TOLERANCING

TOLER (REFERENCE MANUAL SECTION) COMMAND PROMPTS

TOLER-GENERAL INFORMATION - Tolerancing is the process by which changes in optical system performance are characterized in terms of changes in optical system constructional parameters There are three forms of tolerancing implemented in this program. They are: the sensitivity analysis, the Monte-Carlo analysis and the inverse sensitivity analysis. During any of these three types of tolerancing, the user may choose to perform an automatic optical performance compensation. This automatic performance compensation is performed after the introduction of the constructional parameter changes and before the computation of the resultant changes in the optical performance. After tolerance analysis calculations are completed, the results of the analysis may be output in several useful and flexible formats. All three types of tolerance analysis require the user to define at least:

1. "tolerance variables", which are the optical system constructional parameters which will be automatically varied during the tolerance analysis.
2. "tolerance operands", which are the measures of optical system performance. If focus or other types of optical system performance compensation are to be performed, the user must also define:
3. "compensation variables", which are the optical system constructional parameters which will be varied automatically during the compensation process so as to return the values of the "compensation operands" to near their starting values.
4. "compensation operands", which are the "targets" of the compensation process. The next few sections describe how to set up and modify the tolerance and compensation variables and the tolerance and compensation operands.

Tolerance analyses are performed only upon the main configuration of an optical system. Alternate configurations are always ignored. If a tolerance analysis needs to be performed upon an alternate lens configuration, then use the "DEZOOM" command to change that configuration into the "main" configuration.

TOLERANCE VARIABLES

CREATING TOLERANCE VARIABLES

TVAR - The "TVAR" command causes the program to leave the CMD level and enter the TVAR input level. The tolerance variables memory area is wiped clean and is ready for new tolerance variables input. Between "TVAR" and "EOS" or "END, any TVAR input level command may be entered. The program can have up to 390 tolerance variables defined at any one time.

EOS or **END** - The "EOS" or "END" command, issued from the TVAR level, causes the program to return to the CMD level. The tolerance variables set is left in memory and is ready for tolerancing.

MODIFYING TOLERANCE VARIABLES

UPDATE TVAR or **U TVB** - The "UPDATE TVAR" command, or its abbreviated form "U TVB", causes the program to leave the CMD level and enter the UPDATE TVAR level. The tolerance variables memory area is opened and is ready for modification. Between "UPDATE TVAR" or "U TVB" and "EOS" or "END", any UPDATE TVAR level command may be entered.

DEL (tvariable name) , i - The "DEL" command, issued from the UPDATE TVAR level, causes the program to delete the tolerance variable with name = "tvariable name" at surface "i".

EOS or **END**The "EOS" or "END" command, issued from the UPDATE TVAR level, causes the program to return to the CMD level. The tolerance variables set is left in memory and is ready for tolerancing.

TOLERANCE VARIABLES COMMANDS

SIMPLE TOLERANCE VARIABLES - Simple tolerance variables are very similar to optimization variables in that they are associated with only one lens database surface and they are characterized by one numeric value. The name of a simple tolerance variable or "tvariable" is the name of the command used to insert that tolerance variable into the tolerance variable set. The simple tolerance variable commands have the following form:

(Tolerance Variable Name) , i , delta - "i" is the surface number in the lens database to which the tolerance variable is associated. The "delta" value is the change to the variable used in the tolerance analysis. During a sensitivity analysis, the "delta" value is the change made to that tolerance variable. During a Monte-Carlo analysis, the "delta" change value is considered to be the one-sigma value which that tolerance variable may take on during any one Monte-Carlo cycle. "delta" values, if not explicitly input by the user, are set to "default" values. The default "delta" values are different for each variable. The following table lists the lens and special surface database items which may be included in the tolerance variables set and their associated default "delta" values. The nature of the random distribution used during a Monte-Carlo simulation varies for each variable type and is listed as part of the next table.

TOL VARIABLE NAME	DESCRIPTION	DEFAULT "delta" VALUE
RD or **CV**	Surface radius of curvature or curvature. Units are % of current value.	0.1% of current radius of curvature value. (used for non-flat surfaces only) (Uniform Distribution in Monte-Carlo)
RD_FR or **CV_FR**	Surface radius of curvature or curvature. (fringe input mode). Units are fringes of power at 0.5461µ	4 fringes of curvature over the diameter corresponding to the current "inr" value and computed at 0.5461µ (use CV-FR for flat surfaces) (use RD-FR for non-flat surfaces) (Uniform Distribution in Monte-Carlo)
TH	Axial distance to next surface	0.001 lens units (Uniform Distribution in Monte-Carlo)
CC	Surface conic constant	1.0D-6 (Normal Distribution in Monte-Carlo)

AD	4th order aspheric coefficient	1.0D-10 / 1.0D-6 (Normal Distribution in Monte-Carlo)
AE	6th order aspheric coefficient	1.0D-14 / 1.0D-6 (Normal Distribution in Monte-Carlo)
AF	8th order aspheric coefficient	1.0D-18 / 1.0D-6 (Normal Distribution in Monte-Carlo)
AG	10th order aspheric coefficient	1.0D-22 / 1.0D-6 (Normal Distribution in Monte-Carlo)
AH	12th order aspheric coefficient	1.0D-26 / 1.0D-6 (Normal Distribution in Monte-Carlo)
AI	14th order aspheric coefficient	1.0D-30 / 1.0D-6 (Normal Distribution in Monte-Carlo)
AJ	16th order aspheric coefficient	1.0D-34 / 1.0D-6 (Normal Distribution in Monte-Carlo)
AK	18th order aspheric coefficient	1.0D-36 / 1.0D-6 (Normal Distribution in Monte-Carlo)
AL	20th order aspheric coefficient	1.0D-40 / 1.0D-6 (Normal Distribution in Monte-Carlo)
RDTOR or **CVTOR**	Toric radius or toric curvature (If the surface is not already toroidal, it will be defined as a Y-TORIC) . Units are % of current value.	0.025% of current toric radius of curvature value. (used for non-flat surfaces only) (Uniform Distribution in Monte-Carlo)
RDTFR or **CVTFR**	Toric radius or toric curvature (If the surface is not already toroidal, it will be defined as a Y-TORIC). Units are fringes of power at 0.5461µ	1 fringe of cylinder over the diameter corresponding to the current "inr" value and computed at 0.5461µ (use CVTFR if toric curvature is 0.0) (use RDTFR if toric curvature is not 0.0) (Uniform Distribution in Monte-Carlo)
CCTOR	Toric conic constant (Surface must be defined as a TORIC)	1.0D-6 (Normal Distribution in Monte-Carlo)
ADTOR	4th order anamorphic aspheric term (Surface must be defined as a TORIC)	1.0D-10 / 1.0D-6 (Normal Distribution in Monte-Carlo)
AETOR	6th order anamorphic aspheric term (Surface must be defined as a TORIC)	1.0D-14 / 1.0D-6 (Normal Distribution in Monte-Carlo)
AFTOR	8th order anamorphic aspheric term (Surface must be defined as a TORIC)	1.0D-18 / 1.0D-6 (Normal Distribution in Monte-Carlo)
AGTOR	10th order anamorphic aspheric term (Surface must be defined as a TORIC)	1.0D-22 / 1.0D-6 (Normal Distribution in Monte-Carlo)
ALPHA	Alpha surface tilt angle (degrees)	1.0 mrad (0.0573 deg) (Normal Distribution in Monte-Carlo)
BETA	Beta surface tilt angle (degrees)	1.0 mrad (0.0573 deg) (Normal Distribution in Monte-Carlo)
GAMMA	Gamma surface tilt angle (degrees)	1.0 mrad (0.0573 deg) (Normal Distribution in Monte-Carlo)
XD	Surface X-decentration	0.001 lens unit (Normal Distribution in Monte-Carlo)
YD	Surface Y-decentration	0.001 lens unit (Normal Distribution in Monte-Carlo)
ZD	Surface Z-decentration	0.001 lens unit (Normal Distribution in Monte-Carlo)
PIVX	X-surface pivot point location	0.001 lens unit (Normal Distribution in Monte-Carlo)
PIVY	Y-surface pivot point location	0.001 lens unit (Normal Distribution in Monte-Carlo)
PIVZ	Z-surface pivot point location	0.001 lens unit (Normal Distribution in Monte-Carlo)
N1 through N10	Refractive index at wavelength 1 to 10 for a "MYGLASS" material	1.0D-5 (Uniform Distribution in Monte-Carlo)
INDEX	Nd value of a "MODEL" glass	1.0D-5 (Uniform Distribution in Monte-Carlo)
VNUM	Vd value of a "MODEL" glass	1.0D-5 (Uniform Distribution in Monte-Carlo)
DPART	Partial dispersion shift for a "MODEL" glass	1.0D-5 (Uniform Distribution in Monte-Carlo)

C1 through C96	96 special surface coefficients	1.0D-10 (Normal Distribution in Monte-Carlo)
AC	2nd order surface aspheric term	1.0D-6 / 1.0D-6 (Normal Distribution in Monte-Carlo)
CLPX	X - clear aperture height	0.001 lens units (Uniform Distribution in Monte-Carlo)
CLPY	Y - clear aperture height	0.001 lens units (Uniform Distribution in Monte-Carlo)
GRS	diffraction grating spacing	0.001 lens units (Normal Distribution in Monte-Carlo)
GALPHA	Global alpha surface tilt angle (degrees)	1.0 mrad (0.0573 deg) (Normal Distribution in Monte-Carlo)
GBETA	Global beta surface tilt angle (degrees)	1.0 mrad (0.0573 deg) (Normal Distribution in Monte-Carlo)
GGAMMA	Global gamma surface tilt angle (degrees)	1.0 mrad (0.0573 deg) (Normal Distribution in Monte-Carlo)
GXD	Surface global X-decentration	0.001 lens unit (Normal Distribution in Monte-Carlo)
GYD	Surface global Y-decentration	0.001 lens unit (Normal Distribution in Monte-Carlo)
GZD	Surface global Z-decentration	0.001 lens unit (Normal Distribution in Monte-Carlo)

If "CVTOR" or "RDTOR" are varied on a non-toric surface, the surface is temorarily redefined as a Y-toric. "CCTOR", "ADTOR", "AETOR", "AFTOR" and "AGTOR" only work for anamorphic, aspheric surfaces. The "delta" values used for aspheric surface coefficients have two default values. The first default value will be used if the maximum value of the reference aperture height (semi-diameter) of the current lens is greater than or equal to 1.0 lens units. The second default value will be used if the maximum value of the reference aperture height of the current lens is less than 1.0 lens units. If these defaults cause problems in a particular system, then set these "deltas" by hand. There is no way to reset these default "deltas" to other values. Before refractive indices may be toleranced using the tolerance variables "N1" through "N10", the surface's material type must be explicitly defined using the "MYGLASS" command.

COMPOUND TOLERANCE VARIABLES - Compound tolerance variables are quite different from simple tolerance variables in that they may be associated with multiple lens database surfaces and they are characterized by more than one numeric input value. The name of a compound tolerance variable is the name of the command used to insert that tolerance variable into the tolerance variable set. The compound tolerance variable commands have the following form:

(Tolerance Variable Name) , i , j , k , l - The interpretations of "i", "j", "k" and "l" are listed in the following table. During a sensitivity analysis, the variable change value is the change made to that tolerance variable. During a Monte-Carlo analysis, the variable change value is considered to be the one-sigma value which that tolerance variable may take on during any one Monte-Carlo cycle. Variable change values, if not explicitly input by the user, are set to "default" values. The default values are different for each variable. The following table lists the compound tolerance variables which may be included in the tolerance variables set and their associated default change values. The nature of the random distribution used during a Monte-Carlo simulation for each compound variable is a normal gaussian distribution.

VARIABLE NAME	**"i"**	**"j"**	**"k"**	**"l"**
DISPX (x-displacement of surface or surfaces)	starting surface#	ending surface#	x-displacement change value	(not used)
DISPY (y-displacement of surface or surfaces)	starting surface#	ending surface#	y-displacement change value	(not used)
DISPZ (z-displacement of surface or surfaces)	starting surface#	ending surface#	z-displacement change value	(not used)
STILTA (alpha surface tilt)	surface#	tilt (degrees) change value	(not used)	(not used)
STILTB (beta surface tilt)	surface#	tilt (degrees) change value	(not used)	(not used)
STILTG (gamma surface tilt)	surface#	tilt (degrees) change value	(not used)	(not used)
BTILTA (alpha barrel tilt)	starting surface#	ending surface#	tilt (degrees) change value	(not used)
BTILTB (beta barrel tilt)	starting surface#	ending surface#	tilt (degrees) change value	(not used)
BTILTG (gamma barrel tilt)	starting surface#	ending surface#	tilt (degrees) change value	(not used)
ROLLX (x-roll about a mounting surface)	starting surface#	ending surface#	x-roll change value	roll surface#
ROLLY (y-roll about a mounting surface)	starting surface#	ending surface#	y-roll change value	roll surface#

The above compound tolerance variables are not, in general, compatible with "TILT BEN", "TILT DAR" and "TILT RET". All occurrences of "TILT BEN", "TILT DAR" and "TILT RET" should be removed via the "TILT BEND", "TILT DARD" and "TILT RETD" commands before using compund tolerance variables. Surface tilts, STILTA, STILTB and STILTG are performed such that all other surfaces are left as they were before the tilt of surface "i" was performed. These variables act much the way the CMD level command "STILT" acted at the CMD program level. "STILT" is described in the LENS section of this manual. The default pivot point for the surface tilts is the local origin of surface "i". If an alternate pivot point is desired, then the commands "STILTA PIVOT", "STILTB PIVOT" or "STILTG PIVOT" should be issued immediately before the "STILTA", "STILTB" or "STILTG" commands. The alternate pivot points so defined, with respect to the local origin of surface "i", will be used only for the very next "STILTA", "STILTB" or "STILTG" command encountered.

STILTA PIVOT , x-pivot , y-pivot , z-pivot and
STILTB PIVOT , x-pivot , y-pivot , z-pivot and
STILTG PIVOT , x-pivot , y-pivot , z-pivot - These commands are used to re-define the "pivot" point for the very next "STILT(A, B or C) command encountered.

Barrel tilts can effect a group of surfaces. Barrel tilts, BTILTA, BTILTB and BTILTG are performed such that all other surfaces are left as they were before the tilt of surfaces "i" through "j" was performed. These variables act much the way the CMD level command "BTILT" acted at the CMD program level. "BTILT" is described in the LENS section of this manual. The default pivot point for the barrel tilts is the local origin of surface "i". If an alternate pivot point is desired, then the commands "BTILTA PIVOT", "BTILTB PIVOT" or "BTILTG PIVOT" should be issued immediately before the "BTILTA", "BTILTB" or "BTILTG" commands. The alternate pivot points so defined, with respect to the local origin of surface "i", will be used only for the very next "BTILTA", "BTILTB" or "BTILTG" command encountered.

BTILTA PIVOT , x-pivot , y-pivot , z-pivot and
BTILTB PIVOT , x-pivot , y-pivot , z-pivot and
BTILTG PIVOT , x-pivot , y-pivot , z-pivot - These commands are used to re-define the "pivot" point for the very next "BTILT(A, B or C) command encountered.

Rolls effect a group of surfaces. Roll variables, ROLLX and ROLLY are performed such that all other surfaces are left as they were before the roll of surfaces "i" through "j" was performed. These variables act much the way the CMD level command "ROLL" acted at the CMD program level. "ROLL" is described in the LENS section of this manual. The default pivot point for the roll is the center of curvature of surface "i" If it is desired to roll the surfaces about the center of curvature of surface "j", then the surface number of surface "j" must be entered explicitly as the 4th numeric word "l". A "roll" is a sliding displacement about a mounting surface.

INTERROGATION OF TOLERANCE VARIABLES - This command is valid at the TVAR, the UPDATE TVAR and also at the CMD levels.
TVB , i - The "TVB" command displays the tolerance variable name and number, the associated lens database surface number and the current tolerance variable value and the current "delta" value. If "i" is explicitly input, only data for tolerance variable "i" will be displayed. If "i" is omitted, data for all current tolerance variables will be displayed.

COMPENSATION VARIABLES
CREATING COMPENSATION VARIABLES
COMPVAR - The "COMPVAR" command causes the program to leave the CMD level and enter the COMPVAR input level. The compensation variables memory area is wiped clean and is ready for new compensation variables input. Between "COMPVAR" and "EOS" or "END", any COMPVAR input level command may be entered. The program can have up to 5 compensation variables defined at any one time.
EOS or **END** - The "EOS" or "END" command, issued from the COMPVAR level, causes the program to return to the CMD level. The compensation variables set is left in memory and is ready for tolerancing.

MODIFYING COMPENSATION VARIABLES
UPDATE COMPVAR or **U CMP** - The "UPDATE COMPVAR" command, or its abbreviated form "U CMP", causes the program to leave the CMD level and enter the UPDATE COMPVAR level. The compensation variables memory area is opened and is ready for modification. Between "UPDATE COMPVAR" or "U CMP" and "EOS" or "END", any UPDATE COMPVAR level command may be entered.
DEL , i - The "DEL" command, issued from the UPDATE COMPVAR level, causes the program to delete the "i" th compensation variable
EOS or **END** - The "EOS" or "END" command, issued from the UPDATE COMPVAR level, causes the program to return to the CMD level. The compensation variables set is left in memory and is ready for tolerancing.

