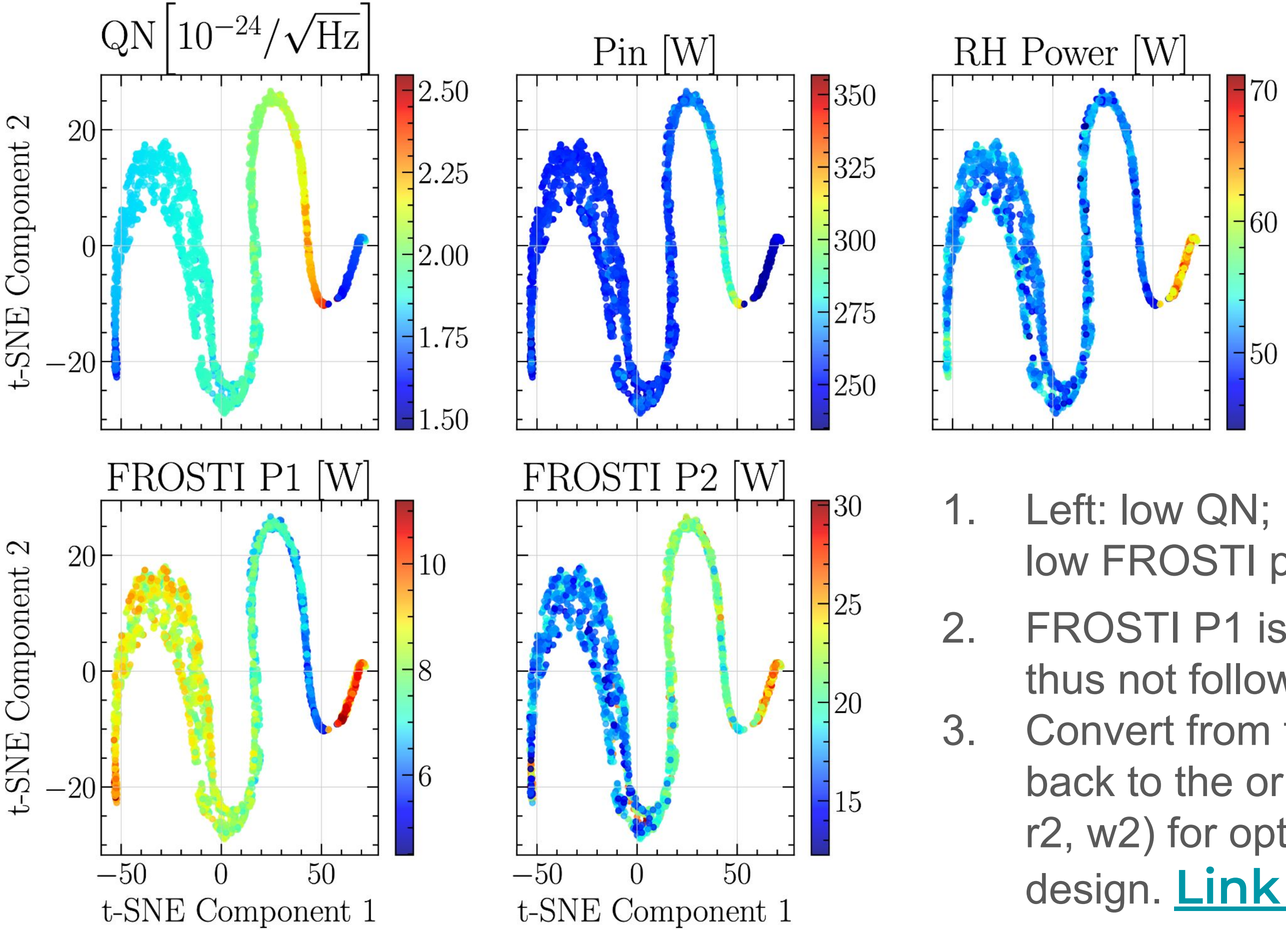
3. Loss function consists of the required input power, the quantum noise, and the requirement powers for thermal actuators



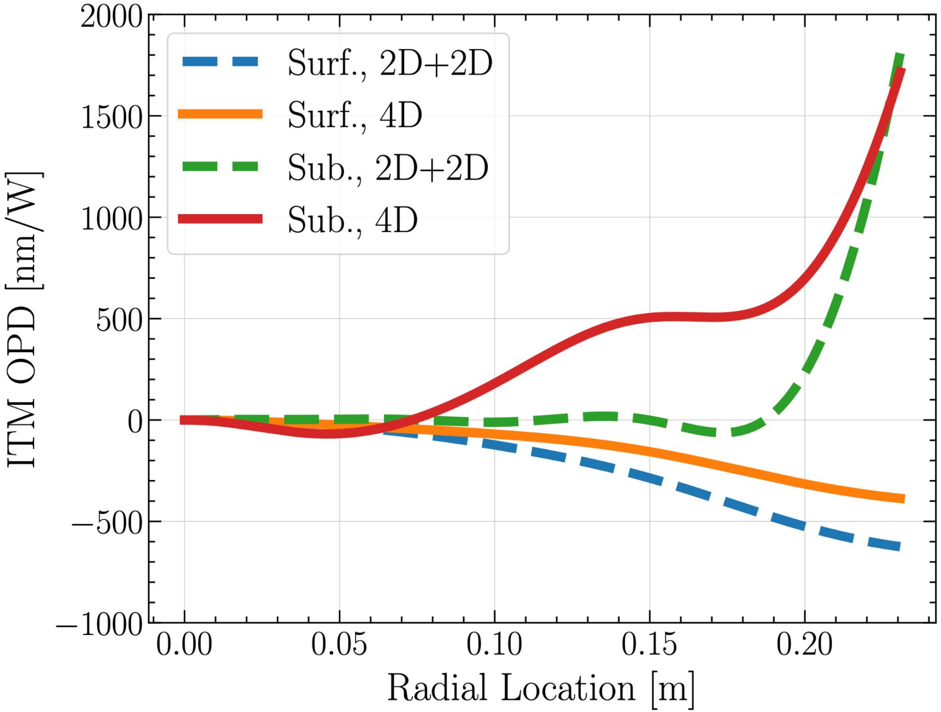
1. Loss function: **QN + I(RH > 60 W) + [I(Pin > 300 W) + I(P_FRO1 > 20 W) + I(P_FRO2 > 60 W)]*0.1**, where I(x>a) is the step function that equals to 1 if x>a, and 0 otherwise.
2. Assign a higher weight to the RH power term to penalize larger values and constrain it to remain lower.
3. Use a dimensionality reduction technique called **t-SNE** (t-distributed Stochastic Neighbor Embedding) to visualize the high-dimensional (4D) data in 2D.



Loss function in the reduced 2D space. Large loss and small loss regions are spatially separated



1. Left: low QN; low Pin; low RH power; low FROSTI powers.
2. FROSTI P1 is small enough (<20 W), thus not following the 2D structure.
3. Convert from the 2D reduced space back to the original 4D space (r1, w1, r2, w2) for optimal dual FROSTI ITM design. [Link to visualization]



1. 2D+2D is when we optimize the two FROSTI rings individually. 4D is this new joint optimization with parameter reduction.
2. For the 4D case: the residual surface is slightly better, and the residual substrate is slightly worse.
3. QN is nearly the same. The input power is higher (still under 300 W). The two FROSTI rings and the RH powers are (significantly) lower.

	QN	Pin	P1	P2	PRH
2D+2D	1.169e-24	211 W	17.3 W	22.9 W	88.7 W
4D	1.708e-24	247 W	**9.38 W**	**17.8 W**	**59.5 W**