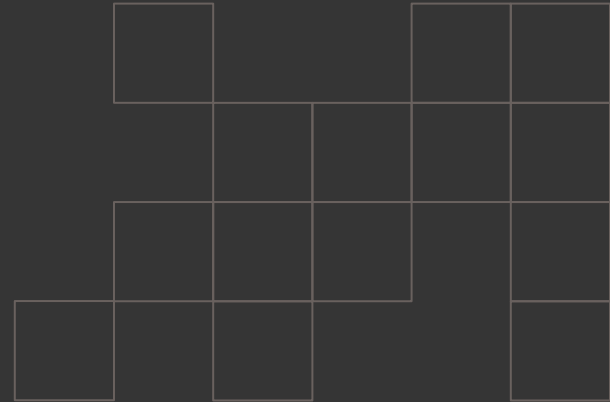


July 31, 2025

Understanding SQZ Mode-mismatch

Interim Presentation

Leo Schrader



Project Goal and Roadmap

Problem:

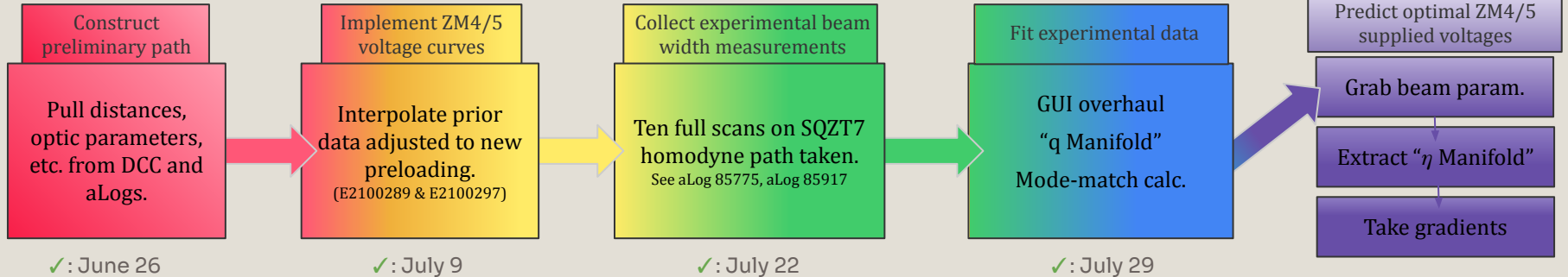
Mode-mismatch from SQZ may account for unexplained losses, we want to minimize such behavior.

Project outcomes:

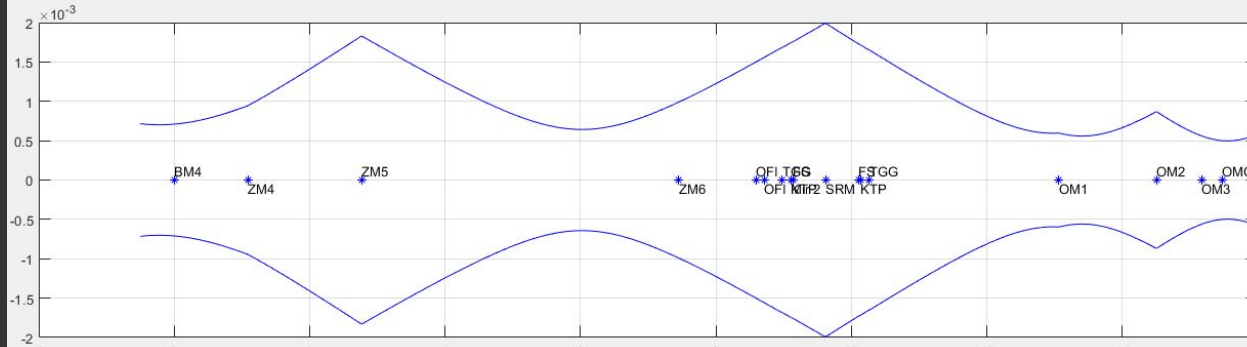
Characterize beam from SQZ → OMC.

Diagnose mode-mismatch sources; optimize ZM4/5 curvature.