COMPENSATION VARIABLES COMMANDS - The name of a compensation variable is the name of the command used to insert that compensation variable into the compensation variable set. The commands have the following form:
(Compensation Variable Name) , compensator # , i , dincr - "compensator #" is a value from 1 to 5. There can be only five (5) compensation variables in a tolerance analysis. "compensator #" must be explicitly input by the user. "i" is the surface in the lens database to which the compensation variable is associated. "i" must be explicitly input. The "dincr" is the change to the variable value used in the compensation calculations. "dincr" values, if not explicitly input by the user, are set to "default" values. The default "dincr" values vary for each compensator. The following table lists the lens and special surface database items and their associated default "dincr" values which may be included in the comensation variables set.

COMPENSATOR NAME	DESCRIPTION	DEFAULT "dincr" VALUE
RD	Radius of curvature. This is automatically converted to CV.	
CV	Surface curvature	1.0D-4
TH	Axial distance to next surface	1.0D-4
CC	Surface conic constant	1.0D-6

AD	4th order aspheric coefficient	1.0D-10 / 1.0D-6 *
AE	6th order aspheric coefficient	1.0D-14 / 1.0D-6 *
AF	8th order aspheric coefficient	1.0D-18 / 1.0D-6 *
AG	10th order aspheric coefficient	1.0D-22 / 1.0D-6 *
AH	12th order aspheric coefficient	1.0D-26 / 1.0D-6 *
AI	14th order aspheric coefficient	1.0D-30 / 1.0D-6 *
AJ	16th order aspheric coefficient	1.0D-34 / 1.0D-6 *
AK	18th order aspheric coefficient	1.0D-36 / 1.0D-6*
AL	20th order aspheric coefficient	1.0D-40 / 1.0D-6 *
RDTOR	Toric radius of curvature. This is automatically converted to CVTOR.	
CVTOR	Toric curvature	1.0D-4
CCTOR	Toric conic constant	1.0D-6
ADTOR	4th order anamorphic aspheric term	1.0D-10 / 1.0D-6 *
AETOR	6th order anamorphic aspheric term	1.0D-14 / 1.0D-6 *
AFTOR	8th order anamorphic aspheric term	1.0D-18 / 1.0D-6 *
AGTOR	10th order anamorphic aspheric term	1.0D-22 / 1.0D-6 *
ALPHA	Alpha surface tilt angle	1.0D-6 (degree)
BETA	Beta surface tilt angle	1.0D-6 (degree)
GAMMA	Gamma surface tilt angle	1.0D-6 (degree)
XD	Surface X-decentration	1.0D-6
YD	Surface Y-decentration	1.0D-6
ZD	Surface Z-decentration	1.0D-6
GALPHA	Global alpha surface tilt angle	1.0D-6 (degree)
GBETA	Global beta surface tilt angle	1.0D-6 (degree)
GGAMMA	Global Gamma surface tilt angle	1.0D-6 (degree)
GXD	Surface global X-decentration	1.0D-6
GYD	Surface global Y-decentration	1.0D-6
GZD	Surface global Z-decentration	1.0D-6
PIVX	X-surface pivot point location	1.0D-6
PIVY	X-surface pivot point location	1.0D-6
PIVZ	X-surface pivot point location	1.0D-6
N1 through **N10**	Refractive index at wavelength 1 to 10	1.0D-5
INDEX	Nd value of a "MODEL" glass	1.0D-5
VNUM	Vd value of a "MODEL" glass	1.0D-5
DPART	Partial dispersion shift for a "MODEL" glass	1.0D-5
C1 through **C96**	96 special surface coefficients	1.0D-10
AC	2nd order surface aspheric term	1.0D-6 / 1.0D-6 *
CLPX	X - clear aperture height	1.0D-4
CLPY	Y - clear aperture height	1.0D-4
GRS	diffraction grating spacing	1.0D-4

The "dincr" values used for aspheric surface coefficients have three default values. The frist default value is based upon an internal program algoithm which considers the control wavelength value and the paraxial marginal and paraxial chief ray heights at the current surface. In the case that both of these paraxial ray height values are zero, then the second or third default values, shown in the table above, will be used. The second default value will be used if the maximum value of the reference aperture height of the current lens is greater than or equal to 1.0 lens units. The third default value will be used if the maximum value of the reference aperture height of the current lens is less than 1.0 lens units. If these defaults cause problems in a particular system, then set these aspheric "dincrs" by hand during compensation variable specification. All lens solves and PIKUPs take precedence over compensation variable definitions. If there is a conflict, the compensation variable definition will be disallowed or deleted. Before refractive indices may be used as compensation variables via the compensation variables "N1" through "N10", the surface's material type must be explicitly defined using the "MYGLASS" command.

INTERROGATION OF COMPENSATION VARIABLES - This command is valid at the COMPVAR, the UPDATE COMPVAR and also at the CMD levels.
COMPS , i - The "COMPS" command displays the compensation variable name and number, the associated lens database surface number and the current compensation variable value and "dincr". If "i" is explicitly input, only data for compensation variable "i" will be displayed. If "i" is omitted, data for all current compensation variables will be displayed.

PIKUPS AND SOLVES IN TOLERANCING - PIKUPs and solves are allowed in tolerancing. All PIKUPs and solves will be resolved BEFORE tolerance operands are computed and will be active as tolerance compensations are performed. Be sure that you want them to be active during tolerancing. If they should not be active, remove them before performing the actual tolerance analysis.

ENTERING TOLERANCE OPERANDS
TOPER - The "TOPER" command causes the program to leave the CMD level and enter the TOLERANCE OPERAND input level. The tolerance operand list is wiped clean and is ready for new tolerance operand input. Between "TOPER" and "EOS" or "END", any TOLERANCE OPERAND input level command may be entered. It is in the TOLERANCE OPERAND and the UPDATE TOLERANCE OPERAND levels where tolerance

operands are defined and input. The program can have up to 5 tolerance operands defined for any one tolerance analysis.
EOS or **END** - The "EOS" or "END" command, issued from the TOLERANCE OPERAND level, causes the program to return to the CMD level. The tolerance operands are left in memory.

MODIFYING TOLERANCE OPERANDS
UPDATE TOPER or **U TOP** - The "UPDATE TOPER" command, or its abbreviated form "U TOP", causes the program to leave the CMD level and enter the UPDATE TOLERANCE OPERAND level. The tolerance operand memory area is opened and is ready for modification. Between "UPDATE TOPER" or "U TOP" and "EOS" or "END", any UPDATE TOLERANCE OPERAND level command may be entered. It is in the TOLERANCE OPERAND and the UPDATE TOLERANCE OPERAND levels where tolerance operands are defined and input.
DEL , i - The "DEL" command, issued from the UPDATE TOLERANCE OPERAND level, causes the program to delete the "i" th tolerance operand from the tolerance operand set.
EOS or **END** - The "EOS" or "END" command, issued from the UPDATE TOLERANCE OPERAND level, causes the program to return to the CMD level. The tolerance operands are left in memory.

INTERROGATING THE TOL-OP SET - The next command is valid at the TOPER, the UPDATE TOPER and the CMD levels:
TOPS , i - The "TOPS" command displays the tolerance operand number, tolerance operand name, "tval1" and "tval2" values and the values of the optional numeric words #1, #2 and #3 which were input when each of the tolerance operands was defined. If "i" is explicitly input, only the tolerance operand data for tolerance operand number "i" will be displayed. If "i" is omitted, data for all current operands will be displayed.

TOLERANCE OPERAND ENTRY - There are two kind of tolerance operands: predefined and user-defined. There are, furthermore, two kinds of predefined tolerance operands: "ray-based" and "non-ray-based". "Ray-based" tolerance operands are based upon the results of the tracing of one or more real trigonometric rays. "Non-ray-based" tolerance operands are everything else. First, predefined, "ray-based" tolerance operands are described; next, predefined, "non-ray-based" tolerance operands are described; and finally, user-defined tolerance operands are described. There can be up to 3995 tolerance operands active during tolerancing.

PREDEFINED RAY-BASED TOLERANCE OPERANDS - Before "ray-based" tolerance operands can be entered, the rays upon which they are based must be defined. Ray-based tolerance operands can either depend upon the definition of individual fields and rays or they can depend upon the definition of grids of rays as established in and for spot diagram tolerance ray tracing.

FIELDS, RAYS AND GRIDS OF RAYS - The individual field of view positions, individual rays and the grid patterns used for spot diagram tolerance ray tracing are defined using the same field, ray and spot diagram definition commands which are described in the OPTIMIZATION section of this manual. They are not redescribed here in any detail. The names of these commands are:
For defining individual field of view positions: **F(n) , Y , X , Z , n , m**
For interrogating field of view position definitions: **FIELDS i , j**
For resetting field of view position definitions to their program default values: **FIELDS RESET**
For defining individual rays: **R(n) , Y , X , n**
For interrogating individual ray definitions: **RAYS i , j**
For resetting individual ray definitions to their program default values: **RAYS RESET**
For setting automatic vignetting for some operands. **VIG (ON or YES or OFF or NO)**
For turning the differential ray trace on or off. **OPDIF (ON or YES or OFF or NO)**
For defining the type of spot grid pattern: **OPSPOT (RECT, RING, RAND)**
The next commands have the same syntax as their counterpart commands which omitt the "OP" at the beginning of the command names and which can be found in the OPTIM section of this manual
For defining the number of rings in a RING type spot pattern: **OPRINGS , n**
For setting a ring's characteristics: **OPRING , i , r , m , θ**
For setting the number of rays across a rectangular grid: **OPRECT , n**
For setting the number of rays in a random type spot: **OPRANNUM , n**
For resetting grid characteristics to their program defaults: **OPSPDRST**
Whenever the characteristics of a spot pattern is modified by the user, all characteristics must be reset by the user. If, for example, the user sets the number of rings to 20, then the characteristics of every ring will need to be reset by the user using the "RING" command.
For setting gaussian profile aperture apodization: **GAUSS or NOGAUSS**
For setting the grid size for complex aperture function and MTF calculations: **TOLNRD , tolnrd**

TOLERANCE OPERAND DESCRIPTORS - To help keep track of tolerance operands, the "OP_DESC" command is provided. It takes operand designators "OP1", "OP2", "OP3", "OP4" or "OP5" as a qualifier word and takes up to a 69 character string description for each operand. These optional descriptions are displayed by the "TOPS" command and during tolerance analysis output.
OP_DESC (operand designator) (operand descrition 1 to 69 characters) - The "OP_DESC" command is used to assign user defined descriptions to each operand.

PREDEFINED TOLERANCE OPERANDS - All predefined tolerance operands are entered at the TOPER and UPDATE TOPER levels with the following command:
(predefined tol-op name) operand # , i , j , k , tval - "tval" is a user input operand change value to be used during an inverse sensitivity analyses. It designates the amount of allowed operand change which should take place. Its default value is -99.9D99. The "tval" value is ignored during a sensitivity analysis or a Monte-Carlo analysis. If the default value of "tval" is found during an inverse sensitivity analysis, the analysis will be aborted with a warning message. The names of all predefined tolerance operands and the meanings of the "i", "j" and "k" input values, numeric words (nw) #1, #2 and #3 are listed in the following table:

PREDEFINED LENS DATABASE TOL-OPS				
OPERAND NAME	**"i" (nw#2)**	**"j" (nw#3)**	**"k" (nw#4)**	**DESCRIPTION**
RD	surf #	(not used)	(not used)	Radius of curvature at surface "i"
CV	surf #	(not used)	(not used)	Curvature at surface "i"
TH	surf #	(not used)	(not used)	Thickness at surface "i"
CC	surf #	(not used)	(not used)	Conic constant at surface "i"
AC	surf #	(not used)	(not used)	2nd order aspheric at surface "i"
AD	surf #	(not used)	(not used)	4th order aspheric at surface "i"
AE	surf #	(not used)	(not used)	6th order aspheric at surface "i"
AF	surf #	(not used)	(not used)	8th order aspheric at surface "i"
AG	surf #	(not used)	(not used)	10th order aspheric at surface "i"
AH	surf #	(not used)	(not used)	12th order aspheric at surface "i"
AI	surf #	(not used)	(not used)	14th order aspheric at surface "i"
AJ	surf #	(not used)	(not used)	16th order aspheric at surface "i"
AK	surf #	(not used)	(not used)	18th order aspheric at surface "i"
AL	surf #	(not used)	(not used)	20th order aspheric at surface "i"
RDTOR	surf #	(not used)	(not used)	Toric radius of curvature at surface "i"
CVTOR	surf #	(not used)	(not used)	Toric curvature at surface "i"
CCTOR	surf #	(not used)	(not used)	Toric conic constant at surface "i"
ADTOR	surf #	(not used)	(not used)	Toric 4th order aspheric at surface "i"
AETOR	surf #	(not used)	(not used)	Toric 6th order aspheric at surface "i"
AFTOR	surf #	(not used)	(not used)	Toric 8th order aspheric at surface "i"
AGTOR	surf #	(not used)	(not used)	Toric 10th order aspheric at surface "i"
ALPHA	surf #	(not used)	(not used)	ALPHA surface tilt angle (degrees) at surface "i"
BETA	surf #	(not used)	(not used)	BETA surface tilt angle (degrees) at surface "i"
GAMMA	surf #	(not used)	(not used)	GAMMA surface tilt angle (degrees) at surface "i"
VNUM	surf #	(not used)	(not used)	V-number or Abbe number for the "MODEL" glass at surface "i"
DPART	surf #	(not used)	(not used)	Partial dispersion shift for the "MODEL" glass at surface "i".
ABBE	surf #	(not used)	(not used)	V-number or Abbe number for the glass at surface "i" It is equal to: $VNUM = \frac{(N_{cw} - 1)}{(N_{pcw1} - N_{pcw2})}$ Where: pcw1 and pcw2 are the primary wavelength pair defined in the lens database.
PARTL	surf #	(not used)	(not used)	Partial Dispersion for the glass at surface "i". It is equal to: $PARTL = \frac{(N_{cw} - N_{pcw2})}{(N_{pcw1} - N_{pcw2})}$ Where: pcw1 and pcw2 are the primary wavelength pair defined in the lens database.
INDEX	surf #	(not used)	(not used)	Refractive index Nd for the "MODEL" glass at surface "i".
N1 to N10	surf #	(not used)	(not used)	Refractive index at wavelength #1 to #10 at surface "i".
XD	surf #	(not used)	(not used)	X-decenter at surface "i"
YD	surf #	(not used)	(not used)	Y-decenter at surface "i"
ZD	surf #	(not used)	(not used)	Z-decenter at surface "i"
XVERT	surf #	Global ref surf #	(not used)	Global X-coordinate of the vertex of surface "i", referenced to a global origin at surface "j".

YVERT	surf #	Global ref surf #	(not used)	Global Y-coordinate of the vertex of surface "i", referenced to a global origin at surface "j".
ZVERT	surf #	Global ref surf #	(not used)	Global Z-coordinate of the vertex of surface "i", referenced to a global origin at surface "j".
LXVERT	surf #	Global ref surf #	(not used)	Global X-direction cosine of the local X-axis of surface "i", referenced to a global origin at surface "j".
MXVERT	surf #	Global ref surf #	(not used)	Global Y-direction cosine of the local X-axis of surface "i", referenced to a global origin at surface "j".
NXVERT	surf #	Global ref surf #	(not used)	Global Z-direction cosine of the local X-axis of surface "i", referenced to a global origin at surface "j".
LYVERT	surf #	Global ref surf #	(not used)	Global X-direction cosine of the local Y-axis of surface "i", referenced to a global origin at surface "j".
MYVERT	surf #	Global ref surf #	(not used)	Global Y-direction cosine of the local Y-axis of surface "i", referenced to a global origin at surface "j".
NYVERT	surf #	Global ref surf #	(not used)	Global Z-direction cosine of the local Y-axis of surface "i", referenced to a global origin at surface "j".
LZVERT	surf #	Global ref surf #	(not used)	Global X-direction cosine of the local Z-axis of surface "i", referenced to a global origin at surface "j".
MZVERT	surf #	Global ref surf #	(not used)	Global Y-direction cosine of the local Z-axis of surface "i", referenced to a global origin at surface "j".
NZVERT	surf #	Global ref surf #	(not used)	Global Z-direction cosine of the local Z-axis of surface "i", referenced to a global origin at surface "j".
LENGTH or OAL	surf # (def=0)	surf # (def=last)	(not used)	Algebraic sum of axial thicknesses from surface "i" to surface "j"
MLENGTH or OPTLEN	surf # (def=0)	surf # (def=last)	(not used)	Physical length from surface "i" to surface "j" along a path connecting surface vertices and ignoring tilts and decentrations. This is the sum of the axial thicknesses multiplied by the refractive index in each space.
ET or ETY	surf #	(not used)	(not used)	Edge thickness from surface "i" to surface "i"+1. Surface tilts and decentrations are ignored. If clear apertures are assigned, they are assumed circular with the YZ-plane value being used. The larger of the values on surface "i" and "i"+1 is used. If no clear apertures are assigned, then the larger of the sums of PY+PCY on surfaces "i" and "i"+1 are used in the calculation. Clear aperture decentrations and tilts are ignored.
ETX	surf #	(not used)	(not used)	Edge thickness from surface "i" to surface "i"+1. Surface tilts and decentrations are ignored. If clear apertures are assigned, they are assumed circular with the XZ-plane value being used. The larger of the values on surface "i" and "i"+1 is used. If no clear apertures are assigned, then the larger of the sums of PX+PCX on surfaces "i" and "i"+1 are used in the calculation. Clear aperture decentrations and tilts are ignored.
GRS	surf#	(not used)	(not used)	diffraction grating spacing
C1 through C96	surf #	(not used)	(not used)	Any one of the 96 coefficients of a special surface attached to surface "i"

SHAPEFAC	surf #	(not used)	(not used)	This returns the shape factor for the lens element which begins at surface "i" and terminates at surface "i+1". The shape factor is defined by : $$SHAPEFAC = \frac{r_{i+1} + r_i}{r_{i+1} - r_i}$$ where: r is the radius of curvature
PIVX	surf#	(not used)	(not used)	X-surface pivot point location
PIVY	surf#	(not used)	(not used)	Y-surface pivot point location
PIVZ	surf#	(not used)	(not used)	Z-surface pivot point location
CLPX	surf #	(not used)	(not used)	X-dimension of the clear aperture height at surface "I". Zero is returned if no clear aperture is assigned.
CLPY	surf #	(not used)	(not used)	Y-dimension of the clear aperture height at surface "I". Zero is returned if no clear aperture is assigned.
WEIGHT	surf # (def=0)	surf # (def=last)	(not used)	MASS in Kgs of elements from surface "i" to surface "j". This calculation assumes spherical surfaces and ignores all decenters and tilts. It uses the specific gravity assigned to surfaces with the lens database command "SPGR".
COST	surf # (def=0)	surf # (def=last)	(not used)	Cost in cost units based upon a WEIGHT calculation multiplied by the individual surface price/Kg values stored in the lens database.

