

Parametric Optimization of a Half-Symmetric Two-Mirror Resonator

Abstract



In VirtualLab Fusion, users can easily construct a two-mirror laser resonator, and analyze the eigenmodes of it. In case of designing a resonator to generate a desired eigenmode, one can use the tool of parametric optimization conveniently. This use case shows firstly how to construct a half-symmetric resonator and analyze the eigenmodes of it, and then how to use parametric optimization for the design / optimization of this resonator.

Modeling Task

- how to construct a laser resonator
- how to use parametric optimization for the design / optimization of a laser resonator



- Construction
 - In the laser resonator toolbox, we build up a halfsymmetric resonator, with one spherical and one plane mirror.
 - Set the *Mirror Radius* of the ideal spherical mirror to -200mm.

🥰 4: Light Path View (Ligh	nt Path Diagram #3)*	
High Reflective (Start) M High Reflective (Start) M High Reflective (Start) M Hideal Plane Mirror Hideal Spherical Mirror Hideal Stored Mirror FL Outer Surface of Dou Programmable Comp Outcoupling Mirrors Hideal Plane Mirror Hideal Spherical Mirror Hideal Stored Mirror FL	Ideal Spherical Mirror Ideal Plane Mirror	Raw Data Detector
Outer Surface of Dou Outer Surface of Dou Programmable Comp Laser Crystal Ormonnents Ormonnents Ormonnents Ormonnents	Y: 0 m Z: 0 m	Y: 0 m Z: 0 m X X X X X X X X X X X X X X X X X X X
Channels	Basic Parameters Physical Parameters Sampling Spherical Parameters Mirror Radius Reflectance Inside Aperture Reflectance	-200 mm

- Construction
 - In the laser resonator toolbox, we build up a halfsymmetric resonator, with one spherical and one plane mirror.
 - Set the Mirror Radius of the ideal spherical mirror to -200mm.
 - Set the distance between mirrors i.e., resonator length to 10mm.



- Eigenmode analyzer
 - Set up the eigenmode analyzer, set the *Wavelength* to be 633nm for the Initial Mode.
 - Keep other settings like iteration number and threshold as default in this example.

dit Paramete	ers of Eigenmode Analyz	zer		×	
Algorithm	Initial Mode Outcoupling	Logging			
Initial Mo	ode Light Source				
Gaussi	an Wave	 ✓ Edit 			
	arimpose Random Phase				
	enimpose Mandoni i nase				
Field Siz	Edit Gaussian Wave				×
Field S					
	Polarization	Mode Selection	Sampling	Ray Selection	
	Basic Parameter	rs Spectrain ai	ameters 2	patiai Parameters	_
	Power Spectrum T	уре	Single Wav	elength 🕓	*
	- Spectral Values				_
	Spectral values				
	Wavelength	633 nm	Weight		
			_		_
			Preview		

- Eigenmode analyzer
 - Run the simulation, and we obtain the converged mode calculation after a few iterations.
 - The mode has a beam diameter of about 176µm.

🛃 19: Eigen Mode Analy	/sis*				[- • •
Go!						
					Iteration Step	
Detector	Subdetector	Combined Output	2	3	4	5
	Eigenvalue, 1st	Data Array	1	1	1	1
	Eigenvalue, 2nd	Data Array	33	0.991	0.991	0.999
	Deviation, absolute (rescal	Data Array	10	1.87E-12	2.49E-14	8.67E-15
Eigenmode Analyzer	Deviation, relative (rescale	Data Array	25	0.000147	2E-06	6.97E-07
	Diameter X	Data Array	ım	176 µm	176 µm	176 µm
	Diameter Y	Data Array	ım	176 µm	176 µm	176 µm
	Losses	Data Array	%	0 %	0 %	0 %
Reference Eigenmode		Animation 🗸 🥖	ld	Harmonic Field	Harmonic Field	Harmonic Field
<						>
Create Output from	Selection					



calculated eigenmode amplitude after interpolation

In this example, the number of displayed digits (global settings) is set to 3. With a different setting, the displayed results may look different.

