PoBO: A Polynomial Bounding Method for Chance-Constrained Yield-Aware Optimization of Photonic ICs

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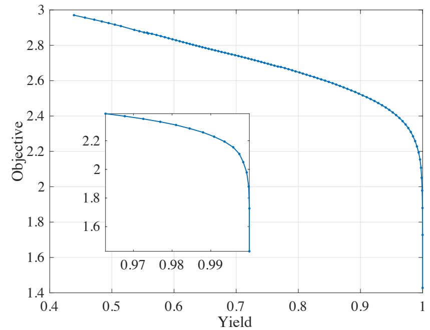
What limits the standard yield optimization?

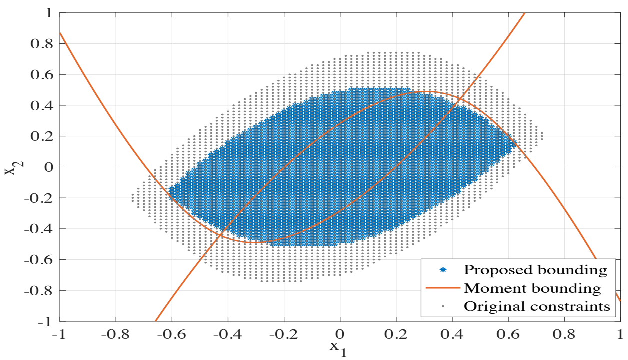


Only yield-driven → Over-conservative design

Chance-constrained yield-aware optimization

$$\max_{\mathbf{x}\in\mathbf{X}} \quad \mathbb{E}_{\boldsymbol{\xi}}[f(\mathbf{x},\boldsymbol{\xi})]$$
$$\text{s.t.} \quad \mathbb{P}_{\boldsymbol{\xi}}(y_i(\mathbf{x},\boldsymbol{\xi}) \leq u_i) \geq 1-\epsilon_i, \forall i=[n].$$

Optimizing the design metric while certifying the guarantee on probabilistic yield constraints



Two key components:

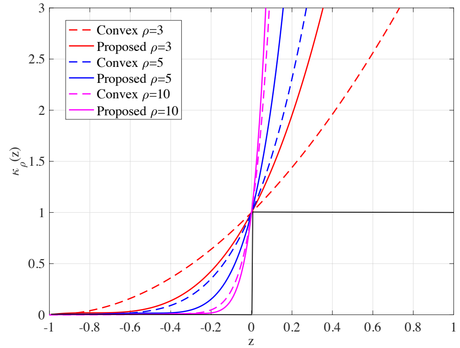
- Performance modeling
- Tractable stochastic programming algorithm

Our PoBO solution

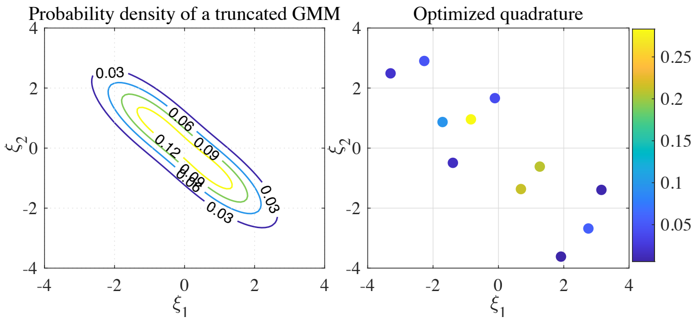
- An optimal polynomial kinship function to upper bound the probabilistic constraints

$$\mathbb{P}_{\boldsymbol{\xi}}(y_i(\mathbf{x},\boldsymbol{\xi}) > u_i) \leq \int_{\Xi} \kappa_\rho(y_i(\mathbf{x},\boldsymbol{\xi}) - u_i)\mu(\boldsymbol{\xi})d\boldsymbol{\xi} \leq \epsilon_i$$

$\kappa(\cdot)$ solved by semi-definite programming, aiming to make the upper bound tight



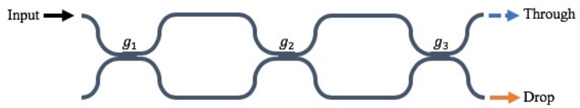
- Efficient numerical implementation



Numerical integration by quadrature points, free-lunch from performance modeling

- Globally optimal design via polynomial optimization solver

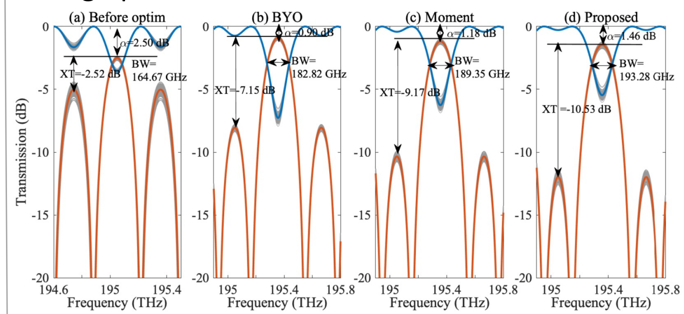
Case study on Mach-Zehnder interferometer



Design task:

$$\max_{\mathbf{x}\in\mathbf{X}} \quad \mathbb{E}_{\boldsymbol{\xi}}[\mathrm{BW}(\mathbf{x},\boldsymbol{\xi})]$$
$$\text{s.t.} \quad \mathbb{P}_{\boldsymbol{\xi}}(\mathrm{XT}(\mathbf{x},\boldsymbol{\xi}) \leq \mathrm{XT}_0) \geq 1-\epsilon_1,$$
$$\mathbb{P}_{\boldsymbol{\xi}}(\alpha(\mathbf{x},\boldsymbol{\xi}) \leq \alpha_0) \geq 1-\epsilon_2.$$

Design performance:



Better performance + smaller constraint gap Δ

Risk ϵ	Method	$\mathbb{E}$[BW]	Δ_1 (%)	Δ_2 (%)	Yield (%)	# Simulation
0.07	Moment [2]	187.02	7.53	7.53	100	35
	PoBO	192.1	7.53	7.2	99.7	35
0.1	Moment [2]	189.35	11.11	11.11	100	35
	PoBO	193.28	11.11	4.22	93.8	35
N/A	BYO [3]	182.82	N/A	N/A	100	2020

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Reference

[1] This work has been accepted by TCAD, arXiv: 2107.12593
[2] Cui et al. TCAD 2020
[3] Wang et al. DAC 2017