PREDEFINED REAL SINGLE RAY BASED TOL-OPS				
TOL-OP NAME	**"i" (nw#2)**	**"j" (nw#3)**	**"k" (nw#4)**	**DESCRIPTION**
X	surf # (def=img)	Field Pos. #	Ray Pos.#	X-local coordinate at surface "i" at field position number "j" and ray position number "k" of last ray traced
Y	surf # (def=img)	Field Pos. #	Ray Pos.#	Y-local coordinate at surface "i" at field position number "j" and ray position number "k" of last ray traced
Z	surf # (def=img)	Field Pos. #	Ray Pos.#	Z-local coordinate at surface "i" at field position number "j" and ray position number "k" of last ray traced
DCL or K	surf # (def=img)	Field Pos. #	Ray Pos.#	L-direction cosine at surface "i" at field position number "j" and ray position number "k" of last ray traced
DCM or L	surf # (def=img)	Field Pos. #	Ray Pos.#	Z-direction cosine at surface "i" at field position number "j" and ray position number "k" of last ray traced
DCN or M	surf # (def=img)	Field Pos. #	Ray Pos.#	Z-direction cosine at surface "i" at field position number "j" and ray position number "k" of last ray traced
DX	surf # (def=img)	Field Pos. #	Ray Pos.#	DX at surface "i" of last ray traced X-Ray Coordinate minus X-Chief ray Coordinate
DY	surf # (def=img)	Field Pos. #	Ray Pos.#	DY at surface "i" of last ray traced Y-Ray Coordinate minus Y-Chief ray Coordinate
DXA	surf # (def=img)	Field Pos. #	Ray Pos.#	DXA at surface "i" of last ray traced XANG-Ray slope minus XANG-Chief ray slope (radians)
DYA	surf # (def=img)	Field Pos. #	Ray Pos.#	DYA at surface "i" of last ray traced YANG-Ray slope minus YANG-Chief ray slope (radians)
DR	surf # (def=img)	Field Pos. #	Ray Pos.#	DR at surface "i" of last ray traced Radial-Ray Coordinate minus Radial-Chief ray Coordinate

DRA	surf # (def=img)	Field Pos. #	Ray Pos.#	DRA at surface "i" of last ray traced Radial-Ray slope minus Radial-Chief ray slope (radians)
XANG	surf # (def=img)	Field Pos. #	Ray Pos.#	XZ-plane slope angle at surface "i" of the last ray traced (radians)
YANG	surf # (def=img)	Field Pos. #	Ray Pos.#	YZ-plane slope angle at surface "i" of the last ray traced (radians)
OPL	surf #	Field Pos. #	Ray Pos.#	Optical path length along the specified ray from surface "i-1" to surface "i" (in lens units)
OPD	Field Pos #	Ray Pos. #	(not used)	Optical path difference between the specified ray and the reference ray (in lens units).
OPDW	Field Pos #	Ray Pos. #	(not used)	Optical path difference between the specified ray and the reference ray (in waves at the wavelength used to trace the reference ray).
LOLD	surf # (def=img)	Field Pos. #	Ray Pos.#	X-direction cosine at surface "i" of the specified ray (before refraction, reflection or diffraction)
MOLD	surf # (def=img)	Field Pos. #	Ray Pos.#	Y-direction cosine at surface "i" of the specified ray (before refraction, reflection or diffraction)
AII	surf # (def=img)	Field Pos. #	Ray Pos.#	Cosine of the angle of incidence of specified ray at surface "i"
AIP	surf # (def=img)	Field Pos. #	Ray Pos.#	Cosine of the angle of refraction, reflection or diffraction of specified ray at surface "i"
LN	surf #	Field Pos. #	Ray Pos.#	Local surface coordinate system X-direction cosine of the surface normal at surface "i" where the specified ray intersects surface "i"
MN	surf #	Field Pos. #	Ray Pos.#	Local surface coordinate system Y-direction cosine of the surface normal at surface "i" where the specified ray intersects surface "i"
NN	surf #	Field Pos. #	Ray Pos.#	Local surface coordinate system Z-direction cosine of the surface normal at surface "i" where the specified ray intersects surface "i"
PXPX	surf # (def=img)	Field Pos. #	(not used)	Derivative, at surface "i", of the X-coordinate of the specified chief ray traced with respect to a change in that chief ray's X-coordinate at the current object surface.
PXPY	surf # (def=img)	Field Pos. #	(not used)	Derivative, at surface "i", of the X-coordinate of the specified chief ray traced with respect to a change in that chief ray's Y-coordinate at the current object surface.
PYPX	surf # (def=img)	Field Pos. #	(not used)	Derivative, at surface "i", of the Y-coordinate of the specified chief ray traced with respect to a change in that chief ray's X-coordinate at the current object surface.
PYPY	surf # (def=img)	Field Pos. #	(not used)	Derivative, at surface "i", of the Y-coordinate of the specified chief ray traced with respect to a change in that chief ray's Y-coordinate at the current object surface.
PXAPX	surf # (def=img)	Field Pos. #	(not used)	Derivative, at surface "i", of the XZ-plane radian measure slope angle of the specified chief ray traced with respect to a change in that chief ray's X-coordinate at the current object surface.
PXAPY	surf # (def=img)	Field Pos. #	(not used)	Derivative, at surface "i", of the XZ-plane radian measure slope angle of the specified chief ray traced with respect to a change in that chief ray's Y-coordinate at the current object surface.
PYAPX	surf # (def=img)	Field Pos. #	(not used)	Derivative, at surface "i", of the YZ-plane radian measure slope angle of the specified chief ray traced with respect to a change in that chief ray's X-coordinate at the current object surface.

PYAPY	surf # (def=img)	Field Pos. #	(not used)	Derivative, at surface "i", of the YZ-plane radian measure slope angle of the specified chief ray traced with respect to a change in that chief ray's Y-coordinate at the current object surface.
DXDX	surf # (def=img)	Field Pos. #	Ray Pos.#	Derivative, at surface "i", of the X-coordinate of the specified ray traced with respect to a change in that ray's X-coordinate at the current reference surface.
DXDY	surf # (def=img)	Field Pos. #	Ray Pos.#	Derivative, at surface "i", of the X-coordinate of the specified ray traced with respect to a change in that ray's Y-coordinate at the current reference surface.
DYDX	surf # (def=img)	Field Pos. #	Ray Pos.#	Derivative, at surface "i", of the Y-coordinate of the specified ray traced with respect to a change in that ray's X-coordinate at the current reference surface.
DYDY	surf # (def=img)	Field Pos. #	Ray Pos.#	Derivative, at surface "i", of the Y-coordinate of the specified ray traced with respect to a change in that ray's Y-coordinate at the current reference surface.
DXADX	surf # (def=img)	Field Pos. #	Ray Pos.#	Derivative, at surface "i", of the XZ-plane radian measure slope angle of the specified ray traced with respect to a change in that chief ray's X-coordinate at the current reference surface.
DXADY	surf # (def=img)	Field Pos. #	Ray Pos.#	Derivative, at surface "i", of the XZ-plane radian measure slope angle of the specified ray traced with respect to a change in that chief ray's Y-coordinate at the current reference surface.
DYADX	surf # (def=img)	Field Pos. #	Ray Pos.#	Derivative, at surface "i", of the YZ-plane radian measure slope angle of the specified ray traced with respect to a change in that chief ray's X-coordinate at the current reference surface.
DYADY	surf # (def=img)	Field Pos. #	Ray Pos.#	Derivative, at surface "i", of the YZ-plane slope angle of the specified ray traced with respect to a change in that ray's Y-coordinate at the current reference surface.
XREF	surf # (def=img)	Field Pos. #	(not used)	X-coordinate of the specified reference ray at surface "i"
YREF	surf # (def=img)	Field Pos. #	(not used)	Y-coordinate of the specified reference ray at surface "i"
ZREF	surf # (def=img)	Field Pos. #	(not used)	Z-coordinate of the specified reference ray at surface "i"
LREF	surf # (def=img)	Field Pos. #	(not used)	X-direction cosine of the specified reference ray at surface "i" after refraction, reflection or diffraction
MREF	surf # (def=img)	Field Pos. #	(not used)	Y-direction cosine of the specified reference ray at surface "i" after refraction, reflection or diffraction
NREF	surf # (def=img)	Field Pos. #	(not used)	Z-direction cosine of the specified reference ray at surface "i" after refraction, reflection or diffraction
LREFOL	surf # (def=img)	Field Pos. #	(not used)	X-direction cosine of the specified reference ray at surface "i" before refraction, reflection or diffraction
MREFOL	surf # (def=img)	Field Pos. #	(not used)	Y-direction cosine of the specified reference ray at surface "i" before refraction, reflection or diffraction
NREFOL	surf # (def=img)	Field Pos. #	(not used)	Z-direction cosine of the specified reference ray at surface "i" before refraction, reflection or diffraction
LENREF	surf #	Field Pos. #	(not used)	Physical length along the specified reference ray from surface "i-1" to surface "i"

OPLREF	surf #	Field Pos. #	(not used)	Optical path length along the specified reference ray from surface "i-1" to surface "i"
IREF	surf # (def=img)	Field Pos. #	(not used)	Cosine of the angle of incidence of the specified reference ray at surface "i"
IPREF	surf # (def=img)	Field Pos. #	(not used)	Cosine of the angle of refraction, reflection or diffraction of the specified reference ray at surface "i"
XAREF	surf # (def=img)	Field Pos. #	Ray Pos.#	XZ-plane slope angle of the specified reference ray at surface "i", measured in radians
YAREF	surf # (def=img)	Field Pos. #	(not used)	YZ-plane slope angle of the specified reference ray at surface "i", measured in radians
LNREF	surf #	Field Pos. #	(not used)	X-direction cosine of the surface normal at surface "i" where the specified reference ray intersects surface "i"
MNREF	surf #	Field Pos. #	(not used)	Y-direction cosine of the surface normal at surface "i" where the specified reference ray intersects surface "i"
NNREF	surf #	Field Pos. #	(not used)	Z-direction cosine of the surface normal at surface "i" where the specified reference ray intersects surface "i"
GLX	surf #	Field Pos. #	Ray Pos.#	Global X-coordinate of the specified ray at surface "i"
GLY	surf #	Field Pos. #	Ray Pos.#	Global Y-coordinate of the specified ray at surface "i"
GLZ	surf #	Field Pos. #	Ray Pos.#	Global Z-coordinate of the specified ray at surface "i"
GLL	surf #	Field Pos. #	Ray Pos.#	Global X-direction cosine of the specified ray traced at surface "i" after refraction, reflection or diffraction
GLM	surf #	Field Pos. #	Ray Pos.#	Global Y-direction cosine of the specified ray traced at surface "i" after refraction, reflection or diffraction
GLN	surf #	Field Pos. #	Ray Pos.#	Global Z-direction cosine of the specified ray traced at surface "i" after refraction, reflection or diffraction
GLLOLD	surf #	Field Pos. #	Ray Pos.#	Global X-direction cosine of the specified ray traced at surface "i" before refraction, reflection or diffraction
GLMOLD	surf #	Field Pos. #	Ray Pos.#	Global Y-direction cosine of the specified ray traced at surface "i" before refraction, reflection or diffraction
GLNOLD	surf #	Field Pos. #	Ray Pos.#	Global Z-direction cosine of the specified ray traced at surface "i" before refraction, reflection or diffraction
SYMX (symmetrical aberration determined from two rays in the XZ-plane of the current reference surface)	fractional ray height	Field Pos. #	Wavelength.#	For two rays traced in the XZ-plane of the current reference surface at fractional ray heights + and - "I", at field position "j" and at wavelength number "k", SYMX is the difference between the DX values of the two rays divided by 2.0 (modes FOCAL and UFOCAL) and is the difference between the DXA values of the two rays divided by 2.0 (modes AFOCAL ans UAFOCAL). The "VIG" setting affects this operand.
SYMY (symmetrical aberration determined from two rays in the YZ-plane of the current reference surface)	fractional ray height	Field Pos. #	Wavelength.#	The same as SYMX but using DY or DYA values of rays traced in the YZ-plane of the current reference surface at field position "j" and at wavelength number "k". The "VIG" setting affects this operand.

ASYMX (asymmetrical aberration determined from two rays in the XZ-plane of the current reference surface)	fractional ray height	Field Pos. #	Wavelength.#	For two rays traced in the XZ-plane of the current reference surface at fractional ray heights + and - "I", at field position "j" and at wavelength number "k", ASYMX is the sum of the DX values of the two rays divided by 2.0 (modes FOCAL and UFOCAL) and is the sum of the DXA values of the two rays divided by 2.0 (modes AFOCAL ans UAFOCAL). The "VIG" setting affects this operand.
ASYMY (symmetrical aberration determined from two rays in the YZ-plane of the current reference surface)	fractional ray height	Field Pos. #	Wavelength.#	The same as ASYMX but using DY or DYA values of rays traced in the YZ-plane of the current reference surface at field position "j" and at wavelength number "k". The "VIG" setting affects this operand.
PACM	(not used)	(not used)	(not used)	Primary Axail Color Marginal. Sums of the absolute values of real ray DX and DY (mode FOCAL or UFOCAL) or DXA and DYA (mode AFOCAL or UAFOCAL) value differences, at the current image surface, for four on-axis marginal rays, traced at the current primary wavelength pair.
PACZ	(not used)	(not used)	(not used)	Primary Axail Color Zonal. Sums of the absolute values of real ray DX and DY (mode FOCAL or UFOCAL) or DXA and DYA (mode AFOCAL or UAFOCAL) value differences, at the current image surface, for four on-axis 0.7 zonal rays, traced at the current primary wavelength pair.
SACM	(not used)	(not used)	(not used)	Secondary Axail Color Marginal. Sums of the absolute values of real ray DX and DY (mode FOCAL or UFOCAL) or DXA and DYA (mode AFOCAL or UAFOCAL) value differences, at the current image surface, for four on-axis marginal rays, traced at the current secondary wavelength pair.
SACZ	(not used)	(not used)	(not used)	Secondary Axail Color Zonal. Sums of the absolute values of real ray DX and DY (mode FOCAL or UFOCAL) or DXA and DYA (mode AFOCAL or UAFOCAL) value differences, at the current image surface, for four on-axis 0.7 zonal rays, traced at the current secondary wavelength pair.
PLCM	(not used)	(not used)	(not used)	Primary Lateral Color Marginal. Sums of the absolute values of real ray DX and DY (mode FOCAL or UFOCAL) or DXA and DYA (mode AFOCAL or UAFOCAL) value differences, at the current image surface, for four full FOV , zero relative height rays, traced at the current primary wavelength pair.
PLCZ	(not used)	(not used)	(not used)	Primary Lateral Color Zonal. Sums of the absolute values of real ray DX and DY (mode FOCAL or UFOCAL) or DXA and DYA (mode AFOCAL or UAFOCAL) value differences, at the current image surface, for four 0.7 zonal FOV, zero relative height rays, traced at the current primary wavelength pair.
SLCM	(not used)	(not used)	(not used)	Secondary Lateral Color Marginal. Sums of the absolute values of real ray DX and DY (mode FOCAL or UFOCAL) or DXA and DYA (mode AFOCAL or UAFOCAL) value differences, at the current image surface, for four full FOV , zero relative height rays, traced at the current secondary wavelength pair.

SLCZ	(not used)	(not used)	(not used)	Secondary Lateral Color Zonal. Sums of the absolute values of real ray DX and DY (mode FOCAL or UFOCAL) or DXA and DYA (mode AFOCAL or UAFOCAL) value differences, at the current image surface, for four 0.7 zonal FOV, zero relative height rays, traced at the current secondary wavelength pair.
DMINUSD	(not used)	(not used)	(not used)	Conrady Σ(D-d)Δn achromatization operand, where D are the optical path lengths along the +0.7, YZ-plane marginal ray traced from an on-axis image point at the control wavelength, d are axial separations and Δn are the refractive index variations for the primary chromatic pair of wavelegths. The summation is over all surfaces.

