

激光束整形器和扩束器设计

SYNOPSYS光学设计软件



设计目标

本课程的目的是使光通量尽可能均匀,目标是在出射口孔径上,光通量变化在10%以内,将通过以下几种形式来分别设计:

- 采用球面透镜来设计
- 采用非球面透镜来设计
- 采用DOE面来设计







- C15M1激光器
- 检查系统的光通量
- 添加球面镜片优化
- 优化结果评估



设置工作目录

• 选择Dbook-II 工作目录



参考Donald Dilworth《Lens Design(Second Edition) Automatic and quasiautonomous computational methods and techniques》第15章

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激光束整形器的初始系统

- 点击Open MACro按钮 🛎
- 打开C15M1.MAC, 点击Open
- 点击Run按钮 ■



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C15M1.MAC

Light Further

RLE	! Beginning of lens input file.
ID LASER BEAM SHAPER	
WA1 .6328	! Single wavelength
UNI MM	! Lens is in millimeters
OBG .35 2	! Gaussian object; waist radius35 mm; define
full aperture as twice	the 1/e**2 point.
1 TH 22	! Surface 2 is 22 mm from the waist .
2 RD -5 TH 2 GTB S	! Guess some reasonable lens parameters; use glass
type SF6 from Schott ca	atalog
SF6	
3 UMC 0.3 YMT 5	! Solve for the curvature of surface 3 so
the marginal ray has an	n angle of 0.3;
! find spacing so ray	height is 5 mm on next surface
4 RD 20 TH 4 PIN 2	! Guesses for surface 4
5 UMC 0 TH 50	! Solve for curvature of 5 so beam is collimated.
7	! Surfaces 6 and 7 exist
AFOCAL	! because they are required for AFOCAL output.
END	! End of lens input file.



检查能量密度方法一

- 检查能量密度如何从孔径的中心下降到边缘
- 点击Lens Date and Viewer →Lens System Utilities或在 Command Window中输入 FLUX 100 P 3

Flux Calculation (FLUX)			
Number of Zones (NB): 100	Color (ICOL): P (1-1), P	Surface Number (SN): 3	Run FLUX ?
Lens Data and Viewer Image Ana	FLUX INTENSITY]	
2D Drawings 3D Drawings Lens Data Listing	FLUX AS A FUNCTION OF RELATIVE APERTURE, ON SURFACE 3 THIS ANALYSIS ASSUMES ROTATIONAL SYMMETRY WAVELENGTH GEODRO		
Lens Surface Utilities			
Lens System Utilities	DLASE MEMORY W2 - COSOWA FIEL - 2000 WA - 2 300		

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检查能量密度方法二

- 点击Open MACro按钮 ≤, 打开C15M2.MAC, 点击Open
 , 点击Run按钮 ■
- 在Command Window中输入如下命令STEPS = 100
- 在命令窗口中输入DD
- 方法二是FLUX像差



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C15M2.MAC宏

```
DD: DO MACRO FOR AIP = -1 TO 1

COMPOSITE ! Ready a composite definition.

CD1 P FLUX 0 0 AIP 0 3 ! Composite data number 1 is the flux

at a relative Y- coordinate of AIP

! (defined later) on surface 3.

= CD1

Z1 = FILE 1

= 1 + Z1

ORD = FILE 1
```



添加元件

- 点击WorkSheet Lens Edit按钮 ≠
- 点击Insert Element按钮
- 在表面5的右侧添加两个元件
- 点击Checkpoint按钮 "



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优化四个透镜

- 点击Open MACro按钮 🖻
- 打开C15M3.MAC, 点击Open
- 点击Run按钮 ■
- 您的结果可能会有所不同,因为您点击插入元件的确切位 置是不可预测的