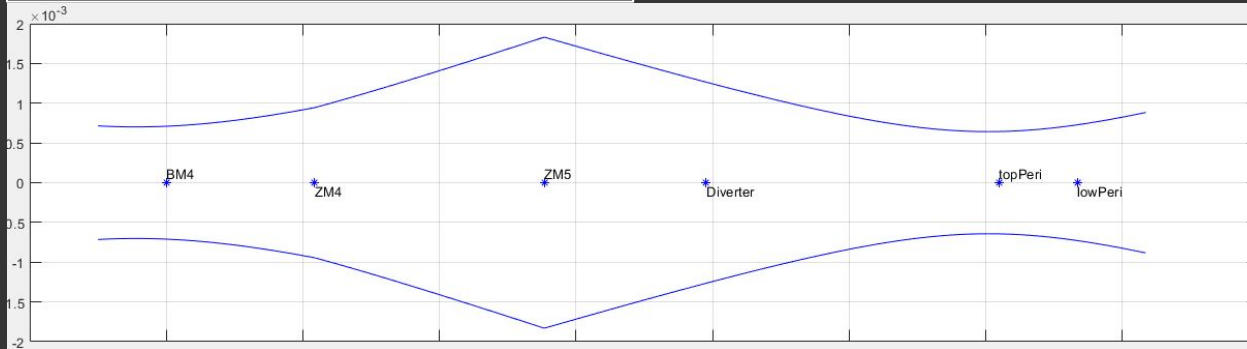
Progression:



Beam width from SQZ to OMC



Beam width from SQZ to SQZT7

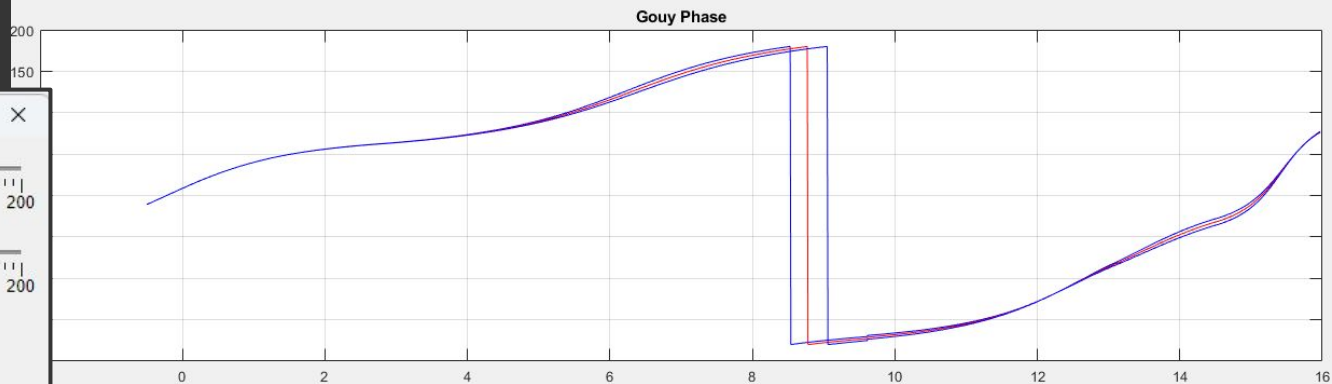
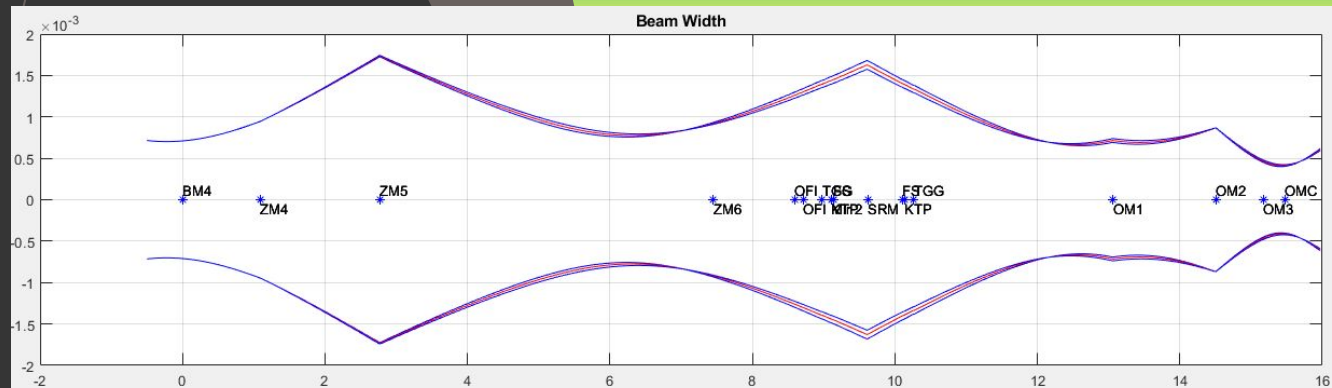


All measurement sources are documented in the respective Matlab scripts.



<https://git.ligo.org/leendert.schrader/alm-beam-simulation-for-sqz>

- Liberal estimates of ZM4/5 RoC error.
- Needed full range data on ZM4/5 to check accuracy rigorously.