- Beam size optimization
 - It is often required to obtain a desired beam size for certain applications.
 - In this example, we expect a diameter of the output mode to be 200 µm.



 For this task, we use the parametric optimization, in which the mirror radius will be varied so to find the proper value that delivers the expected beam diameter.



- Optimization settings
 - Check Mirror Radius of the spherical mirror as the variable (type in keywords to locate the parameter quickly).

∠ 26: Parametric Optimiza	tion of Light	Path Editor (C:\	Users\\	2017-07-31_SZ_Ha	lfSymmetricResonator.lpd #3
Parameter Selection					
Select the parameters whic	h shall be vari	ied during optimi	zation.		
You can select one or more	parameter wh	nich shall be vari	ed within	the optimization.	
rad					
Object	Category	Parameter	Vary	Original Value	
Ideal Spherical Mirror #0		Mirror Radius	\checkmark	-200 mm	
	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~		~~~		

- Optimization settings
  - Check Mirror Radius of the spherical mirror as the variable (type in keywords to locate the parameter quickly).
  - Set the constraints for the optimization: *Mirror Radius* in the range between -1 m and -100 mm; *Diameter X/Y* should reach the target value of 200 µm.

ameter Selection									
lect the parameters which	shall be vari	ied durin	g optin	nization.					
ou can select one or more p	arameter wr	nich shai	i be va	ried with	in the optir	nizatior	1.		
ad									
Object	Category	Para	meter	Vary	Origi	nal Valu	e I		
deal Spherical Mirror #0		Mirror F	Radius		-20	0 mm			
26: Parametric Optimiz Constraint Specifications Select and specify the cor	ation of Lig	ht Path E ch shall t	Editor ( pe cons	C:\Users	\\2017-( uring optim	07-31_S	Z_HalfS	mmetricf	Resonator.lp
26: Parametric Optimiz Constraint Specifications Select and specify the cor Constraint Host	ation of Lig Instraints whice Constrain	ht Path E ch shall b nt Name	Editor ( De cons	C:\Users	\\2017-( uring optim	07-31_S iization. t Type	Z_HalfSy Value 1	/mmetricf	Resonator.lp Start Value
26: Parametric Optimiz Constraint Specifications Select and specify the cor Constraint Host Ideal Spherical Mirror #0	ation of Lig estraints which Constraint Mirror Ra	ht Path E ch shall t nt Name idius	Editor ( be cons	C:\Users sidered d Weight	\\2017-0 uring optim Constraint Range	07-31_S nization. t Type	Z_HalfSy Value 1 -1 m	/mmetricf Value 2 -100 mm	Start Value -200 mm
26: Parametric Optimiz Constraint Specifications Select and specify the cor Constraint Host Ideal Spherical Mirror #0	ation of Lig Instraints whie Constrain Mirror Ra Losses	ht Path E ch shall b nt Name adius	Editor ( be cons	C:\Users	\\2017-( uring optim Constrain Range	07-31_S nization.	Z_HalfSy Value 1 -1 m	/mmetricf Value 2 -100 mm	Resonator.1p Start Value -200 mm
26: Parametric Optimiz Constraint Specifications Select and specify the cor Constraint Host Ideal Spherical Mirror #0 Eigenmode Analyzer #80	ation of Lig estraints whic Constrain Mirror Ra Losses Diameter	ht Path E ch shall b nt Name adius X	Editor ( De cons	C:\Users sidered d Weight	\\2017-( uring optim Constraint Range Target Val	07-31_S nization.	Z_HalfSy Value 1 -1 m 200 µm	vmmetricf Value 2 -100 mm	Start Value -200 mm

- Optimization settings
  - Click on Update button, and have an overview on the optimization: e.g., to check the contribution of each constraint according to their weight.