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slide 12

再次评估光通量均匀性

- 为了确定情况是否有所改善,我们需要再次评估光通量
 均匀性
- 在Command Window中输入 FLUX 100 P 10
- 光通量没有改善



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编辑光源

- 在WorkSheet中,在表面框中输入数字0,然后单击
 "Update"
- 该光源目前定义为 OBG 0.35 2.000000, 意思是高斯物, 腰半径0.35 mm, 全孔径在两倍1/e²点
- 将其更改为 OBG .35 1 并单击 "Update"

WS WorkSheet Lens-Edit Window	×
°5 5 쓴 ₩ ⊞ ⊖ © ⅔ 🖙 🖬 H - ≰	0 🔶> Update SEL. Close
RLE ID LASER BEAM SHAPER 56153	Curvature type not supported Fast
LOG 56153 WA1 .6328000 WT1 1.00000 APS 1	Bending type not supported Spacing type not supported
AFOCAL UNITS MM OBG 0.35000000 1.0000000 0 AIR	Slide element can't do THO
	C Offset
	To SpreadSheet
<	>

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优化并模拟退火

- 点击Run按钮 围,再次运行C15M3.MAC
- 点击 ▶ , 模拟退火(22, 1, 50)



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Light Further

dide 15

四个透镜的光通量均匀性

- FLUX 100 P 10
- 现在光通量稍好一些,但仍 然不够均匀。
- 在保持光线角度控制的同时
 使强度分布变均匀并不容易

0

这是所能达到四个元件的一
 个好的结果



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再添加两个透镜

- 点击WorkSheet Lens Edit按钮
- 点击Insert Element按钮
- 在表面9的右侧添加两个元件





优化六个透镜

- 点击Open MACro按钮 ≤, 打开C15M4.MAC
- 点击Open, 点击Run按钮 🔳
- 点击 1, 模拟退火(22, 1, 50)



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六片透镜的光通量均匀性

- FLUX 100 P 14
- 光通量完全在10%的均匀度的 目标范围内
- 可以使用全球面透镜完成激
 光整形器,但需要六片透镜



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足迹图

- 点击Image Analysis →Footprint Plots或在
 Command Window中输入MFP
- 关闭开关27,选择表面13, Scale X Times

10,600条光线

Select Surface for Footprint Plot
Surface Number (ISN): 13
Scale Factor (TSCF): 10
Center of Plot
Center Position: Y-Position (YOS): 0 X-Position (XOS): 0
C Center at Chief Ray (CR)
Show Vignetted Rays on the Plot (Switch 21) (Make sure that the 'Check Vignetting' mode is activated. Click '?' for more details)
List Vignetted Rays (Switch 16) (Make sure that the 'Check Vignetting' mode is activated. Click '?' for more details)
Spot Display Option:
Show spots as dots C Show spots as symbols Enter symbol size (SSIZE): 0.020000

光线更多地在中心附近散开,在边缘附近
 压缩,这正是使光束更均匀的正确方法。

	Image Analysis	Optimization + Design					
	Aberrations						
	Footprint Pl	Footprint Plots					
	Ghost Analy	/sis					
	Knife Edge	Knife Edge					
	MTF (Diffra	ction)					
- 1	MTF (Geom	etrical)					
	PSF						