ZM Voltage Controller

V_{ZM4} (V):

V_{ZM5} (V):

To Homodyne

Run Simulation

Version 3: SQZ_simulation_v3.m

ZM Voltage Controller

V_{ZM4} (V):

V_{ZM5} (V):

Homodyne diagnostics q-Manifold Plot

Select Homodyne Beam Width Data for Plotting

A1_13.5	BeamWidths_0ZM4_NomZM5.txt
A2_13.5	BeamWidths_0ZM5_200ZM5.txt
A1_D4S	BeamWidths_200ZM4_0ZM5.txt
A2_D4S	BeamWidths_200ZM4_NomZM5.txt
	BeamWidths_200_All.txt
	BeamWidths_6SGZM4_0ZM5.txt
	BeamWidths_6SGZM4_160ZM5.txt
	BeamWidths_6SGZM4_200ZM5.txt

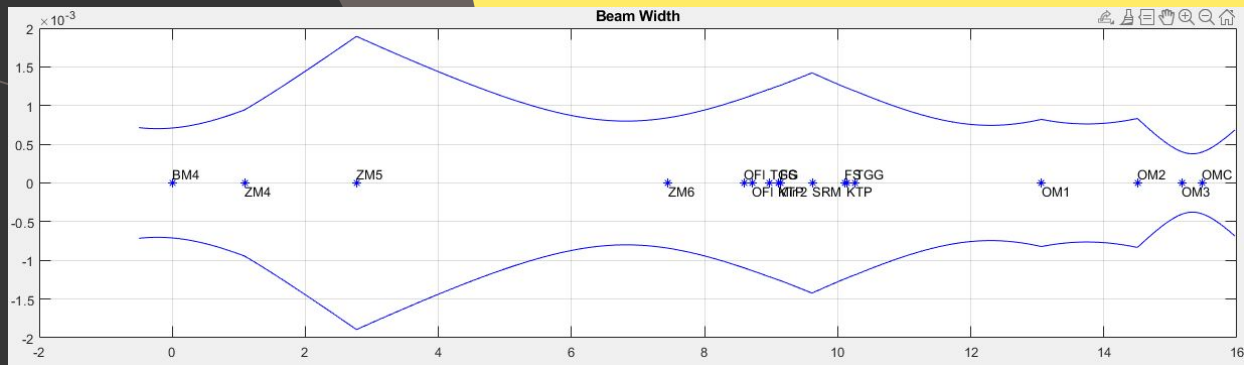
Run Simulation

Homodyne diagnostics q-Manifold Plot

Select Homodyne Beam Width Data for Plotting

A1_13.5	BeamWidths_200ZM4_0ZM5.txt
A2_13.5	BeamWidths_200ZM4_NomZM5.txt
A1_D4S	BeamWidths_200_All.txt
A2_D4S	BeamWidths_6SGZM4_0ZM5.txt
	BeamWidths_6SGZM4_160ZM5.txt
	BeamWidths_6SGZM4_200ZM5.txt
	BeamWidths_Nominal_All.txt
	BeamWidths_Zero_All.txt

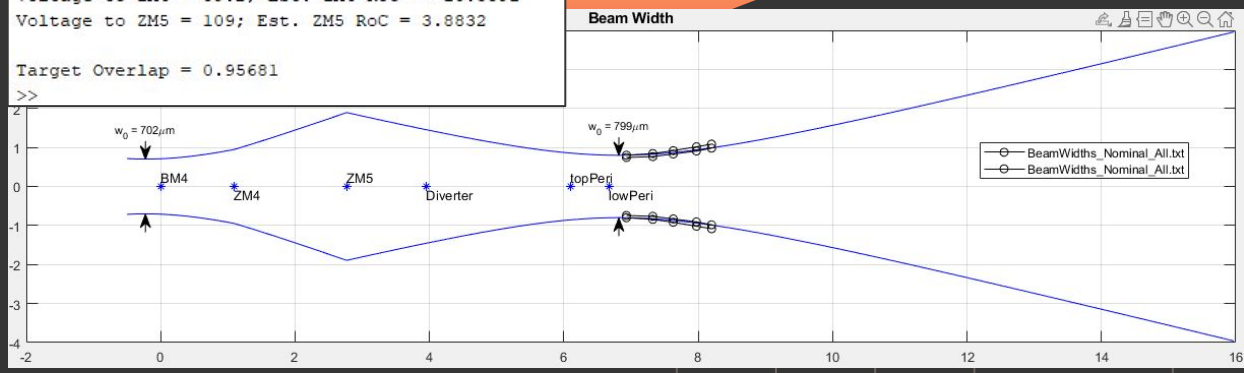
Run Simulation



Voltage to ZM4 = 89.2; Est. ZM4 RoC = -10.3591
Voltage to ZM5 = 109; Est. ZM5 RoC = 3.8832