PREDEFINED SPOT DIAGRAM AND COMPLEX APERTURE FUNCTION (CAPFN) BASED TOL-OPS				
TOL-OP NAME	**"i" (nw#2)**	**"j" (nw#3)**	**"k" (nw#4)**	**DESCRIPTION**
CENTX	Field Pos. #	Wavelength #	(not used)	X- centroid location in the current image surface of the spot diagram centroid. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.
CENTY	Field Pos. #	Wavelength #	(not used)	Y- centroid location in the current image surface of the spot diagram centroid. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.
RMS	Field Pos. #	Wavelength #	(not used)	RMS spot diameter for the spot diagram, at the specified field position, centered about the spot centroid location. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.
RMSX	Field Pos. #	Wavelength #	(not used)	X-dimension of the RMS spot size for the spot diagram, at the specified field position,. centered about the spot centroid location. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.
RMSY	Field Pos. #	Wavelength #	(not used)	Y-dimension of the RMS spot size for the spot diagram centered about the spot centroid location. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.
RSS	Field Pos. #	Wavelength #	(not used)	RSS spot diameter for the spot diagram, at the specified field position, centered about the chief ray location. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.
RSSX	Field Pos. #	Wavelength #	(not used)	X-dimension of the RSS spot size for the spot diagram ,at the specified field position, centered about the chief ray location. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.
RSSY	Field Pos. #	Wavelength #	(not used)	Y-dimension of the RSS spot size for the spot ,at the specified field position, diagram centered about the cheif ray location. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.
RMSYX	Field Pos. #	Wavelength #	(not used)	Ratio of the Y-dimension of the RMS spot size to the X-dimension spot size for the spot ,at the specified field position, diagram centered about the cheif ray location. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.

RMSOPD	Field Pos. #	Wavelength #	(not used)	RMSOPD, in waves at the control wavelength, of the CAPFN at the specified field position. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.
GREYS	Field Pos #	OPD weight	Wavelength #	See the section above which describes Grey's optimization method. This operand uses the spot diagram ray pattern currently in effect. Ray are traced from the specified Field Pos # and Wavelength #. The "VIG" setting affects this operand.
ZERN37	Field Pos. #	Zern Coef #	Wavelength #	If a CAPFN for the specified field position does not exist, it is created using the default CAPFN ray grid. The wavefront, at wavelength "k",is fitted to a 37-term Fringe-Zernike Polynomial. The coefficient number "j" becomes the operand.
MGOTF or **GOTFM**	Field Pos. #	spatial frequency	Orientation 0=vert bars 90=horiz bars	Value of the modulus of the geometrical polychromatic optical transfer function at field position "i" and spatial frequency "j".
PGOTF or **GOTFP**	Field Pos. #	spatial frequency	Orientation 0=vert bars 90=horiz bars	Value of the phase of the geometrical polychromatic optical transfer function at field position "i" and spatial frequency "j".
MDOTF or **DOTFM**	Field Pos. #	spatial frequency	Orientation 0=vert bars 90=horiz bars	Value of the modulus of the diffraction polychromatic optical transfer function at field position "i" and spatial frequency "j".
PDOTF or **DOTFP**	Field Pos. #	spatial frequency	Orientation 0=vert bars 90=horiz bars	Value of the phase of the diffraction polychromatic optical transfer function at field position "i" and spatial frequency "j".
RED	Field Pos #	% energy	(not used)	Diameter of the circle, in the appropriate units depending upon lens mode, which encircles "j" percent of the energy in a spot for field position "i". This is based upon the geometrical spot diagram and ignores diffraction. It is centered at the chief ray of field position "i".
REDCEN	Field Pos #	% energy	(not used)	Diameter of the circle, in the appropriate units depending upon lens mode, which encircles "j" percent of the energy in a spot for field position "i". This is based upon the geometrical spot diagram and ignores diffraction. It is centered at the location of the spot centroid.

PREDEFINED PARAXIAL RAY BASED TOL-OPS				
TOL-OP NAME	**"i" (nw#2)**	**"j" (nw#3)**	**"k" (nw#4)**	**DESCRIPTION**
PWRY	surf # (def=0)	surf # (def=last)	(not used)	YZ-plane paraxial, optical power of optical system from surface "i" to surface "j". Defaults for "i" and "j" are 0 and the final surface number.
PWRX	surf # (def=0)	surf # (def=last)	(not used)	Same as above except in the XZ-plane.
FLCLTH or **FLCLTHY**	surf # (def=0)	surf # (def=last)	(not used)	YZ-plane, paraxial, effective focal length at the control wavelength of optical system from surface "i" to surface "j". Defaults for "i" and "j" are 0 and the final surface number.
FLCLTHX	surf # (def=0)	surf # (def=last)	(not used)	Same as FLCLTH except in the XZ-plane.
PY	surf # (def=last)	wavelength # (def=cw)	(not used)	YZ-plane, marginal paraxial ray eight at surface "i" and at wavelength "j"
PX	surf # (def=last)	wavelength # (def=cw)	(not used)	Same as above except in the XZ-plane.
PCY	surf # (def=last)	wavelength # (def=cw)	(not used)	YZ-plane, chief paraxial ray height at surface "i" and at wavelength "j"

PCX	surf # (def=last)	wavelength # (def=cw)	(not used)	Same as above except in the XZ-plane.
PUY	surf # (def=last)	wavelength # (def=cw)	(not used)	YZ-plane, marginal paraxial ray tangent at surface "i" and at wavelength "j" after refraction or reflection
PUX	surf # (def=last)	wavelength # (def=cw)	(not used)	Same as above except in the XZ-plane.
PUCY	surf # (def=last)	wavelength # (def=cw)	(not used)	YZ-plane, chief paraxial ray tangent at surface "i" and at wavelength "j" after refraction or reflection
PUCX	surf # (def=last)	wavelength # (def=cw)	(not used)	Same as above except in the XZ-plane.
PIY	surf # (def=last)	wavelength # (def=cw)	(not used)	YZ-plane, marginal paraxial ray incident angle tangent at surface "i" and at wavelength "j"
PIX	surf # (def=last)	wavelength # (def=cw)	(not used)	Same as above except in the XZ-plane.
PICY	surf # (def=last)	wavelength # (def=cw)	(not used)	YZ-plane, chief paraxial ray incident angle tangent at surface "i" and at wavelength "j" before refraction or reflection
PICX	surf # (def=last)	wavelength # (def=cw)	(not used)	Same as above except in the XZ-plane.
PIYP	surf # (def=last)	wavelength # (def=cw)	(not used)	YZ-plane, marginal paraxial ray angle of refraction or reflection (tangent) at surface "i" and at wavelength "j"
PIXP	surf # (def=last)	wavelength # (def=cw)	(not used)	Same as above except in the XZ-plane.
PICYP	surf # (def=last)	wavelength # (def=cw)	(not used)	YZ-plane, chief paraxial ray angle of refraction or reflection (tangent) at surface "i" and at wavelength "j"
PICXP	surf # (def=last)	wavelength # (def=cw)	(not used)	Same as above except in the XZ-plane.
IMDISX	surf #	(not used)	(not used)	XZ-plane. This is the position at which the paraxial marginal ray, in the space following surface "i", has zero height. It is represented in the coordinate system of surface "i".
IMDISY	surf #	(not used)	(not used)	Same as above except in the XZ-plane.

PREDEFINED PARAXIAL CHROMATIC TOL-OPS

NOTE: Entering the number of the last surface (the default) for "i" in the next eight aberrations results in the system aberration total for that aberration being used as the operand value.

TOL-OP NAME	**"i" (nw#2)**	**"j" (nw#3)**	**"k" (nw#4)**	**DESCRIPTION**
PACY	surf # (def=last)	(not used)	(not used)	YZ-plane, primary axial chromatic aberration at surface "i". If "i" is the final surface, system totals are calculated. This is the same data as displayed in the "FCHY" and "FCHX" commands.
PACX	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PLCY	surf # (def=last)	(not used)	(not used)	YZ-plane, primary lateral chromatic aberration at surface "i". If "i" is the final surface, system totals are calculated. This is the same data as displayed in the "FCHY" and "FCHX" commands.
PLCX	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SACY	surf # (def=last)	(not used)	(not used)	YZ-plane, secondary axial chromatic aberration at surface "i". If "i" is the final surface, system totals are calculated. This is the same data as displayed in the "FCHY" and "FCHX" commands.
SACX	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.

SLCY	surf # (def=last)	(not used)	(not used)	YZ-plane secondary lateral chromatic aberration at surface "i". If "i" is the final surface, system totals are calculated. This is the same data as displayed in the "FCHY" and "FCHX" commands.
SLCX	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.

PREDEFINED SPECIAL REAL RAY/PARAXIAL RAY BASED TOL-OPS				
TOL-OP NAME	**"i" (nw#2)**	**"j" (nw#3)**	**"k" (nw#4)**	**DESCRIPTION**
MAGX	Field Pos. #	(not used)	(not used)	XZ-plane magnification. Uses the ratio of the X-slope of differential chief ray at the current object surface to the X-slope of differential chief ray at the current image surface.
MAGY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
MAGXOR	Field Pos. #	(not used)	(not used)	XZ-plane reference magnification. Uses the ratio of X-slope of differential chief ray at object surface to the X-slope of differential chief ray at reference surface.
MAGYOR	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
FFLX	Field Pos. #	(not used)	(not used)	XZ-plane front focal length. Based upon differential ray data.
FFLY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
BFLX	Field Pos. #	(not used)	(not used)	XZ-plane back focal length. Based upon differential ray data.
BFLY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
FFNX	Field Pos. #	(not used)	(not used)	XZ-plane front F-number. Uses the reciprocal of -2 times the scaled up slope of differential marginal ray at the current object surface.
FFNY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
BFNX	Field Pos. #	(not used)	(not used)	XZ-plane back F-number. Uses the reciprocal of -2 times the scaled up slope of differential marginal ray at the current image surface.
BFNY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
EFLX	Field Pos. #	(not used)	(not used)	XZ-plane effective focal length. Based upon differential ray data.
EFLY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
ENDIAX	Field Pos. #	(not used)	(not used)	XZ-plane entrance pupil diameter. Based upon differential ray data.
ENDIAY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
EXDIAX	Field Pos. #	(not used)	(not used)	XZ-plane exit pupil diameter. Based upon differential ray data.
EXDIAY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
ENPOSX	Field Pos. #	(not used)	(not used)	X-coordinate of the center of the entrance pupil. Differential ray data is used in the calculation and the value is represented in the coordinate system of the NEWOBJ+1 surface.
ENPOSY	Field Pos. #	(not used)	(not used)	Same as above except the Y-coordinate.
ENPOSZ	Field Pos. #	(not used)	(not used)	Same as above except the Z-coordinate.
EXPOSX	Field Pos. #	(not used)	(not used)	X-coordinate of the center of the exit pupil. Differential ray data is used in the calculation and the value is represented in the coordinate system of the NEWIMG surface.

EXPOSY	Field Pos. #	(not used)	(not used)	Same as above except the Y-coordinate.
EXPOSZ	Field Pos. #	(not used)	(not used)	Same as above except the Z-coordinate.
FNUMX	Field Pos. #	(not used)	(not used)	Image space F-number. Uses extreme upper and lower real marginal rays in the XZ-plane of the reference surface for the current FOB. Takes vignetting into account automatically. If no chief ray exist, a paxaial value is used instead.
FNUMY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
OBFNUMX	Field Pos. #	(not used)	(not used)	Object space F-number. Uses extreme upper and lower real marginal rays in the XZ-plane of the reference surface for the current FOB. Takes vignetting into account automatically. If no chief ray exist, a paxaial value is used instead.
OBFNUMY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
ENPDIAX	Field Pos. #	(not used)	(not used)	Entrance pupil diameter. Uses extreme upper and lower real marginal rays in the XZ-plane of the reference surface for the current FOB. Takes vignetting into account automatically. If no chief ray exist, a paxaial value is used instead.
ENPDIAY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
EXPDIAX	Field Pos. #	(not used)	(not used)	Exit pupil diameter. Uses extreme upper and lower real marginal rays in the XZ-plane of the reference surface for the current FOB. Takes vignetting into account automatically. If no chief ray exist, a paxaial value is used instead.
EXPDIAY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
PUPDIAX	surf #	(not used)	(not used)	XZ-plane. This is 2.0 times the height of the paraxial marginal ray at the position relative to surface "i" at which the paraxial chief ray has zero height.
PUPDIAY	surf #	(not used)	(not used)	Same as above except in the YZ-plane.
PUPDISX	surf #	(not used)	(not used)	XZ-plane. This is the position at which the paraxial chief ray, in the space folloing surface "i", has zero height. It is represented in the coordinate system of surface "i".
PUPDISY	surf #	(not used)	(not used)	Same as above except in the YZ-plane.
CHFIMX	surf #	(not used)	(not used)	XZ-plane. This is the height of the paraxial chief ray at the position relative to surface "i" at which the paraxial marginal ray has zero height.
CHFIMY	surf #	(not used)	(not used)	Same as above except in the YZ-plane.
GPX	surf #	Field Pos. #	(not used)	XZ-plane generalized paraxial marginal ray height based upon differential rays about the chief ray.
GPY	surf #	Field Pos. #	(not used)	Same as above except in the YZ-plane.
GPUX	surf #	Field Pos. #	(not used)	XZ-plane generalized paraxial marginal ray slope based upon differential rays about the chief ray.
GPUY	surf #	Field Pos. #	(not used)	Same as above except in the YZ-plane.
GPCX	surf #	Field Pos. #	(not used)	XZ-plane generalized paraxial chief ray height based upon differential rays about the chief ray.
GPCY	surf #	Field Pos. #	(not used)	Same as above except in the YZ-plane.
GPUCX	surf #	Field Pos. #	(not used)	XZ-plane generalized paraxial chief ray slope based upon differential rays about the chief ray.

GPUCY	surf #	Field Pos. #	(not used)	Same as above except in the YZ-plane.
DIST	Field Pos. #	(not used)	(not used)	Uses real chief and real chief differential ray traces to calculate percent distortion at the specified field point. Calculation is performed at the wavelength specified by the field point definition and for the current lens configuration. Value is valid for tilted and decentered systems. All surface types including special surfaces are recognized. See the "DIST" command in the CMD section.
FISHDIST	Field Pos. #	(not used)	(not used)	Similar to DIST but uses ray slope angles rather than slope angle tangents. See the "FISHDIST" command in the CMD section.
XFOC	Field Pos. #	(not used)	(not used)	XFOC returns the distance from the current image surface to the focus position of close XZ-plane marginal differential rays traced about the specified field point. Calculation is performed at the wavelength specified by the field point definition and for the current lens configuration. This distance is measured along the local Z-axis of the current image surface in the coordinate system of the current image surface **This is the X-field curvature. In modes FOCAL and UFOCAL, the units are lens units. In modes AFOCAL and UAFOCAL, the units are diopters. If, in the AFOCAL or UAFOCAL mode, the field curvature is too large to represent, it will be set to 1.0D20.**
YFOC	Field Pos. #	(not used)	(not used)	**Same as above except in the YZ-plane. This is the Y-field curvature. In modes FOCAL and UFOCAL, the units are lens units. In modes AFOCAL and UAFOCAL, the units are diopters. If, in the AFOCAL or UAFOCAL mode, the field curvature is too large to represent, it will be set to 1.0D20.**
AST	Field Pos. #	(not used)	(not used)	AST returns the the astigmatism along the specified field point. It is just the YFOC value minus the XFOC value. Calculation is performed at the wavelength specified by the field point definition and for the current lens configuration. **In modes FOCAL and UFOCAL, the units are lens units. In modes AFOCAL and UAFOCAL, the units are diopters. If, in the AFOCAL or UAFOCAL mode, the astigmatism is too large to represent, it will be set to 1.0D20.**

PREDEFINED 3RD, 5TH AND 7TH ORDER ABERRATION TOL-OPS				
NOTE: Entering the number of the last surface (the default) for "i" in the 3rd, 5th and 7th order aberrations results in the system aberration total for that aberration being used as the operand value.				
TOL-OP NAME	**"i" (nw#2)**	**"j" (nw#3)**	**"k" (nw#4)**	**DESCRIPTION**
SA3	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order SPHERICAL ABERRATION at surface "i" and at the control wavelength
XSA3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
CMA3	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order COMA at surface "i" and at the control wavelength
XCMA3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
AST3	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order ASTIGMATISM at surface "i" and at the control wavelength

XAST3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
DIS3	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order DISTORTION at surface "i" and at the control wavelength
XDIS3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ3	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order PETZVAL CURVATURE at surface "i" and at the control wavelength
XPTZ3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SA5	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order SPHERICAL ABERRATION at surface "i" and at the control wavelength
XSA5	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
CMA5	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order COMA at surface "i" and at the control wavelength
XCMA5	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
AST5	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order ASTIGMATISM at surface "i" and at the control wavelength
XAST5	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
DIS5	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order DISTORTION at surface "i" and at the control wavelength
XDIS5	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ5	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order PETZVAL CURVATURE at surface "i" and at the control wavelength
XPTZ5	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
TOBSA	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL OBLIQUE SPHERICAL ABERRATION at surface "i" and at the control wavelength
XTOBSA	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SOBSA	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order SAGITTAL OBLIQUE SPHERICAL ABERRATION at surface "i" and at the control wavelength
XSOBSA	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
ELCMA	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order ELLIPTICAL COMA at surface "i" and at the control wavelength
XELCMA	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
TAS	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL ASTIGMATISM at surface "i" and at the control wavelength
XTAS	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SAS	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order SAGITTAL ASTIGMATISM at surface "i" and at the control wavelength
XSAS	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.