onstraint Specifications								
Select and specify the const	raints which shall be	consid	lered duri	ng optimization.				
Constraint Host	Constraint Name	Use	Weight	Constraint Type	Value 1	Value 2	Start Value	Contribution
Ideal Spherical Mirror #0	Mirror Radius		1	Range	-1 m	-100 mm	-200 mm	
	Losses							
Eigenmode Analyzer #800	Diameter X		1	Target Value	200 µm		176 µm	5
	Diameter Y		1	Target Value	200 µm		176 µm	5
	brancer r							
	Dianata 1							

- Optimization settings
  - Click on Update button, and have an overview on the optimization: e.g., to check the contribution of each constraint according to their weight.
  - Set the algorithm parameters and start the optimization

In this example, we use the default local optimization and keep the default parameters

general settings for the op	timization (e.g.	the optimization alo	orithm).	
,				
Optimization Strategy				
Local Optimization	O Glo	bal Optimization		
Maximal Number of Iteratio	Downnill Simp		500	
Maximum Tolerance		1	IE-12	
Initial Step Width Scale Fa	ctor		1	

#### • Optimization result

 After a few iterations, the mirror radius is found to be -475mm, so the resonator delivers an output beam with the diameter of 200µm.

Start or stop the optimization	n routine. The results are show	n in the ta	able.							
A Gol										
V 00:										
					S	Imulation	Step			
Detector	Subdetector	13	14	15	16	17	18	19	20	
Optimizer Logging	Target Function Value	11E-12	1.46E-12	4.81E-12	1.11E-13	1.46E-12	1E-14	2.77E-13	1.31E-14	1E-1
Parameter Constraints	Mirror Radius (Ideal Spheri	40 mm	-460 mm	-500 mm	-470 mm	-460 mm	-475 mm	-480 mm	-473 mm	-475 m
E: I A I #200	Diameter X	198 µm	199 µm	202 µm	200 µm	199 µm	200 µm	200 µm	200 µm	200 µ
Eigenmode Analyzer #800	Diameter Y	198 µm	199 µm	202 µm	200 µm	199 µm	200 µm	200 µm	200 µm	200 µ

- Optimization result
  - After a few iterations, the mirror radius is found to be -475mm, so the resonator delivers an output beam with the diameter of 200 µm.

Numerical Data Array

Optimization Results Start or stop the optimization	n routine. The results are shown in the table	Mirror Radius (Ideal Spherical Mi.	neterOfOutputBeam
Detector	Subdetector 13	Simulation Step	
Optimizer Logging	Target Function Value 11E-12 1.4	]	
Parameter Constraints	Mirror Radius (Ideal Spheri 40 mm -4		
Einen de Anal #000	Diameter X 198 µm		μ Σ σ
Eigenmode Analyzer #800	Diameter Y 198 µm		ameter 0.1
<	ction	$\longrightarrow$	5 10 15 20 Simulation Step

- Optimization result
  - After a few iterations, the mirror radius is found to be -475mm, so the resonator delivers an output beam with the diameter of 200 µm.

				S	imulation	Step				
bdetector	13	14	15	16	17	18	19	20	21	
get Function Value	11E-12	1.46E-12	4.81E-12	1.11E-13	1.46E-12	1E-14	2.77E-13	1.31E-14	1E-14	
or Radius (Ideal Spheri	40 mm	-460 mm	-500 mm	-470 mm	-460 mm	-475 mm	-480 mm	-473 mm	-475 mm	
meter X	198 µm	199 µm	202 µm	200 µm	199 µm	200 µm	200 µm	200 µm	200 µm	
meter Y	198 µm	199 µm	202 µm	200 µm	199 µm	200 µm	200 µm	200 µm	200 µm	
]		7							>	The LPD containing th optimized system can b
						< Back	Ne:	t> S	how LPD 🔻	easily extracted at las
									Show Init	ial Light Path Diagram
									Show Lig	ht Path Diagram for Certain Simulation Step
										- '

#### **Document Information**

title	Parametric Optimization of a Half-Symmetric Two- Mirror Resonator
version	1.0
VL version used for simulations	7.0.3.4
category	Feature Use Case