Target Overlap = 0.95681

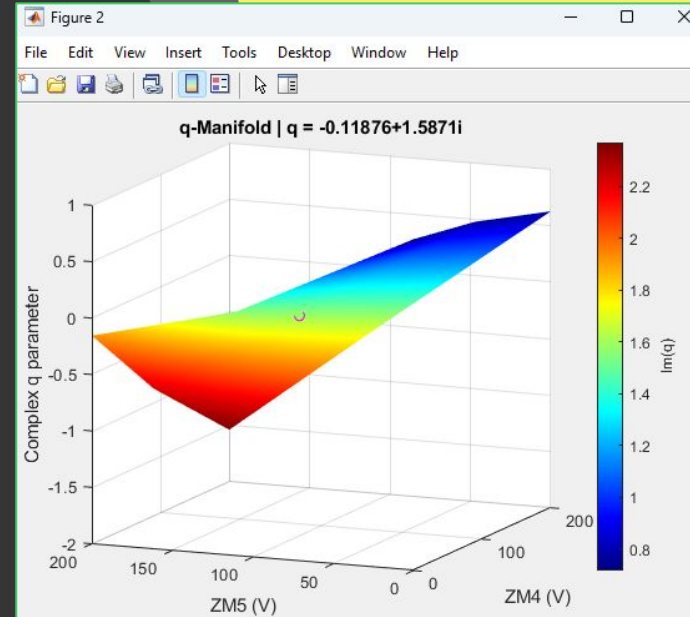
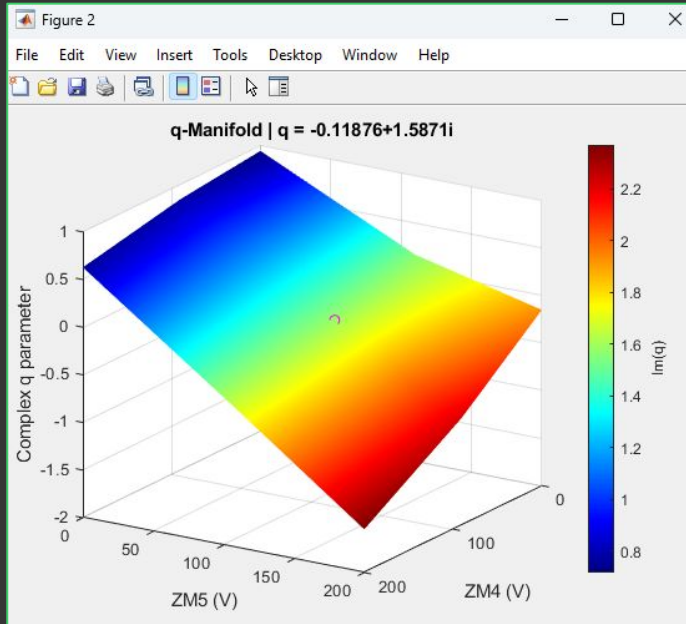
>>



Q: How do we calculate mode overlap?

A: Macro-level interpolation of SQZT7 data.

q Manifold with Nominal Voltages



**Using this method, we need only input voltages.
We back-propagate this q value to obtain ZM4/5 curvatures.**

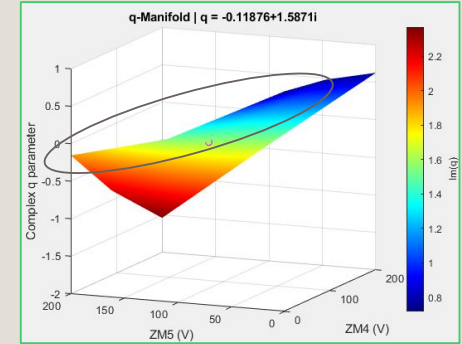
Next Steps

Current Issue:

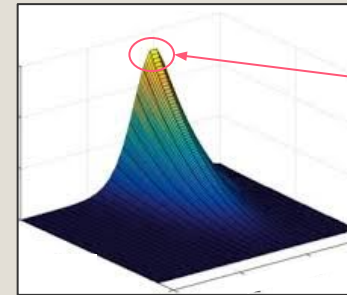
ZM4/5 curvature calculations collapse at “extreme” voltage combinations.
Why? Nonlinearity and perturbations in ZM4.

What comes next?

1. Need a second q manifold for vertical width measurements.
2. Build “ η manifold”, a plot of mode-match efficiency w.r.t. q manifold.
Yields mode-match maxima, and thus optimal V_{ZM4} , V_{ZM5} .



(hypothetical η manifold)



“Optimal matching”