SA7	surf # (def=last)	(not used)	(not used)	YZ-plane, 7th order SPHERICAL ABERRATION at surface "i" and at the control wavelength
XSA7	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SA3P	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSA3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
CMA3P	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order COMA, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XCMA3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
AST3P	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order ASTIGMATISM, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XAST3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
DIS3P	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order DISTORTION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XDIS3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ3P	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order PETZVAL CURVATURE, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XPTZ3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SA5P	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSA5P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
CMA5P	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order COMA, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XCMA5P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
AST5P	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order ASTIGMATISM, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XAST5P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
DIS5P	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order DISTORTION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength

XDIS5P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ5P	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order PETZVAL CURVATURE, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XPTZ5P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
TOBSAP	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL OBLIQUE SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XTOBSAP	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SOBSAP	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order SAGITTAL OBLIQUE SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSOBSAP	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
ELCMAP	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order ELLIPTICAL COMA, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XELCMAP	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
TASP	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL ASTIGMATISM, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XTASP	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SASP	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order SAGITTAL ASTIGMATISM, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSASP	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SA7P	surf # (def=last)	(not used)	(not used)	YZ-plane, 7th order SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSA7P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SA3S	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSA3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
CMA3S	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order COMA, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength

XCMA3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
AST3S	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order ASTIGMATISM, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XAST3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
DIS3S	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order DISTORTION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XDIS3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ3S	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order PETZVAL CURVATURE, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XPTZ3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SA5S	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSA5S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
CMA5S	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order COMA, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XCMA5S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
AST5S	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order ASTIGMATISM, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XAST5S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
DIS5S	surf #	(not used)	(not used)	YZ-plane, 5th order DISTORTION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XDIS5S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ5S	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order PETZVAL CURVATURE, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XPTZ5S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
TOBSAS	surf #	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL OBLIQUE SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XTOBSAS	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.

SOBSAS	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order SAGITTAL OBLIQUE SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSOBSAS	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
ELCMAS	surf #	(not used)	(not used)	YZ-plane, 5th order ELLIPTICAL COMA, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XELCMAS	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
TASS	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL ASTIGMATISM, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XTASS	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SASS	surf #	(not used)	(not used)	YZ-plane, 5th order SAGITTAL ASTIGMATISM, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSASS	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SA7S	surf # (def=last)	(not used)	(not used)	YZ-plane, 7th order SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSA7S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SA5I	surf #	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order SPHERICAL ABERRATION at surface "i" and at the control wavelength
XSA5I	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
CMA5I	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order COMA at surface "i" and at the control wavelength
XCMA5I	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
AST5I	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order ASTIGMATISM at surface "i" and at the control wavelength
XAST5I	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
DIS5I	surf #	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order DISTORTION at surface "i" and at the control wavelength
XDIS5I	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ5I	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order PETZVAL CURVATURE at surface "i" and at the control wavelength
XPTZ5I	surf #	(not used)	(not used)	Same as above except in the XZ-plane.

TOBSAI	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order TANGENTIAL OBLIQUE SPHERICAL ABERRATION at surface "i" and at the control wavelength
XTOBSAI	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SOBSAI	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order SAGITTAL OBLIQUE SPHERICAL ABERRATION at surface "i" and at the control wavelength
XSOBSAI	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
ELCMAI	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order ELLIPTICAL COMA at surface "i" and at the control wavelength
XELCMAI	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
TASI	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order TANGENTIAL ASTIGMATISM at surface "i" and at the control wavelength
XTASI	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SASI	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order SAGITTAL ASTIGMATISM at surface "i" and at the control wavelength
XSASI	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SA7I	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 7th order SPHERICAL ABERRATION at surface "i" and at the control wavelength
XSA7I	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PSA3	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order SPHERICAL ABERRATION at surface "i" and at the control wavelength
XPSA3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PCMA3	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order COMA at surface "i" and at the control wavelength
PXCMA3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PAST3	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order ASTIGMATISM at surface "i" and at the control wavelength
XPAST3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PDIS3	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order DISTORTION at surface "i" and at the control wavelength
XPDIS3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PPTZ3	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order PETZVAL CURVATURE at surface "i" and at the control wavelength

XPPTZ3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PSA3P	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i"
XPSA3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PCMA3P	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order COMA, PRIMARY CHROMATIC DIFFERENCES at surface "i"
XPCMA3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PAST3P	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order ASTIGMATISM, PRIMARY CHROMATIC DIFFERENCES at surface "i"
XPAST3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PDIS3P	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order DISTORTION, PRIMARY CHROMATIC DIFFERENCES at surface "i"
XPDIS3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PPTZ3P	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order PETZVAL CURVATURE, PRIMARY CHROMATIC DIFFERENCES at surface "i"
XPPTZ3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PSA3S	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i"
PXSA3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PCMA3S	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order COMA, SECONDARY CHROMATIC DIFFERENCES at surface "i"
XPCMA3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PAST3S	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order ASTIGMATISM, SECONDARY CHROMATIC DIFFERENCES at surface "i"
XPAST3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PDIS3S	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order DISTORTION, SECONDARY CHROMATIC DIFFERENCES at surface "i"
XPDIS3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.

PPTZ3S	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order PETZVAL CURVATURE, SECONDARY CHROMATIC DIFFERENCES at surface "i"
XPPTZ3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PTZCV	surf # (def=last)	(not used)	(not used)	This is the YZ-plane, third order Petzval curvature. Its value is independent of lens mode.
XPTZCV	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.

PREDEFINED GAUSSIAN BEAM TOL-OPS				
TOL-OP NAME	**"i" (nw#2)**	**"j" (nw#3)**	**"k" (nw#4)**	**DESCRIPTION**
GBRADX	surf #	Field Pos. #	(not used)	The XZ-plane $1/e^2$ semi-diameter of the gaussian beam at surface "i" and at field position "j". Wavelength defined in the field position definition.
GBRADY	surf #	Field Pos. #	(not used)	This is the same as GBRADX except that it works in the YZ-plane.
GBDISX	surf #	Field Pos. #	(not used)	The distance from surface "i" to the next XZ-plane beam waist in the image space of surface "i". Wavelength defined in the field position definition.
GBDISY	surf #	Field Pos. #	(not used)	This is the same as GBDISX except that it works in the YZ-plane.
GBRCVX	surf #	Field Pos. #	(not used)	The XZ-plane wavefront radius of curvature at surface "i" in the image space of surface "i". Wavelength defined in the field position definition.
GBRCVY	surf #	Field Pos. #	(not used)	This is the same as GBRCVX except that it works in the YZ-plane.
GBWAISTX	surf #	(not used)	(not used)	The XZ-plane $1/e^2$ semi-diameter of the beam waist in the image space of surface "I". Wavelength defined in the field position definition.
GBWAISTY	surf #	(not used)	(not used)	This is the same as GBWAISTX except that it works in the YZ-plane.

PREDEFINED REAL RAY SPECTROMETER TOL-OPS **(See description following the GET list in the CMD section)**				
TOL-OP NAME	**"i" (nw#2)**	**"j" (nw#3)**	**"k" (nw#4)**	**DESCRIPTION**
CTSX or **CTSY**	wavelength #	pixel size (optional)	(not used)	Cross-track Spectral Co-registration Error at wavelength number "i".
SCEX or **SCEY**	pixel size (optional)	(not used)	(not used)	Spatial Co-registration Error for all defined wavelengths.

USER-DEFINED TOLERANCE OPERANDS - In the cases where the predefined tolerance operands discussed above are not appropriate for a particular tolerance analysis, user-defined tolerance operands are available. User-defined tolerance operands are specified as members of the tolerance operand set through the following command:

(macro function name) (tolerance operand name) , operand # , n , tval1 , tval2 , tval - "macro function name" is the **command word** of this command. "macro function name" can be "**FUNC01**" through "**FUNC10**". (See the discussion of macro functions and macros in the MACRO section). For user-defined operand entry, the macro function name is always explicitly required. "operand name" is the **qualifier word**. This is the **user-supplied** name or label for the operand. It can be any valid eight-character name as long as it is not the same as one of the predefined operand names described above. The first numeric word, "operand #", is as described for pre-defined tolerance operands. The second numeric word "n" is the number of a general purpose storage register (valid range 1 to MAXREG/MAXOPT) where the value of the tolerance operand is to be found after it is evaluated in the macro function designated by the command word. (See the discussion of the general purpose storage registers in the CMD section). "n" must always be explicitly input. "tval1" and "tval2" are optional numeric words which may be passed to the macro function. In the macro function, they are seen as numeric words #1 and #2. "tval" is a user input operand change value to be used during an inverse sensitivity analyses. It designates the amount of allowed operand change which should take place. Its default value is -99.9D99. The "tval" value is ignored during a sensitivity analysis or a Monte-Carlo analysis. If the default value of "tval" is found during an inverse sensitivity analysis, the analysis will be aborted with a warning message. The user adds a tolerance operand definition using the above command. The user then writes a macro function with the name designated by the command word. In that macro function, the value or values of tolerance operands are defined and placed in the

appropriate general purpose storage registers. The designated macro functions are executed and tolerance operand values are evaluated and stored in the designated general purpose storage registers, automatically, during the tolerancing process. Anything that can be calculated in a macro function can be used as a tolerance operand. Since macro functions are always memory resident and are precomplied, they execute very fast. This architecture is extremely flexible and powerful.

ENTERING FOCRIT OPERANDS

FOCRIT - The "FOCRIT" (FOCus CRITeria) command causes the program to leave the CMD level and enter the FOCRIT input level. The FOCRIT list is wiped clean and is ready for new fOCRIT input. Between "FOCRIT" and "EOS" or "END", any FOCRIT OPERAND input level command may be entered. It is in the FOCRIT and the UPDATE FOCRIT levels where focus criteria operands are defined and input. The program can have up to 5 focus criteria or FOCRIT operands defined for any one tolerance analysis.

EOS or **END** - The "EOS" or "END" command, issued from the FOCRIT level, causes the program to return to the CMD level. The FOCRIT operands are left in memory.

MODIFYING FOCRIT OPERANDS

UPDATE FOCRIT or U FC - The "UPDATE FOCRIT" command, or its abbreviated form "U FC", causes the program to leave the CMD level and enter the UPDATE FOCRIT OPERAND level. The FOCRIT memory area is opened and is ready for modification. Between "UPDATE FOCRIT" or "U FC" and "EOS" or "END", any UPDATE FOCRIT level command may be entered. It is in the FOCRIT and the UPDATE FOCRIT levels where FOCRIT operands are defined and input.

DEL , i - The "DEL" command, issued from the UPDATE FOCRIT level, causes the program to delete the "i" th FOCRIT operand from the FOCRIT set.

EOS or **END** - The "EOS" or "END" command, issued from the UPDATE FOCRIT level, causes the program to return to the CMD level. The FOCRIT operands are left in memory.

INTERROGATING THE FOCRIT SET - The next command is valid at the FOCRIT, the UPDATE FOCRIT and the CMD levels:

CRITS , i - The "CRITS" command displays the FOCRIT operand number, FOCRIT operand name, FOCRIT target value and the values of the optional numeric words #1, #2 and #3 which were input when each of the FOCRIT operands was defined. If "i" is explicitly input, only the FOCRIT operand data for FOCRIT number "i" will be displayed. If "i" is omitted, data for all current FOCRIT operands will be displayed.

FOCRIT OPERAND ENTRY - There are two kind of FOCRIT operands: predefined and user-defined. There are, furthermore, two kinds of predefined FOCRIT operands: "ray-based" and "non-ray-based". "Ray-based" FOCRIT operands are based upon the results of the tracing of one or more real trigonometric rays. "Non-ray-based" FOCRIT operands are everything else. First, predefined, "ray-based" FOCRIT operands are described; next, predefined, "non-ray-based" FOCRIT operands are described; and finally, user-defined FOCRIT operands are described.

PREDEFINED, RAY-BASED FOCRIT OPERANDS - Before "ray-based" FOCRIT operands can be entered, the rays upon which they are based must be defined. Ray-based FOCRIT operands can either depend upon the definition of individual fields and rays or they can depend upon the definition of grids of rays as established in and for spot diagram tolerance ray tracing.

FIELDS, RAYS AND GRIDS OF RAYS - The individual field of view positions, individual rays and the grid patterns used for spot diagram tolerance ray tracing are defined using the same field, ray and spot diagram definition commands which are described in the OPTIMIZATION section of this manual. They are not redescribed here in any detail. The names of these commands are:

For defining individual field of view positions: **F(n) , Y , X , Z , n , m**
For interrogating field of view position definitions: **FIELDS i , j**
For resetting field of view position definitions to their program default values: **FIELDS RESET**
For defining individual rays: **R(n) , Y , X , n**
For interrogating individual ray definitions: **RAYS i , j**
For resetting individual ray definitions to their program default values: **RAYS RESET**
For setting automatic vignetting for some operands. **VIG (ON or YES or OFF or NO)**
For turning the differential ray trace on or off. **OPDIF (ON or YES or OFF or NO)**
For defining the type of spot grid pattern: **OPSPOT (RECT, RING, RAND)**

The next commands have the same syntax as their counterpart commands which omitt the "OP" at the beginning of the command names and which can be found in the OPTIM section of this manual.

For defining the number of rings in a RING type spot pattern: **OPRINGS , n**
For setting a ring's characteristics: **OPRING , i , r , m , θ**
For setting the number of rays across a rectangular grid: **OPRECT , n**
For setting the number of rays in a random type spot: **OPRANNUM , n**
For resetting grid characteristics to their program defaults: **OPSPDRST**

Whenever the characteristics of a spot pattern is modified by the user, all characteristics must be reset by the user. If, for example, the user sets the number of rings to 20, then the characteristics of every ring will need to be reset by the user using the "RING" command.

For setting gaussian profile aperture apodization: **GAUSS or NOGAUSS**
For setting the grid size for complex aperture function and MTF calculations: **TOLNRD , tolnrd**

FOCRIT OPERAND DESCRIPTORS - To help keep track of FOCRIT operands, the "OP_DESC" command is provided. It takes operand designators "OP1", "OP2", "OP3", "OP4" or "OP5" as a qualifier word and takes up to a 69 character string description for each operand. These optional descriptions are displayed by the "CRITS" command and during tolerance analysis output.

OP_DESC (operand designator) (operand descrition 1 to 69 characters) - The "OP_DESC" command is used to assign user defined descriptions to each operand.

PREDEFINED FOCRIT OPERANDS - There can be up to five FOCRIT operands at one time. The focrit number (1 to 5) must be entered explicitly as numeric word #1. All predefined FOCRIT operands are entered at the MERIT and UPDATE MERIT levels with the following command:

(predefined focrit operand name) focrit # , i , j , k - The names of all predefined FOCRIT operands and the meanings of the "i", "j" and "k" values, numeric words (nw) #2, #3 and #4, are listed in the following table:

PREDEFINED LENS DATABASE FOCRIT OPERANDS				
OPERAND NAME	**"i" (nw#2)**	**"j" (nw#3)**	**"k" (nw#4)**	**DESCRIPTION**
RD	surf #	(not used)	(not used)	Radius of curvature at surface "i"
CV	surf #	(not used)	(not used)	Curvature at surface "i"
TH	surf #	(not used)	(not used)	Thickness at surface "i"
CC	surf #	(not used)	(not used)	Conic constant at surface "i"
AC	surf #	(not used)	(not used)	2nd order aspheric at surface "i"
AD	surf #	(not used)	(not used)	4th order aspheric at surface "i"
AE	surf #	(not used)	(not used)	6th order aspheric at surface "i"
AF	surf #	(not used)	(not used)	8th order aspheric at surface "i"
AG	surf #	(not used)	(not used)	10th order aspheric at surface "i"
AH	surf #	(not used)	(not used)	12th order aspheric at surface "i"
AI	surf #	(not used)	(not used)	14th order aspheric at surface "i"
AJ	surf #	(not used)	(not used)	16th order aspheric at surface "i"
AK	surf #	(not used)	(not used)	18th order aspheric at surface "i"
AL	surf #	(not used)	(not used)	20th order aspheric at surface "i"
RDTOR	surf #	(not used)	(not used)	Toric radius of curvature at surface "i"
CVTOR	surf #	(not used)	(not used)	Toric curvature at surface "i"
CCTOR	surf #	(not used)	(not used)	Toric conic constant at surface "i"
ADTOR	surf #	(not used)	(not used)	Toric 4th order aspheric at surface "i"
AETOR	surf #	(not used)	(not used)	Toric 6th order aspheric at surface "i"
AFTOR	surf #	(not used)	(not used)	Toric 8th order aspheric at surface "i"
AGTOR	surf #	(not used)	(not used)	Toric 10th order aspheric at surface "i"
ALPHA	surf #	(not used)	(not used)	ALPHA surface tilt angle (degrees) at surface "i"
BETA	surf #	(not used)	(not used)	BETA surface tilt angle (degrees) at surface "i"
GAMMA	surf #	(not used)	(not used)	GAMMA surface tilt angle (degrees) at surface "i"
VNUM	surf #	(not used)	(not used)	V-number for the "MODEL" glass at surface "i"
DPART	surf #	(not used)	(not used)	Partial dispersion shift for the "MODEL" glass at surface "i"
ABBE	surf #	(not used)	(not used)	V-number or Abbe number for the glass at surface "i" It is equal to: $VNUM = \frac{(N_{cw} - 1)}{(N_{pcw1} - N_{pcw2})}$ Where: pcw1 and pcw2 are the primary wavelength pair defined in the lens database.
PARTL	surf #	(not used)	(not used)	Partial Dispersion for the glass at surface "i". It is equal to: $PARTL = \frac{(N_{cw} - N_{pcw2})}{(N_{pcw1} - N_{pcw2})}$ Where: pcw1 and pcw2 are the primary wavelength pair defined in the lens database.
INDEX	surf #	(not used)	(not used)	Refractive index Nd for the "MODEL" glass at surface "i".
N1 to N10	surf #	(not used)	(not used)	Refractive index at wavelength #1 to #10 at surface "i".