Select ndy Fallen	enter april					
Selected	PUPIL 1: Defau	lt Raygrid		Hexapolar Raygrid (S	Swith 90)	
Pupil Pattern C	PUPIL 2: X-Ray	fan				
	PUPIL 2: Y-Ray	fan				
	PUPIL 3: Shrink	is or expands to fit u	ser-defined apertures	PUPIL	3 has been disabled because:	
	Connect rayp	oints with line		1. The Apertu	ere is no User-Defined Hard res (CAO's) in the lens system	
	Activate Vign	etting Mode (VIG)		2. Vigr	netting mode is not activated	
Obscuration Center Select Field Point	er, Fractional Y-C s and Colors	oordinate: 0	Norma	lized Radius of the O	bscuration: 0 (Between	n 0 - 1)
Obscuration Cente Select Field Point First Field	r, Fractional Y-C s and Colors I Point to trace Color number (1 - 1) or P	Fractional Y-Field (HBAR)	Fractional X-Field (GBAR)	Number of Rays	Note: Yellow and White are drawn on black background, and will be black on white background. Plot Color	n 0 - 1)
Obscuration Cente Select Field Point First Field TRACE	r, Fractional Y-C s and Colors I Point to trace Color number (1 - 1) or P P	Fractional Y-Field (HBAR)	Fractional X-Field (QBAR) 0	lized Radius of the O	Note: Yellow and White are drawn on black background, and will be black on white background. Plot Color Red	n 0 - 1)
Obscuration Cente Select Field Point First Field TRACE Check the	r, Fractional Y-C s and Colors I Point to trace Color number (1 - 1) or P P see to trace up to	Fractional Y-Field (HBAR) 0 4 additional Field F	Fractional X-Field (GBAR) 0	Number of Rays	Note: Yellow and White are drawn on black background, and will be black on white background. Plot Color Red	n 0 - 1)
Obscuration Cente Select Field Point First Field TRACE Check the TRACI	r, Fractional Y-C s and Colors I Point to trace Color number (1 - 1) or P P ese to trace up to E P	Fractional Y-Field (HBAR) 0 4 additional Field P	Fractional X-Field (GBAR) 0 foints 0	Number of Rays	Note: Yellow and White are drawn on black background, and will be black on white background. Plot Color Red •	n 0 - 1)
Obscuration Cente Select Field Point First Field TRACE Check the TRACI	r, Fractional Y-C s and Colors I Point to trace Color number (1 - 1) or P P E E P E P	Fractional Y-Field (HBAR) 0 4 additional Field P	Fractional X-Field (GBAR) 0 0	Number of Rays 600 20 20 20 20	Note: Yellow and White are drawn on black background, and will be black on white background. Plot Color Red Blue Blue Green	n 0 - 1)
Obscuration Cente Select Field Point First Field TRACE Check the Check the TRACE	r, Fractional Y-C a and Colors Point to trace Color number (1 - 1) or P P esse to trace up to E P E P E P	Fractional Y-Field (HEAR) 0 4 additional Field P 0 0	Fractional X-Field ((BAR) 0 10 10 10 10 10 10 10 10 10 10 10 10 1	Number of Rays 600 20 20 20 20	Note: Yellow and White are drawn on black background, and will be black on white background. Plot Color Red Blue Green Magenta	n D - 1)
Obscuration Cente Select Field Point First Field TRACE Check the TRACI TRACI TRACI TRACI	rr, Fractional Y-CC as and Colors IPoint to trace Color number (1 - 1) or P P E P E P E P E P E P	Fractional Y-Field (HBAR) 0 4 additional Field P 0 0 0	Fractional X-Field (GBAR) 0 0 0 0 0	Number of Rays [600 20 20 20 20 20 20 20 20 20 20	Note: Yellow and White are drawn on black beckground, and will be black on white beckground. Plot Color Red Blue Green	10-1)

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足迹图

光线更多地在中心附近散开,在边缘 附近压缩,这正是使光束更均匀的正 确方法。

FOOTPRINT ON S	SURFACE 13	
CENTER AT 0.0 0.0 ID LASER BEAM SHAPER SCALE 10.00000	58153	
WAVELENGTH 0.632800 •		
		11-JAN-21 15:08:40

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检测能量密度方法三

- 方法三是DPROP衍射 传播特性
 - 新建宏,输入如下命令: CHG CFIX 1 TH 0 END



DPROP P 0 0 13 SURF 3 R RESAMPLE



小结

使用全球面镜可以设计激光整形器,可以达到光束 均匀的要求,但需要六片透镜。球面透镜需要的镜片数 量多,但是球面透镜易于加工。我们接下可以尝试,使 用非球面来设计激光整形器。