XD	surf #	(not used)	(not used)	X-decenter at surface "i"
YD	surf #	(not used)	(not used)	Y-decenter at surface "i"
ZD	surf #	(not used)	(not used)	Z-decenter at surface "i"
XVERT	surf #	Global ref surf #	(not used)	Global X-coordinate of the vertex of surface "i", referenced to a global origin at surface "j".
YVERT	surf #	Global ref surf #	(not used)	Global Y-coordinate of the vertex of surface "i", referenced to a global origin at surface "j".
ZVERT	surf #	Global ref surf #	(not used)	Global Z-coordinate of the vertex of surface "i", referenced to a global origin at surface "j".
LXVERT	surf #	Global ref surf #	(not used)	Global X-direction cosine of the local X-axis of surface "i", referenced to a global origin at surface "j".
MXVERT	surf #	Global ref surf #	(not used)	Global Y-direction cosine of the local X-axis of surface "i", referenced to a global origin at surface "j".
NXVERT	surf #	Global ref surf #	(not used)	Global Z-direction cosine of the local X-axis of surface "i", referenced to a global origin at surface "j".
LYVERT	surf #	Global ref surf #	(not used)	Global X-direction cosine of the local Y-axis of surface "i", referenced to a global origin at surface "j".
MYVERT	surf #	Global ref surf #	(not used)	Global Y-direction cosine of the local Y-axis of surface "i", referenced to a global origin at surface "j".
NYVERT	surf #	Global ref surf #	(not used)	Global Z-direction cosine of the local Y-axis of surface "i", referenced to a global origin at surface "j".
LZVERT	surf #	Global ref surf #	(not used)	Global X-direction cosine of the local Z-axis of surface "i", referenced to a global origin at surface "j".
MZVERT	surf #	Global ref surf #	(not used)	Global Y-direction cosine of the local Z-axis of surface "i", referenced to a global origin at surface "j".
NZVERT	surf #	Global ref surf #	(not used)	Global Z-direction cosine of the local Z-axis of surface "i", referenced to a global origin at surface "j".
LENGTH or OAL	surf # (def=0)	surf # (def=last)	(not used)	Algebraic sum of axial thicknesses from surface "i" to surface "j"
MLENGTH or OPTLEN	surf # (def=0)	surf # (def=last)	(not used)	Physical length from surface "i" to surface "j" along a path connecting surface vertices and ignoring tilts and decentrations. This is the sum of the axial thicknesses multiplied by the refractive index in each space.
ET or ETY	surf #	(not used)	(not used)	Edge thickness from surface "i" to surface "i"+1. Surface tilts and decentrations are ignored. If clear apertures are assigned, they are assumed circular with the YZ-plane value being used. The larger of the values on surface "i" and "i"+1 is used. If no clear apertures are assigned, then the larger of the sums of PY+PCY on surfaces "i" and "i"+1 are used in the calculation. Clear aperture decentrations and tilts are ignored.
ETX	surf #	(not used)	(not used)	Edge thickness from surface "i" to surface "i"+1. Surface tilts and decentrations are ignored. If clear apertures are assigned, they are assumed circular with the XZ-plane value being used. The larger of the values on surface "i" and "i"+1 is used. If no clear apertures are assigned, then the larger of the sums of PX+PCX on surfaces "i" and "i"+1 are used in the calculation. Clear aperture decentrations and tilts are ignored.
C1 through C96	surf #	(not used)	(not used)	Any one of the 96 coefficients of a special surface attached to surface "i"

SHAPEFAC	surf #	(not used)	(not used)	This returns the shape factor for the lens element which begins at surface "i" and terminates at surface "i+1". The shape factor is defined by : $SHAPEFAC = \frac{r_{i+1} + r_i}{r_{i+1} - r_i}$ where: r is the radius of curvature
PIVX	surf#	(not used)	(not used)	X-surface pivot point location
PIVY	surf#	(not used)	(not used)	Y-surface pivot point location
PIVZ	surf#	(not used)	(not used)	Z-surface pivot point location
CLPX	surf #	(not used)	(not used)	X-dimension of the clear aperture height at surface "I". Zero is returned if no clear aperture is assigned.
CLPY	surf #	(not used)	(not used)	Y-dimension of the clear aperture height at surface "I". Zero is returned if no clear aperture is assigned.
GRS	surf#	(not used)	(not used)	diffraction grating spacing
WEIGHT	surf # (def=0)	surf # (def=last)	(not used)	MASS in Kgs of elements from surface "i" to surface "j". This calculation assumes spherical surfaces and ignores all decenters and tilts. It uses the specific gravity assigned to surfaces with the lens database command "SPGR".
COST	surf # (def=0)	surf # (def=last)	(not used)	Cost in cost units based upon a WEIGHT calculation multiplied by the individual surface price/Kg values stored in the lens database.

PREDEFINED REAL SINGLE RAY BASED FOCRIT OPERANDS				
OPERAND NAME	**"i" (nw#2)**	**"j" (nw#3)**	**"k" (nw#4)**	**DESCRIPTION**
X	surf # (def=img)	Field Pos. #	Ray Pos.#	X-local coordinate at surface "i" at field position number "j" and ray position number "k" of last ray traced
Y	surf # (def=img)	Field Pos. #	Ray Pos.#	Y-local coordinate at surface "i" at field position number "j" and ray position number "k" of last ray traced
Z	surf # (def=img)	Field Pos. #	Ray Pos.#	Z-local coordinate at surface "i" at field position number "j" and ray position number "k" of last ray traced
DCL or K	surf # (def=img)	Field Pos. #	Ray Pos.#	L-direction cosine at surface "i" at field position number "j" and ray position number "k" of last ray traced
DCM or L	surf # (def=img)	Field Pos. #	Ray Pos.#	Z-direction cosine at surface "i" at field position number "j" and ray position number "k" of last ray traced
DCN or M	surf # (def=img)	Field Pos. #	Ray Pos.#	Z-direction cosine at surface "i" at field position number "j" and ray position number "k" of last ray traced
DX	surf # (def=img)	Field Pos. #	Ray Pos.#	DX at surface "i" of last ray traced X-Ray Coordinate minus X-Chief ray Coordinate
DY	surf # (def=img)	Field Pos. #	Ray Pos.#	DY at surface "i" of last ray traced Y-Ray Coordinate minus Y-Chief ray Coordinate
DXA	surf # (def=img)	Field Pos. #	Ray Pos.#	DXA at surface "i" of last ray traced XANG-Ray slope minus XANG-Chief ray slope (radians)
DYA	surf # (def=img)	Field Pos. #	Ray Pos.#	DYA at surface "i" of last ray traced YANG-Ray slope minus YANG-Chief ray slope (radians)
DR	surf # (def=img)	Field Pos. #	Ray Pos.#	DR at surface "i" of last ray traced Radial-Ray Coordinate minus Radial-Chief ray Coordinate

DRA	surf # (def=img)	Field Pos. #	Ray Pos.#	DRA at surface "i" of last ray traced Radial-Ray slope minus Radial-Chief ray slope (radians)
XANG	surf # (def=img)	Field Pos. #	Ray Pos.#	XZ-plane slope angle at surface "i" of the last ray traced (radians)
YANG	surf # (def=img)	Field Pos. #	Ray Pos.#	YZ-plane slope angle at surface "i" of the last ray traced (radians)
OPL	surf #	Field Pos. #	Ray Pos.#	Optical path length along the specified ray from surface "i-1" to surface "i" (in lens units)
OPD	Field Pos #	Ray Pos. #	(not used)	Optical path difference between the specified ray and the reference ray (in lens units).
OPDW	Field Pos #	Ray Pos. #	(not used)	Optical path difference between the specified ray and the reference ray (in waves at the wavelength used to trace the reference ray).
LOLD	surf # (def=img)	Field Pos. #	Ray Pos.#	X-direction cosine at surface "i" of the specified ray (before refraction, reflection or diffraction)
MOLD	surf # (def=img)	Field Pos. #	Ray Pos.#	Y-direction cosine at surface "i" of the specified ray (before refraction, reflection or diffraction)
NOLD	surf # (def=img)	Field Pos. #	Ray Pos.#	Z-direction cosine at surface "i" of the specified ray (before refraction, reflection or diffraction)
LEN	surf #	Field Pos. #	Ray Pos.#	Physical length along the specified ray from surface "i-1" to surface "i"
AII	surf # (def=img)	Field Pos. #	Ray Pos.#	Cosine of the angle of incidence of specified ray at surface "i"
AIP	surf # (def=img)	Field Pos. #	Ray Pos.#	Cosine of the angle of refraction, reflection or diffraction of specified ray at surface "i"
LN	surf #	Field Pos. #	Ray Pos.#	Local surface coordinate system X-direction cosine of the surface normal at surface "i" where the specified ray intersects surface "i"
MN	surf #	Field Pos. #	Ray Pos.#	Local surface coordinate system Y-direction cosine of the surface normal at surface "i" where the specified ray intersects surface "i"
NN	surf #	Field Pos. #	Ray Pos.#	Local surface coordinate system Z-direction cosine of the surface normal at surface "i" where the specified ray intersects surface "i"
PXPX	surf # (def=img)	Field Pos. #	(not used)	Derivative, at surface "i", of the X-coordinate of the specified chief ray traced with respect to a change in that chief ray's X-coordinate at the current object surface.
PXPY	surf # (def=img)	Field Pos. #	(not used)	Derivative, at surface "i", of the X-coordinate of the specified chief ray traced with respect to a change in that chief ray's Y-coordinate at the current object surface.
PYPX	surf # (def=img)	Field Pos. #	(not used)	Derivative, at surface "i", of the Y-coordinate of the specified chief ray traced with respect to a change in that chief ray's X-coordinate at the current object surface.
PYPY	surf # (def=img)	Field Pos. #	(not used)	Derivative, at surface "i", of the Y-coordinate of the specified chief ray traced with respect to a change in that chief ray's Y-coordinate at the current object surface.
PXAPX	surf # (def=img)	Field Pos. #	(not used)	Derivative, at surface "i", of the XZ-plane radian measure slope angle of the specified chief ray traced with respect to a change in that chief ray's X-coordinate at the current object surface.
PXAPY	surf # (def=img)	Field Pos. #	(not used)	Derivative, at surface "i", of the XZ-plane radian measure slope angle of the specified chief ray traced with respect to a change in that chief ray's Y-coordinate at the current object surface.

PYAPX	surf # (def=img)	Field Pos. #	(not used)	Derivative, at surface "i", of the YZ-plane radian measure slope angle of the specified chief ray traced with respect to a change in that chief ray's X-coordinate at the current object surface.
PYAPY	surf # (def=img)	Field Pos. #	(not used)	Derivative, at surface "i", of the YZ-plane radian measure slope angle of the specified chief ray traced with respect to a change in that chief ray's Y-coordinate at the current object surface.
DXDX	surf # (def=img)	Field Pos. #	Ray Pos.#	Derivative, at surface "i", of the X-coordinate of the specified ray traced with respect to a change in that ray's X-coordinate at the current reference surface.
DXDY	surf # (def=img)	Field Pos. #	Ray Pos.#	Derivative, at surface "i", of the X-coordinate of the specified ray traced with respect to a change in that ray's Y-coordinate at the current reference surface.
DYDX	surf # (def=img)	Field Pos. #	Ray Pos.#	Derivative, at surface "i", of the Y-coordinate of the specified ray traced with respect to a change in that ray's X-coordinate at the current reference surface.
DYDY	surf # (def=img)	Field Pos. #	Ray Pos.#	Derivative, at surface "i", of the Y-coordinate of the specified ray traced with respect to a change in that ray's Y-coordinate at the current reference surface.
DXADX	surf # (def=img)	Field Pos. #	Ray Pos.#	Derivative, at surface "i", of the XZ-plane radian measure slope angle of the specified ray traced with respect to a change in that chief ray's X-coordinate at the current reference surface.
DXADY	surf # (def=img)	Field Pos. #	Ray Pos.#	Derivative, at surface "i", of the XZ-plane radian measure slope angle of the specified ray traced with respect to a change in that chief ray's Y-coordinate at the current reference surface.
DYADX	surf # (def=img)	Field Pos. #	Ray Pos.#	Derivative, at surface "i", of the YZ-plane radian measure slope angle of the specified ray traced with respect to a change in that chief ray's X-coordinate at the current reference surface.
DYADY	surf # (def=img)	Field Pos. #	Ray Pos.#	Derivative, at surface "i", of the YZ-plane slope angle of the specified ray traced with respect to a change in that ray's Y-coordinate at the current reference surface.
XREF	surf # (def=img)	Field Pos. #	(not used)	X-coordinate of the specified reference ray at surface "i"
YREF	surf # (def=img)	Field Pos. #	(not used)	Y-coordinate of the specified reference ray at surface "i"
ZREF	surf # (def=img)	Field Pos. #	(not used)	Z-coordinate of the specified reference ray at surface "i"
LREF	surf # (def=img)	Field Pos. #	(not used)	X-direction cosine of the specified reference ray at surface "i" after refraction, reflection or diffraction
MREF	surf # (def=img)	Field Pos. #	(not used)	Y-direction cosine of the specified reference ray at surface "i" after refraction, reflection or diffraction
NREF	surf # (def=img)	Field Pos. #	(not used)	Z-direction cosine of the specified reference ray at surface "i" after refraction, reflection or diffraction
LREFOL	surf # (def=img)	Field Pos. #	(not used)	X-direction cosine of the specified reference ray at surface "i" before refraction, reflection or diffraction
MREFOL	surf # (def=img)	Field Pos. #	(not used)	Y-direction cosine of the specified reference ray at surface "i" before refraction, reflection or diffraction

NREFOL	surf # (def=img)	Field Pos. #	(not used)	Z-direction cosine of the specified reference ray at surface "i" before refraction, reflection or diffraction
LENREF	surf #	Field Pos. #	(not used)	Physical length along the specified reference ray from surface "i-1" to surface "i"
OPLREF	surf #	Field Pos. #	(not used)	Optical path length along the specified reference ray from surface "i-1" to surface "i"
IREF	surf # (def=img)	Field Pos. #	(not used)	Cosine of the angle of incidence of the specified reference ray at surface "i"
IPREF	surf # (def=img)	Field Pos. #	(not used)	Cosine of the angle of refraction, reflection or diffraction of the specified reference ray at surface "i"
XAREF	surf # (def=img)	Field Pos. #	Ray Pos.#	XZ-plane slope angle of the specified reference ray at surface "i", measured in radians
YAREF	surf # (def=img)	Field Pos. #	(not used)	YZ-plane slope angle of the specified reference ray at surface "i", measured in radians
LNREF	surf #	Field Pos. #	(not used)	X-direction cosine of the surface normal at surface "i" where the specified reference ray intersects surface "i"
MNREF	surf #	Field Pos. #	(not used)	Y-direction cosine of the surface normal at surface "i" where the specified reference ray intersects surface "i"
NNREF	surf #	Field Pos. #	(not used)	Z-direction cosine of the surface normal at surface "i" where the specified reference ray intersects surface "i"
GLX	surf #	Field Pos. #	Ray Pos.#	Global X-coordinate of the specified ray at surface "i"
GLY	surf #	Field Pos. #	Ray Pos.#	Global Y-coordinate of the specified ray at surface "i"
GLZ	surf #	Field Pos. #	Ray Pos.#	Global Z-coordinate of the specified ray at surface "i"
GLL	surf #	Field Pos. #	Ray Pos.#	Global X-direction cosine of the specified ray traced at surface "i" after refraction, reflection or diffraction
GLM	surf #	Field Pos. #	Ray Pos.#	Global Y-direction cosine of the specified ray traced at surface "i" after refraction, reflection or diffraction
GLN	surf #	Field Pos. #	Ray Pos.#	Global Z-direction cosine of the specified ray traced at surface "i" after refraction, reflection or diffraction
SYMX (symmetrical aberration determined from two rays in the XZ-plane of the current reference surface)	fractional ray height	Field Pos. #	Wavelength.#	For two rays traced in the XZ-plane of the current reference surface at fractional ray heights + and - "I", at field position "j" and at wavelength number "k", SYMX is the difference between the DX values of the two rays divided by 2.0 (modes FOCAL and UFOCAL) and is the difference between the DXA values of the two rays divided by 2.0 (modes AFOCAL ans UAFOCAL). The "VIG" setting affects this operand.
SYMY (symmetrical aberration determined from two rays in the YZ-plane of the current reference surface)	fractional ray height	Field Pos. #	Wavelength.#	The same as SYMX but using DY or DYA values of rays traced in the YZ-plane of the current reference surface at field position "j" and at wavelength number "k". The "VIG" setting affects this operand.