Light Further

概述

- C16M1激光整形器初始系统
- 优化模拟退火
- FLUX非球面设计的光通量均匀性
- TFAN子午光扇分析
- DPROP衍射传播特性
- ADEF非球面镜与最佳拟合球体距离
- ADEF最佳拟合球体条纹图



设置工作目录

• 选择Dbook-II 工作目录



参考Donald Dilworth《Lens Design(Second Edition) Automatic and quasiautonomous computational methods and techniques》第16章

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激光束整形器的初始系统

- 点击Open MACro按钮≝
- 打开C16M1.MAC, 点击Open
- 点击Run按钮 ■





优化并模拟退火

- 点击Open MACro按钮 些, 打开C16M2.MAC, 点击Run按钮 ■
- 点击Simulated Annealing按钮 ▶, 模拟退火参数 (22,1,50)



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非球面设计的光通量均匀性

- FLUX 100 P 5
- 光通量几乎完全均匀



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子午光扇分析

 点击Image Analysis -> Ray Fan或在 Command Window 中输入如下命令

CVNODCVC ATS	TEAN 5 D			кау Fan
SINUPSIS AIZ	IFAN D F			Ray Trace
ID LASER BEAM SHAPER		56154	11-JAN-21 15:46:47	RMS
TANGENTIAL RAY F	AN ANALYSIS			Spot Diagram
				Transmission Calculations
FRACT. OBJECT HE	IGHT	HBAR 0.000000	GBAR 0.000000	Wavefront
COLOR NUMBER		1		
CHIEF RAY COORD.	AT IMAGE	Y 0.000000	Ray Fans	
GAUSSIAN IMAGE H	EIGHT	0.00000	Printed Ray Fans Plotted Ray Fans	
REL ENT PUPIL	RAY A	BERRATIONS	Printed Ray Fans	
YEN	DELTA Y	DELTA X	Ray Fans Options:	
			C Trace a Sadittal Fan of Bays (SEAN)	
-1.000	3.933936E-05	0.00000		
-0.800	-5.242490E-06	0.00000	Trace a Tangential Fan of Rays (TFAN)	
-0.600	2.734351E-06	0.00000	C Trace a Set of SFAN and TFAN Fans (FANS)	
-0.400	-1.961788E-06	0.00000		
-0.200	8.586321E-07	0.00000	C Transverse Aberration . Optical Path Difference	
0.200	-8.586322E-07	0.00000		
0.400	1.961788E-06	0.00000	Number of Rays (from Axis to Pupil Edge) (NRYS): 5	
0.600	-2.734353E-06	0.00000	Color: P (Color number (ICOL) 1 - 1 or P)	Wavelength 0.632800 microns
0.800	5.242493E-06	0.00000		
1.000	-3.933939E-05	0.00000	Field Point:	
SYNOPSYS AI>			Fractional Y-field (HBAR):	
			Fractional X-field (GBAR):	
			Command Line(e): TEAN 5 P	

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Image Analysis Optimization + Design

Aberrations

Footprint Plots Ghost Analysis Knife Edge

MTF (Diffraction) MTF (Geometrical)

PSF



DPROP衍射传播特性





非球面镜与最佳拟合球体距离

命令窗口输入如下: ADEF 3 PLOT



命令窗口输入如下: ADEF 4 PLOT



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最佳拟合球体条纹图

命令窗口输入如下: ADEF 3 FRINGES

命令窗口输入如下: ADEF 4 FRINGES



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小结

采用非球面设计激光整形器,通过两个非球面的设计 达到光通量均匀性的要求,并分析了非球面的可加工性。 接下来让我们采用DOE面型,来做同样的设计尝试。





概述

- 衍射光学元件(DOE)光束整形器的初始结构
- 优化模拟退火
- FLUX光通量均匀性
- MMA空间频率
- 优化降低空间频率,以利于制造
- DPROP衍射传播分析光通量分布



设置工作目录

• 选择Dbook-II 工作目录



参考Donald Dilworth《Lens Design(Second Edition) Automatic and quasiautonomous computational methods and techniques》第17章

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DOE 光束整形器的初始结构

- 点击Open MACro按钮≝, 打开C17M1.MAC
- 点击Open, 点击Run按钮 ■
- DOE意思是衍射光学元件



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优化模拟退火

- 点击Open MACro按钮 ≝,
- 打开C17M2.MAC点击Open,
- 点击Run按钮 ᠍
- 再次点击Run按钮
- 模拟退火(22,1,50)





光通量随孔径变化

- FLUX 100 P 6
- 光通量均匀。

ο

• DOE面型是否可以加工? 表面 4 的空间频率是多少? 如果它太高,制造工艺上可能存在难度



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表面4的空间频率

在CW输入MMA

- 选择PUPIL
- 选择HSFREQ
- 选择POINT, 0
- 选择CREC, grid 7
- 选择DIGITAL
- 选择PLOT the map





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降低空间频率

- 在PANT文件中添加VY 5 RAD
- 在AANT文件中添加

M 50 .01 A P HSFREQ 0 0 1 0 4

• 点击Run按钮 ■





DPROP衍射传播分析

- DPROP P 0 0 3 SURF 3 L RESAMPLE
- DPROP P 0 0 6 SURF 3 L RESAMPLE
- 表面3为高斯分布,表面6均匀分布



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总结

- 使用全球面透镜设计激光整形器需要六片透镜。
- 使用非球面或衍射元件需要更少的透镜,因此值得我们
 ,通过设计要求和最终的生产成本,去评估决定采用哪
 种面型结构,来加工制造。



高斯光束

最快的优化算法

SYNOPSYS光学设计软件







- BEAM高斯光束追迹
- RAY真实光线追迹
- 高斯光束的强度分布
- MDI高斯光束的衍射图



设置工作目录

• 选择Dbook-II 工作目录



参考Donald Dilworth《Lens Design(Second Edition) Automatic and quasiautonomous computational methods and techniques》第33章

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• 点击 『打开C33L1





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BEAM高斯光束追迹

- 在Command Window中输入BEAM
- 由于衍射作用,表面2上的光束半径大于表面1
 上的光束半径。

SYNOPSYS AI>beam

ID OBG DEMO

212

11-JAN-21 17:05:33

GAUSSIAN BEAM ANALYSIS

SURF	BEAM RADIUS	5 WAIST LOCATION	WAIST RADIU	S DIVERGENCE
1	0.150000	-7.5157030E-15	0.150000	0.001343
2	0.164341	-7.368983	0.005965	0.022287
3	0.208892	-6.563589	0.006332	0.031811
4	3.389933	-357.899054	0.014036	0.009472
5	3.408876	-2087.561971	3.406641	5.9127598E-05
6	3.408985	-2137.561971	3.406641	5.9127598E-05
7	3.408985	-2137.561971	3.406641	5.9127598E-05
SYNOPSYS	AI>			



RAY真实光线追迹

 点击Image Analysis →Raytrace或在Command Window中输入 RAY P 0 0 .5 SURF

	Raytrace	>
Image Analysis Optimization + Design	Paraxial Raytrace Real-Ray Raytrace	
Aberrations		
Footprint Plots	Trace a Single Ray	
Ghost Analysis	Analysis Modes:	
Knife Edge MTF (Diffraction)	 Basic Raytrace (RAY) 	
MTF (Geometrical)	C Polarization Raytrace (PRAY) (Requires that POLarization mode be on)	
PSF	C Global Raytrace (GRAY)	
Ray Fans	Output is in the accordinate system of this surface (ICOORD)	
Raytrace		
RMS	C Transmission along Ray (RTRANS) (Considering absorption only)	
Spot Diagram		
Transmission Calculations	Surface-By-Surface Listing: (Yes (SURF) (No (0)	
Wavefront	Color: P (Color number (ICOL) 1 - 1 or P) Wavelength 0.632800 microns	
	Field Point: Fractional Y-field (HBAR): 0 Fractional X-field (GBAR):	
	Pupil Coordinate: Fractional Y-Aperture (YEN): .5 Fractional X-Aperture (XEN): 0	
	Command Line(s): RAY P 0 0 .5 SURF	≀un ?
	RAY P 0 0 .5 SURF	