ASYMX (asymmetrical aberration determined from two rays in the XZ-plane of the current reference surface)	fractional ray height	Field Pos. #	Wavelength.#	For two rays traced in the XZ-plane of the current reference surface at fractional ray heights + and - "I", at field position "j" and at wavelength number "k", ASYMX is the sum of the DX values of the two rays divided by 2.0 (modes FOCAL and UFOCAL) and is the sum of the DXA values of the two rays divided by 2.0 (modes AFOCAL ans UAFOCAL). The "VIG" setting affects this operand.
ASYMY (symmetrical aberration determined from two rays in the YZ-plane of the current reference surface)	fractional ray height	Field Pos. #	Wavelength.#	The same as ASYMX but using DY or DYA values of rays traced in the YZ-plane of the current reference surface at field position "j" and at wavelength number "k". The "VIG" setting affects this operand.
PACM	(not used)	(not used)	(not used)	Primary Axail Color Marginal. Sums of the absolute values of real ray DX and DY (mode FOCAL or UFOCAL) or DXA and DYA (mode AFOCAL or UAFOCAL) value differences, at the current image surface, for four on-axis marginal rays, traced at the current primary wavelength pair.
PACZ	(not used)	(not used)	(not used)	Primary Axail Color Zonal. Sums of the absolute values of real ray DX and DY (mode FOCAL or UFOCAL) or DXA and DYA (mode AFOCAL or UAFOCAL) value differences, at the current image surface, for four on-axis 0.7 zonal rays, traced at the current primary wavelength pair.
SACM	(not used)	(not used)	(not used)	Secondary Axail Color Marginal. Sums of the absolute values of real ray DX and DY (mode FOCAL or UFOCAL) or DXA and DYA (mode AFOCAL or UAFOCAL) value differences, at the current image surface, for four on-axis marginal rays, traced at the current secondary wavelength pair.
SACZ	(not used)	(not used)	(not used)	Secondary Axail Color Zonal. Sums of the absolute values of real ray DX and DY (mode FOCAL or UFOCAL) or DXA and DYA (mode AFOCAL or UAFOCAL) value differences, at the current image surface, for four on-axis 0.7 zonal rays, traced at the current secondary wavelength pair.
PLCM	(not used)	(not used)	(not used)	Primary Lateral Color Marginal. Sums of the absolute values of real ray DX and DY (mode FOCAL or UFOCAL) or DXA and DYA (mode AFOCAL or UAFOCAL) value differences, at the current image surface, for four full FOV , zero relative height rays, traced at the current primary wavelength pair.
PLCZ	(not used)	(not used)	(not used)	Primary Lateral Color Zonal. Sums of the absolute values of real ray DX and DY (mode FOCAL or UFOCAL) or DXA and DYA (mode AFOCAL or UAFOCAL) value differences, at the current image surface, for four 0.7 zonal FOV, zero relative height rays, traced at the current primary wavelength pair.
SLCM	(not used)	(not used)	(not used)	Secondary Lateral Color Marginal. Sums of the absolute values of real ray DX and DY (mode FOCAL or UFOCAL) or DXA and DYA (mode AFOCAL or UAFOCAL) value differences, at the current image surface, for four full FOV , zero relative height rays, traced at the current secondary wavelength pair.

SLCZ	(not used)	(not used)	(not used)	Secondary Lateral Color Zonal. Sums of the absolute values of real ray DX and DY (mode FOCAL or UFOCAL) or DXA and DYA (mode AFOCAL or UAFOCAL) value differences, at the current image surface, for four 0.7 zonal FOV, zero relative height rays, traced at the current secondary wavelength pair.
DMINUSD	(not used)	(not used)	(not used)	Conrady Σ(D-d)Δn achromatization operand, where D are the optical path lengths along the +0.7, YZ-plane marginal ray traced from an on-axis image point at the control wavelength, d are axial separations and Δn are the refractive index variations for the primary chromatic pair of wavelegths. The summation is over all surfaces.

PREDEFINED SPOT DIAGRAM AND COMPLEX APERTURE FUNCTION (CAPFN) BASED FOCRIT OPERANDS				
OPERAND NAME	**"i" (nw#2)**	**"j" (nw#3)**	**"k" (nw#4)**	**DESCRIPTION**
CENTX	Field Pos. #	Wavelength #	(not used)	X- centroid location in the current image surface of the spot diagram centroid. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.
CENTY	Field Pos. #	Wavelength #	(not used)	Y- centroid location in the current image surface of the spot diagram centroid. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.
RMS	Field Pos. #	Wavelength #	(not used)	RMS spot diameter for the spot diagram, at the specified field position, centered about the spot centroid location. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.
RMSX	Field Pos. #	Wavelength #	(not used)	X-dimension of the RMS spot size for the spot diagram, at the specified field position,. centered about the spot centroid location. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.
RMSY	Field Pos. #	Wavelength #	(not used)	Y-dimension of the RMS spot size for the spot diagram centered about the spot centroid location. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.
RSS	Field Pos. #	Wavelength #	(not used)	RSS spot diameter for the spot diagram, at the specified field position, centered about the chief ray location. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.
RSSX	Field Pos. #	Wavelength #	(not used)	X-dimension of the RSS spot size for the spot diagram ,at the specified field position, centered about the chief ray location. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.
RSSY	Field Pos. #	Wavelength #	(not used)	Y-dimension of the RSS spot size for the spot ,at the specified field position, diagram centered about the cheif ray location. If numeric word "j" is not explicitly entered, all wavelengths and spectral weights are used.
RMSOPD	Field Pos. #	Wavelength #	(not used)	RMSOPD of the CAPFN at the specified field position.
GREYS	Field Pos #	OPD weight	Wavelength #	See the section above which describes Grey's optimization method. This operand uses the spot diagram ray pattern currently in effect. Ray are traced from the specified Field Pos # and Wavelength #. The "VIG" setting affects this operand.

ZERN37	Field Pos. #	Zern Coef #	Wavelength #	If a CAPFN for the specified field position does not exist, it is created using the default CAPFN ray grid. The wavefront, at wavelength "k",is fitted to a 37-term Fringe-Zernike Polynomial. The coefficient number "j" becomes the operand.
MGOTF or **GOTFM**	Field Pos. #	spatial frequency	Orientation 0=vert bars 90=horiz bars	Value of the modulus of the geometrical polychromatic optical transfer function at field position "i" and spatial frequency "j".
PGOTF or **GOTFP**	Field Pos. #	spatial frequency	Orientation 0=vert bars 90=horiz bars	Value of the phase of the geometrical polychromatic optical transfer function at field position "i" and spatial frequency "j".
MDOTF or **DOTFM**	Field Pos. #	spatial frequency	Orientation 0=vert bars 90=horiz bars	Value of the modulus of the diffraction polychromatic optical transfer function at field position "i" and spatial frequency "j".
PDOTF or **DOTFP**	Field Pos. #	spatial frequency	Orientation 0=vert bars 90=horiz bars	Value of the phase of the diffraction polychromatic optical transfer function at field position "i" and spatial frequency "j".
RED	Field Pos #	% energy	(not used)	Diameter of the circle, in the appropriate units depending upon lens mode, which encircles "j" percent of the energy in a spot for field position "i". This is based upon the geometrical spot diagram and ignores diffraction. It is centered at the chief ray of field position "i".
REDCEN	Field Pos #	% energy	(not used)	Diameter of the circle, in the appropriate units depending upon lens mode, which encircles "j" percent of the energy in a spot for field position "i". This is based upon the geometrical spot diagram and ignores diffraction. It is centered at the location of the spot centroid.

PREDEFINED PARAXIAL RAY BASED FOCRIT OPERANDS				
OPERAND NAME	**"i" (nw#2)**	**"j" (nw#3)**	**"k" (nw#4)**	**DESCRIPTION**
PWRY	surf # (def=0)	surf # (def=last)	(not used)	YZ-plane paraxial, optical power of optical system from surface "i" to surface "j". Defaults for "i" and "j" are 0 and the final surface number.
PWRX	surf # (def=0)	surf # (def=last)	(not used)	Same as above except in the XZ-plane.
FLCLTH or **FLCLTHY**	surf # (def=0)	surf # (def=last)	(not used)	YZ-plane, paraxial, effective focal length at the control wavelength of optical system from surface "i" to surface "j". Defaults for "i" and "j" are 0 and the final surface number.
FLCLTHX	surf # (def=0)	surf # (def=last)	(not used)	Same as FLCLTH except in the XZ-plane.
PY	surf # (def=last)	wavelength # (def=cw)	(not used)	YZ-plane, marginal paraxial ray eight at surface "i" and at wavelength "j"
PX	surf # (def=last)	wavelength # (def=cw)	(not used)	Same as above except in the XZ-plane.
PCY	surf # (def=last)	wavelength # (def=cw)	(not used)	YZ-plane, chief paraxial ray height at surface "i" and at wavelength "j"
PCX	surf # (def=last)	wavelength # (def=cw)	(not used)	Same as above except in the XZ-plane.
PUY	surf # (def=last)	wavelength # (def=cw)	(not used)	YZ-plane, marginal paraxial ray tangent at surface "i" and at wavelength "j" after refraction or reflection
PUX	surf # (def=last)	wavelength # (def=cw)	(not used)	Same as above except in the XZ-plane.
PUCY	surf # (def=last)	wavelength # (def=cw)	(not used)	YZ-plane, chief paraxial ray tangent at surface "i" and at wavelength "j" after refraction or reflection
PUCX	surf # (def=last)	wavelength # (def=cw)	(not used)	Same as above except in the XZ-plane.

PIY	surf # (def=last)	wavelength # (def=cw)	(not used)	YZ-plane, marginal paraxial ray incident angle tangent at surface "i" and at wavelength "j"
PIX	surf # (def=last)	wavelength # (def=cw)	(not used)	Same as above except in the XZ-plane.
PICY	surf # (def=last)	wavelength # (def=cw)	(not used)	YZ-plane, chief paraxial ray incident angle tangent at surface "i" and at wavelength "j" before refraction or reflection
PICX	surf # (def=last)	wavelength # (def=cw)	(not used)	Same as above except in the XZ-plane.
PIYP	surf # (def=last)	wavelength # (def=cw)	(not used)	YZ-plane, marginal paraxial ray angle of refraction or reflection (tangent) at surface "i" and at wavelength "j"
PIXP	surf # (def=last)	wavelength # (def=cw)	(not used)	Same as above except in the XZ-plane.
PICYP	surf # (def=last)	wavelength # (def=cw)	(not used)	YZ-plane, chief paraxial ray angle of refraction or reflection (tangent) at surface "i" and at wavelength "j"
PICXP	surf # (def=last)	wavelength # (def=cw)	(not used)	Same as above except in the XZ-plane.
IMDISX	surf #	(not used)	(not used)	XZ-plane. This is the position at which the paraxial marginal ray, in the space following surface "i", has zero height. It is represented in the coordinate system of surface "i".
IMDISY	surf #	(not used)	(not used)	Same as above except in the XZ-plane.

PREDEFINED PARAXIAL CHROMATIC FOCRIT OPERANDS

NOTE: Entering the number of the last surface (the default) for "i" in the next eight aberrations results in the system aberration total for that aberration being used as the operand value.

OPERAND NAME	"i" (nw#2)	"j" (nw#3)	"k" (nw#4)	DESCRIPTION
PACY	surf # (def=last)	(not used)	(not used)	YZ-plane, primary axial chromatic aberration at surface "i". If "i" is the final surface, system totals are calculated. This is the same data as displayed in the "FCHY" and "FCHX" commands.
PACX	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PLCY	surf # (def=last)	(not used)	(not used)	YZ-plane, primary lateral chromatic aberration at surface "i". If "i" is the final surface, system totals are calculated. This is the same data as displayed in the "FCHY" and "FCHX" commands.
PLCX	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SACY	surf # (def=last)	(not used)	(not used)	YZ-plane, secondary axial chromatic aberration at surface "i". If "i" is the final surface, system totals are calculated. This is the same data as displayed in the "FCHY" and "FCHX" commands.
SACX	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SLCY	surf # (def=last)	(not used)	(not used)	YZ-plane secondary lateral chromatic aberration at surface "i". If "i" is the final surface, system totals are calculated. This is the same data as displayed in the "FCHY" and "FCHX" commands.
SLCX	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.

PREDEFINED SPECIAL REAL RAY/PARAXIAL RAY BASED FOCRIT OPERANDS

OPERAND NAME	"i" (nw#2)	"j" (nw#3)	"k" (nw#4)	DESCRIPTION

MAGX	Field Pos. #	(not used)	(not used)	XZ-plane magnification. Uses the ratio of the X-slope of differential chief ray at the current object surface to the X-slope of differential chief ray at the current image surface.
MAGY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
MAGXOR	Field Pos. #	(not used)	(not used)	XZ-plane reference magnification. Uses the ratio of X-slope of differential chief ray at object surface to the X-slope of differential chief ray at reference surface.
MAGYOR	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
FFLX	Field Pos. #	(not used)	(not used)	XZ-plane front focal length. Based upon differential ray data.
FFLY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
BFLX	Field Pos. #	(not used)	(not used)	XZ-plane back focal length. Based upon differential ray data.
BFLY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
FFNX	Field Pos. #	(not used)	(not used)	XZ-plane front F-number. Uses the reciprocal of -2 times the scaled up slope of differential marginal ray at the current object surface.
FFNY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
BFNX	Field Pos. #	(not used)	(not used)	XZ-plane back F-number. Uses the reciprocal of -2 times the scaled up slope of differential marginal ray at the current image surface.
BFNY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
EFLX	Field Pos. #	(not used)	(not used)	XZ-plane effective focal length. Based upon differential ray data.
EFLY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
ENDIAX	Field Pos. #	(not used)	(not used)	XZ-plane entrance pupil diameter. Based upon differential ray data.
ENDIAY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
EXDIAX	Field Pos. #	(not used)	(not used)	XZ-plane exit pupil diameter. Based upon differential ray data.
EXDIAY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
ENPOSX	Field Pos. #	(not used)	(not used)	X-coordinate of the center of the entrance pupil. Differential ray data is used in the calculation and the value is represented in the coordinate system of the NEWOBJ+1 surface.
ENPOSY	Field Pos. #	(not used)	(not used)	Same as above except the Y-coordinate.
ENPOSZ	Field Pos. #	(not used)	(not used)	Same as above except the Z-coordinate.
EXPOSX	Field Pos. #	(not used)	(not used)	X-coordinate of the center of the exit pupil. Differential ray data is used in the calculation and the value is represented in the coordinate system of the NEWIMG surface.
EXPOSY	Field Pos. #	(not used)	(not used)	Same as above except the Y-coordinate.
EXPOSZ	Field Pos. #	(not used)	(not used)	Same as above except the Z-coordinate.
FNUMX	Field Pos. #	(not used)	(not used)	Image space F-number. Uses extreme upper and lower real marginal rays in the XZ-plane of the reference surface for the current FOB. Takes vignetting into account automatically. If no chief ray exist, a paxaial value is used instead.
FNUMY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.

OBFNUMX	Field Pos. #	(not used)	(not used)	Object space F-number. Uses extreme upper and lower real marginal rays in the XZ-plane of the reference surface for the current FOB. Takes vignetting into account automatically. If no chief ray exist, a paxaial value is used instead.
OBFNUMY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
ENPDIAX	Field Pos. #	(not used)	(not used)	Entrance pupil diameter. Uses extreme upper and lower real marginal rays in the XZ-plane of the reference surface for the current FOB. Takes vignetting into account automatically. If no chief ray exist, a paxaial value is used instead.
ENPDIAY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
EXPDIAX	Field Pos. #	(not used)	(not used)	Exit pupil diameter. Uses extreme upper and lower real marginal rays in the XZ-plane of the reference surface for the current FOB. Takes vignetting into account automatically. If no chief ray exist, a paxaial value is used instead.
EXPDIAY	Field Pos. #	(not used)	(not used)	Same as above except in the YZ-plane.
PUPDIAX	surf #	(not used)	(not used)	XZ-plane. This is 2.0 times the height of the paraxial marginal ray at the position relative to surface "i" at which the paraxial chief ray has zero height.
PUPDIAY	surf #	(not used)	(not used)	Same as above except in the YZ-plane.
PUPDISX	surf #	(not used)	(not used)	XZ-plane. This is the position at which the paraxial chief ray, in the space folloing surface "i", has zero height. It is represented in the coordinate system of surface "i".
PUPDISY	surf #	(not used)	(not used)	Same as above except in the YZ-plane.
CHFIMX	surf #	(not used)	(not used)	XZ-plane. This is the height of the paraxial chief ray at the position relative to surface "i" at which the paraxial marginal ray has zero height.
CHFIMY	surf #	(not used)	(not used)	Same as above except in the YZ-plane.
GPX	surf #	Field Pos. #	(not used)	XZ-plane generalized paraxial marginal ray height based upon differential rays about the chief ray.
GPY	surf #	Field Pos. #	(not used)	Same as above except in the YZ-plane.
GPUX	surf #	Field Pos. #	(not used)	XZ-plane generalized paraxial marginal ray slope based upon differential rays about the chief ray.
GPUY	surf #	Field Pos. #	(not used)	Same as above except in the YZ-plane.
GPCX	surf #	Field Pos. #	(not used)	XZ-plane generalized paraxial chief ray height based upon differential rays about the chief ray.
GPCY	surf #	Field Pos. #	(not used)	Same as above except in the YZ-plane.
GPUCX	surf #	Field Pos. #	(not used)	XZ-plane generalized paraxial chief ray slope based upon differential rays about the chief ray.
GPUCY	surf #	Field Pos. #	(not used)	Same as above except in the YZ-plane.
DIST	Field Pos. #	(not used)	(not used)	Uses real chief and real chief differential ray traces to calculate percent distortion at the specified field point. Calculation is performed at the wavelength specified by the field point definition and for the current lens configuration. Value is valid for tilted and decentered systems. All surface types including special surfaces are recognized.See the "DIST" command in the CMD section.