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RAY真实光线追迹

- RAY P 0 0 .5 SURF
- 真实光线追迹在入瞳点(0,.5), SURF指获取光线坐标和角度的逐面输出
- ZZ是光线路径投影到X-Z平面上的角度的正切,在表面折射之后
- HH是光线路径投影到Y-Z平面上的角度的正切,在表面折射之后
- UNI是在表面折射之前,与表面法线的光线角度,以度为单位,始终为正 SYNOPSYS AI> --- RAY P 0 0 .5 SURF

INDIVIDUAL RAYTRACE ANALYSIS

FRACT. O FRACT. E COLOR NU	BJECT HEIGHT NTRANCE PUPIL MBER	COORD.	HBAR 0.000 YEN 0.500 1	0000 GBAR 0000 XEN	0.000000 0.000000	
		RAY VECTO	RS	(X DIR TAN)	(Y DIR TAN)	(INC. ANG.)
SURF	x	Y	Z	ZZ	HH	UNI
OBJ	0.000000	0.000000	0.000000	0.00000	0.000549	
1	0.000000	0.136910	0.00000	0.000000	0.000549	0.031434
2	0.000000	0.164338	-0.005301	0.000000	0.022307	3.663636
3	0.000000	0.209062	-0.000397	0.000000	0.031846	1.060103
4	0.000000	3.395560	0.057666	0.000000	0.009449	3.769940
5	0.000000	3.413463	-0.047616	0.000000	-5.576629E-05	1.057009
6	0.00000	3.410672	0.000000	0.00000	-5.576629E-05	0.003195
	REDUCED RAY A	NGLES IN RADI	ANS AT IMAGE SU	JRFACE		
	PSI (X)	PHI (Y)	Z			
	0.000000 -5.	576629E-05	0.000000			
SYNOPSYS	AI>					

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Light Further

slide 49

高斯光束的强度分布

- STEPS = 100
- PLOT TRANS FOR YEN = -1 TO 1
- 这显示了一个漂亮的高斯形状



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高斯光束的衍射图

- 在Command Window中输入MDI
- Number of Rays = 9999, 点击PSPRD
- 由于光束是高斯的,远场图像在形状上也是高斯的。



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总结

本例讲述了BEAM高斯光束追迹,RAY真实光线追迹,高斯光束的强度分布,MDI高斯光束的衍射图



ZSEARCH案例之变倍激光扩束镜

武汉墨光科技有限公司







- 工作波长: 632nm
- 变倍比: 1~10X
- 入射光束直径: <=5mm
- 出射光束直径: <=50mm
- 设计确保从全孔径出射的光线与光轴之间的角度小于
 0.03°
- 总长: <200mm





ZSEARCH输入

CORE 8 TIME ZSEARCH 4 QUIET SYSTEM ID AFOCAL ZOOM OBB 0 .001 25 WA1 .6328 AFOCAL UNITS MM END

GOALS ZOOMS 10 GROUPS 2 2 2 2 ZGROUPS 0 Z Z 0 BACK 10 1 FINAL OBB 0 .01 2.5

ZSPACE NONLIN 2 GIHT .01 .1 0 APS 1





ZSEARCH输入

NPASS 30 ASTART 15 COLOR MONO ZMOM .2 1 1 **AFOCAL** TOPD.1 NGRID 6 FOV 0 FWT 1 SNAP 1 ANNEAL 30 10 Q 30 **QUICK 30 30** AGROUP END

SPEC AANT M 2.5 1 A P YA 0 0 1 0 LB1 LUL 200 2 2 A TOTL END

GO

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ZSEARCH输出结果



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ZSEARCH输入

点击 + 打开滑动条



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