FISHDIST	Field Pos. #	(not used)	(not used)	Similar to DIST but uses ray slope angles rather than slope angle tangents. See the "FISHDIST" command in the CMD section.
XFOC	Field Pos. #	(not used)	(not used)	XFOC returns the distance from the current image surface to the focus position of close XZ-plane marginal differential rays traced about the specified field point. Calculation is performed at the wavelength specified by the field point definition and for the current lens configuration. This distance is measured along the local Z-axis of the current image surface in the coordinate system of the current image surface **This is the X-field curvature. In modes FOCAL and UFOCAL, the units are lens units. In modes AFOCAL and UAFOCAL, the units are diopters. If, in the AFOCAL or UAFOCAL mode, the field curvature is too large to represent, it will be set to 1.0D20.**
YFOC	Field Pos. #	(not used)	(not used)	**Same as above except in the YZ-plane. This is the Y-field curvature. In modes FOCAL and UFOCAL, the units are lens units. In modes AFOCAL and UAFOCAL, the units are diopters. If, in the AFOCAL or UAFOCAL mode, the field curvature is too large to represent, it will be set to 1.0D20.**
AST	Field Pos. #	(not used)	(not used)	AST returns the the astigmatism along the specified field point. It is just the YFOC value minus the XFOC value. Calculation is performed at the wavelength specified by the field point definition and for the current lens configuration. **In modes FOCAL and UFOCAL, the units are lens units. In modes AFOCAL and UAFOCAL, the units are diopters. If, in the AFOCAL or UAFOCAL mode, the astigmatism is too large to represent, it will be set to 1.0D20.**
FISHDIST	Field Pos. #	(not used)	(not used)	Similar to DIST but uses ray slope angles rather than slope angle tangents. See the "FISHDIST" command in the CMD section.
XFOC	Field Pos. #	(not used)	(not used)	XFOC returns the distance from the current image surface to the focus position of close XZ-plane marginal differential rays traced about the specified field point. Calculation is performed at the wavelength specified by the field point definition and for the current lens configuration. This distance is measured along the local Z-axis of the current image surface in the coordinate system of the current image surface **This is the X-field curvature. In modes FOCAL and UFOCAL, the units are lens units. In modes AFOCAL and UAFOCAL, the units are diopters. If, in the AFOCAL or UAFOCAL mode, the field curvature is too large to represent, it will be set to 1.0D20.**
YFOC	Field Pos. #	(not used)	(not used)	**Same as above except in the YZ-plane. This is the Y-field curvature. In modes FOCAL and UFOCAL, the units are lens units. In modes AFOCAL and UAFOCAL, the units are diopters. If, in the AFOCAL or UAFOCAL mode, the field curvature is too large to represent, it will be set to 1.0D20.**

AST	Field Pos. #	(not used)	(not used)	AST returns the the astigmatism along the specified field point. It is just the YFOC value minus the XFOC value. Calculation is performed at the wavelength specified by the field point definition and for the current lens configuration. **In modes FOCAL and UFOCAL, the units are lens units. In modes AFOCAL and UAFOCAL, the units are diopters. If, in the AFOCAL or UAFOCAL mode, the astigmatism is too large to represent, it will be set to 1.0D20.**

PREDEFINED 3RD, 5TH AND 7TH ORDER ABERRATION FOCRIT OPERANDS				
NOTE: Entering the number of the last surface (the default) for "i" in the 3rd, 5th and 7th order aberrations results in the system aberration total for that aberration being used as the operand value.				
OPERAND NAME	**"i" (nw#2)**	**"j" (nw#3)**	**"k" (nw#4)**	**DESCRIPTION**
SA3	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order SPHERICAL ABERRATION at surface "i" and at the control wavelength
XSA3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
CMA3	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order COMA at surface "i" and at the control wavelength
XCMA3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
AST3	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order ASTIGMATISM at surface "i" and at the control wavelength
XAST3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
DIS3	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order DISTORTION at surface "i" and at the control wavelength
XDIS3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ3	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order PETZVAL CURVATURE at surface "i" and at the control wavelength
XPTZ3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SA5	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order SPHERICAL ABERRATION at surface "i" and at the control wavelength
XSA5	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
CMA5	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order COMA at surface "i" and at the control wavelength
XCMA5	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
AST5	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order ASTIGMATISM at surface "i" and at the control wavelength
XAST5	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
DIS5	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order DISTORTION at surface "i" and at the control wavelength
XDIS5	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ5	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order PETZVAL CURVATURE at surface "i" and at the control wavelength

XPTZ5	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
TOBSA	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL OBLIQUE SPHERICAL ABERRATION at surface "i" and at the control wavelength
XTOBSA	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SOBSA	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order SAGITTAL OBLIQUE SPHERICAL ABERRATION at surface "i" and at the control wavelength
XSOBSA	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
ELCMA	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order ELLIPTICAL COMA at surface "i" and at the control wavelength
XELCMA	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
TAS	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL ASTIGMATISM at surface "i" and at the control wavelength
XTAS	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SAS	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order SAGITTAL ASTIGMATISM at surface "i" and at the control wavelength
XSAS	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SA7	surf # (def=last)	(not used)	(not used)	YZ-plane, 7th order SPHERICAL ABERRATION at surface "i" and at the control wavelength
XSA7	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SA3P	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSA3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
CMA3P	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order COMA, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XCMA3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
AST3P	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order ASTIGMATISM, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XAST3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
DIS3P	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order DISTORTION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XDIS3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.

PTZ3P	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order PETZVAL CURVATURE, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XPTZ3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SA5P	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSA5P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
CMA5P	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order COMA, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XCMA5P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
AST5P	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order ASTIGMATISM, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XAST5P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
DIS5P	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order DISTORTION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XDIS5P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ5P	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order PETZVAL CURVATURE, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XPTZ5P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
TOBSAP	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL OBLIQUE SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XTOBSAP	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SOBSAP	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order SAGITTAL OBLIQUE SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSOBSAP	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
ELCMAP	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order ELLIPTICAL COMA, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XELCMAP	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.

TASP	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL ASTIGMATISM, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XTASP	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SASP	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order SAGITTAL ASTIGMATISM, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSASP	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SA7P	surf # (def=last)	(not used)	(not used)	YZ-plane, 7th order SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSA7P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SA3S	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSA3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
CMA3S	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order COMA, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XCMA3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
AST3S	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order ASTIGMATISM, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XAST3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
DIS3S	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order DISTORTION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XDIS3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ3S	surf # (def=last)	(not used)	(not used)	YZ-plane, 3rd order PETZVAL CURVATURE, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XPTZ3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SA5S	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSA5S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.

CMA5S	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order COMA, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XCMA5S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
AST5S	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order ASTIGMATISM, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XAST5S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
DIS5S	surf #	(not used)	(not used)	YZ-plane, 5th order DISTORTION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XDIS5S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ5S	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order PETZVAL CURVATURE, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XPTZ5S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
TOBSAS	surf #	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL OBLIQUE SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XTOBSAS	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SOBSAS	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order SAGITTAL OBLIQUE SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSOBSAS	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
ELCMAS	surf #	(not used)	(not used)	YZ-plane, 5th order ELLIPTICAL COMA, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XELCMAS	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
TASS	surf # (def=last)	(not used)	(not used)	YZ-plane, 5th order TANGENTIAL ASTIGMATISM, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XTASS	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SASS	surf #	(not used)	(not used)	YZ-plane, 5th order SAGITTAL ASTIGMATISM, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSASS	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.

SA7S	surf # (def=last)	(not used)	(not used)	YZ-plane, 7th order SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i" and at the control wavelength
XSA7S	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
SA5I	surf #	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order SPHERICAL ABERRATION at surface "i" and at the control wavelength
XSA5I	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
CMA5I	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order COMA at surface "i" and at the control wavelength
XCMA5I	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
AST5I	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order ASTIGMATISM at surface "i" and at the control wavelength
XAST5I	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
DIS5I	surf #	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order DISTORTION at surface "i" and at the control wavelength
XDIS5I	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PTZ5I	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order PETZVAL CURVATURE at surface "i" and at the control wavelength
XPTZ5I	surf #	(not used)	(not used)	Same as above except in the XZ-plane.
TOBSAI	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order TANGENTIAL OBLIQUE SPHERICAL ABERRATION at surface "i" and at the control wavelength
XTOBSAI	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SOBSAI	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order SAGITTAL OBLIQUE SPHERICAL ABERRATION at surface "i" and at the control wavelength
XSOBSAI	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
ELCMAI	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order ELLIPTICAL COMA at surface "i" and at the control wavelength
XELCMAI	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
TASI	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order TANGENTIAL ASTIGMATISM at surface "i" and at the control wavelength
XTASI	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
SASI	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 5th order SAGITTAL ASTIGMATISM at surface "i" and at the control wavelength
XSASI	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.

SA7I	surf # (def=last)	(not used)	(not used)	Intrinsic surface contribution; YZ-plane, 7th order SPHERICAL ABERRATION at surface "i" and at the control wavelength
XSA7I	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PSA3	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order SPHERICAL ABERRATION at surface "i" and at the control wavelength
XPSA3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PCMA3	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order COMA at surface "i" and at the control wavelength
PXCMA3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PAST3	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order ASTIGMATISM at surface "i" and at the control wavelength
XPAST3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PDIS3	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order DISTORTION at surface "i" and at the control wavelength
XPDIS3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PPTZ3	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order PETZVAL CURVATURE at surface "i" and at the control wavelength
XPPTZ3	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PSA3P	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order SPHERICAL ABERRATION, PRIMARY CHROMATIC DIFFERENCES at surface "i"
XPSA3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PCMA3P	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order COMA, PRIMARY CHROMATIC DIFFERENCES at surface "i"
XPCMA3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PAST3P	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order ASTIGMATISM, PRIMARY CHROMATIC DIFFERENCES at surface "i"
XPAST3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PDIS3P	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order DISTORTION, PRIMARY CHROMATIC DIFFERENCES at surface "i"
XPDIS3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.

PPTZ3P	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order PETZVAL CURVATURE, PRIMARY CHROMATIC DIFFERENCES at surface "i"
XPPTZ3P	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PSA3S	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order SPHERICAL ABERRATION, SECONDARY CHROMATIC DIFFERENCES at surface "i"
PXSA3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PCMA3S	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order COMA, SECONDARY CHROMATIC DIFFERENCES at surface "i"
XPCMA3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PAST3S	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order ASTIGMATISM, SECONDARY CHROMATIC DIFFERENCES at surface "i"
XPAST3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PDIS3S	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order DISTORTION, SECONDARY CHROMATIC DIFFERENCES at surface "i"
XPDIS3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PPTZ3S	surf # (def=last)	(not used)	(not used)	Exit pupil; YZ-plane, 3rd order PETZVAL CURVATURE, SECONDARY CHROMATIC DIFFERENCES at surface "i"
XPPTZ3S	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.
PTZCV	surf # (def=last)	(not used)	(not used)	This is the YZ-plane, third order Petzval curvature. Its value is independent of lens mode.
XPTZCV	surf # (def=last)	(not used)	(not used)	Same as above except in the XZ-plane.

PREDEFINED GAUSSIAN BEAM FOCRIT OPERANDS				
OPERAND NAME	**"i" (nw#2)**	**"j" (nw#3)**	**"k" (nw#4)**	**DESCRIPTION**
GBRADX	surf #	Field Pos. #	(not used)	The XZ-plane $1/e^2$ semi-diameter of the gaussian beam at surface "i" and at field position "j". Wavelength defined in the field position definition.
GBRADY	surf #	Field Pos. #	(not used)	This is the same as GBRADX except that it works in the YZ-plane.
GBDISX	surf #	Field Pos. #	(not used)	The distance from surface "i" to the next XZ-plane beam waist in the image space of surface "i". Wavelength defined in the field position definition.
GBDISY	surf #	Field Pos. #	(not used)	This is the same as GBDISX except that it works in the YZ-plane.

GBRCVX	surf #	Field Pos. #	(not used)	The XZ-plane wavefront radius of curvature at surface "i" in the image space of surface "i". Wavelength defined in the field position definition.
GBRCVY	surf #	Field Pos. #	(not used)	This is the same as GBRCVX except that it works in the YZ-plane.
GBWAISTX	surf #	(not used)	(not used)	The XZ-plane $1/e^2$ semi-diameter of the beam waist in the image space of surface "I". Wavelength defined in the field position definition.
GBWAISTY	surf #	(not used)	(not used)	This is the same as GBWAISTX except that it works in the YZ-plane.

PREDEFINED REAL RAY SPECTROMETER FOCRIT OPERANDS (See description following the GET list in the CMD section)				
OPERAND NAME	**"i" (nw#2)**	**"j" (nw#3)**	**"k" (nw#4)**	**DESCRIPTION**
CTSX or CTSY	wavelength #	pixel size (optional)	(not used)	Cross-track Spectral Co-registration Error at wavelength number "i".
SCEX or SCEY	pixel size (optional)	(not used)	(not used)	Spatial Co-registration Error for all defined wavelengths.

OPERAND CALCULATION SPEED - All ray based predefined operands use a field position or a field position and a ray position designator in order to specify the field or field and ray upon which a specific operand is to be based. If operands are grouped together in the MERIT FUNCTION by field and ray position designation, then the program will always know if the existing ray or spot diagram used for the previous operand may be used for the current operand. If the user does this grouping when constructing a MERIT FUNCTION, the user will minimize the amount of time consumed in ray tracing during tolerancing.

USER-DEFINED TOLERANCE OPERANDS - In the cases where the predefined FOCRIT operands discussed above are not appropriate for a particular tolerance analysis, user-defined FOCRIT operands are available. User-defined FOCRIT operands are specified as members of the FOCRIT set through the following command:

macro function name) (FOCRIT name) focrit number , n , tval1 , tval2 - "macro function name" is the **command word** of this command. "macro function name" can be "FUNC01" through "FUNC10". (See the discussion of macro functions and macros in the MACRO section). For user-defined operand entry, the macro function name is always explicitly required. "FOCRIT name" is the **qualifier word**. This is the **user-supplied** name or label for the FOCRIT operand. It can be any valid eight-character name as long as it is not the same as one of the predefined FOCRIT operand names described above. The first numberic word, "focrit number", is as described above for pre-defined FOCRIT operands. The first second word "n" is the number of a general purpose storage register (valid range 1 to MAXOPT) where the value of the FOCRIT operand is to be found after it is evaluated in the macro function designated by the command word. (See the discussion of the general purpose storage registers in the CMD section). "n" must always be explicitly input. "tval1" and "tval2" are optional numeric words which may be passed to the macro function. In the macro function, they are seen as numeric words #1 and #2. The user adds a FOCRIT operand definition using the above command. The user then writes a macro function with the name designated by the command word. In that macro function, the value or values of FOCRIT operands are defined and placed in the appropriate general purpose storage registers. The designated macro functions are executed and FOCRIT operand values are evaluated and stored in the designated general purpose storage registers, automatically, during the focus compensation process. Anything that can be calculated in a macro function can be used as a FOCRIT operand. Since macro functions are always memory resident and are precomplied, they execute very fast. This architecture is extremely flexible and powerful.

OPERAND ACTION IN TOLERANCING - During a tolerance analysis, an attempt will be made to correct FOCRIT values back to the original values which existed prior to the beginning of the tolerance analysis. The optimization process used during FOCRIT operand restoration is a variation of POWELL's method. POWELL's method is described in the OPTIMIZATION section of this manual. There is no one-to-one relationship between FOCRIT operands and their correspondingly numbered compensation variables. The optimization is a one cycle process. Only one pass of ITER POWELL is used to correct the FOCRIT operands back to their starting values using the compensator variables.

START TOLERANCING - All of the foregoing discussions dealt with setting up the tolerance analysis. The actual tolerance analysis is performed by issuing one of the following three commands:

SENSI - The "SENSI" command causes a sensitivity analysis to be performed. Changes to all tolerance operands are calculated and displayed for each tolerance variable. If FOCRITs and compensation variables have been defined, then automatic restoration will be attemped before the tolerance operands are evaluated. The output of the sensitivity anaylsis may be displayed on the screen or it may be redirected to a file using the "OUTPUT" command described in the CMD section of this manual. The sensitivity analysis is also always output to the file "SENSIOUT.DAT".

MONTE , n - The "MONTE" command causes a MONTE-CARLO tolerance analysis to be performed. "n" is the total number of MONTE-CARLO cycles to be performed. It must be explicitly input. A uniform or normal distribution random variation will be applied to each tolerance variable depending on the nature of the variable. The nominal value of the variable will be assumed to be its "mean" value. The "delta" value of each variable will be assumed to represent either the maximum variable change when a uniform distribution is used or a one-sigma variation when a normal distribution is used. The type of distribution used for each tolerance variable is listed in the table of tolerance variables at the beginning of this section. The output of the sensitivity anaylsis may be displayed on the screen or it may be redirected to a file using the "OUTPUT" command described in the CMD section of this manual. The monte-carlo analysis is also always output to the file "MONTEOUT.DAT".

INVSENSI - The "INVSENSI" command causes an inverse sensitivity analysis to be performed. First, a sensitivity analysis is performed. Then the results of this sensitivity analysis are LINEARLY scaled so that variable changes corresponding to the desired operand changes specified by the user

input "tval" values would be produced. "tval" values were input when the tolerance operands were input at the TOPER or UPDATE TOPER program levels. If FOCRITs and compensation variables were defined, the compensation variables are also assumed to be linearly scaled. If the linear scaling exceeds 10.0, a warning message is issued since the assumption of linearity beyond a scale factor of 10.0 should always be checked by the user. The output of the inverse sensitivity anaylsis may be displayed on the screen or it may be redirected to a file using the "OUTPUT" command described in the CMD section of this manual. The inverse sensitivity analysis is also always output to the file "ISENSOUT.DAT".

DUMPING TOLERANCING DATA TO A MACRO

TOLDMP (macro name) - The "TOLDMP" command causes all current tolerance and compensator variables and tolerance and focus criteria operands to be stored in the macro named by the qualifier word. These definitions will be saved in a form which will allow them to be re-established by simply typing the macro's name at the CMD level. This is an excellent way to save the final tolerance definitions when a design has been completed.