

theia

API Documentation

June 6, 2017

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1 Package theia

This is theia, a Python package for Gaussian ray tracing in 3D optical setups.

Version: 0.1.0

Author: R. Duque

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License: GNU GPLv3+

1.1 Modules

- **helpers:** This is the helpers sub-package of theia.
(Section 2, p. 6)
 - **geometry:** Geometry module for theia.
(Section 3, p. 7)
 - **interaction:** Module to define interaction functions for theia.
(Section 4, p. 10)
 - **settings:** Module to initiate all global variables for theia.
(Section 5, p. 11)
 - **tools:** Defines some generic functions for theia.
(Section 6, p. 12)
 - **units:** Various units for theia.
(Section 7, p. 15)
- **main:** Main module of theia, defines the main function.
(Section 8, p. 16)
- **optics:** This is the optics sub-package of theia.
(Section 9, p. 17)
 - **beam:** Defines the GaussianBeam class for theia.
(Section 10, p. 18)
 - **beamdump:** Defines the BeamDump class for theia.
(Section 11, p. 22)
 - **component:** Defines the SetupComponent class for theia.
(Section 12, p. 25)
 - **lens:** Defines the Lens class for theia.
(Section 13, p. 28)
 - **mirror:** Defines the Mirror class for theia.
(Section 14, p. 32)
 - **optic:** Defines the Optic class for theia.
(Section 15, p. 37)
 - **thicklens:** Defines the ThickLens class for theia.
(Section 16, p. 40)
 - **thinlens:** Defines the ThinLens class for theia.
(Section 17, p. 43)
- **rendering:** This is the rendering sub-package of theia.
(Section 18, p. 46)
- **running:** This is the running sub-package of theia.
(Section 19, p. 47)
 - **parser:** Module for the parsing on input data from m.tia file.

- (Section 20, p. 48)*
 - **simulation**: Defines the Simulation class for theia.
(Section 21, p. 50)
- **tree**: This is the tree sub-package of theia.
(Section 22, p. 53)
 - **beamtrees**: Defines the BeamTree class for theia.
(Section 23, p. 54)

2 Package **theia.helpers**

This is the helpers sub-package of theia.

It provides it provides all sorts of generic functions for theia.

Version: 0.1.0

Author: R. Duque

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2.1 Modules

- **geometry:** Geometry module for theia.
(Section 3, p. 7)
- **interaction:** Module to define interaction functions for theia.
(Section 4, p. 10)
- **settings:** Module to initiate all global variables for theia.
(Section 5, p. 11)
- **tools:** Defines some generic functions for theia.
(Section 6, p. 12)
- **units:** Various units for theia.
(Section 7, p. 15)

3 Module *theia.helpers.geometry*

Geometry module for *theia*.

3.1 Functions

refrAngle(*theta*, *n1*, *n2*)

Returns the refraction angle at *n1/n2* interface for incoming *theta*.

May raise a `TotalReflectionError`.

linePlaneInter(*pos*, *dirV*, *planeC*, *normV*, *diameter*)

Computes the intersection between a line and a plane.

pos: position of the beginning of the line. [3D vector]

dirV: directing vector of the line. [3D vector]

planeC: position of the center of the plane. [3D vector]

normV: vector normal to the plane. [3D vector]

diameter: diameter of the plane.

Returns a dictionary with keys:

 'isHit': whether or not the plane is hit. [boolean]

 'distance': geometrical distance from line origin to intersection point.
 [float]

 'intersection point': position of intersection point. [3D vector]

lineSurfInter(*pos, dirV, chordC, chordNorm, kurv, diameter*)

Computes the intersection between a line and a spherical surface.

The spherical surface is supposed to have a cylindrical symmetry around the vector normal to the 'chord', ie the plane which undertends the surface.

Note: the normal vector always looks to the center of the sphere and the surface is supposed to occupy less than a semi-sphere

pos: position of the begingin of the line. [3D vector]

dirV: direction of the line. [3D vector]

chordC: position of the center of the 'chord'. [3D vector]

chordNorm: normal vector the the chord in its center. [3D vector]

kurv: curvature (1/ROC) of the surface. [float]

diameter: diameter of the surface. [float]

Returns a dictionary with keys:

'is Hit': whether the surface is hit or not. [boolean]

'distance': distance to the intersection point from *pos*. [float]

'intersection point': position of intersection point. [3D vector]

lineCylInter(*pos, dirV, faceC, normV, thickness, diameter*)

Computes the intersection of a line and a cylinder in 3D space.

The cylinder is specified by a disk of center *faceC*, an outgoing normal *normV*, a thickness (thus behind the normal) and a diameter.

pos: origin of the line. [3D vector]

dirV: directing vector of the line. [3D vector]

faceC: center of the face of the cylinder where lies the normal vector.
[3D vector]

normV: normal vector to this face (outgoing). [3D vector]

thickness: thickness of the cylinder (counted from *faceC* and behind *normV*)
[float]

diameter: of the cylinder. [float]

Returns a dictionary with keys:

'isHit': whether of not. [boolean]

'distance': geometrical distance of the intersection point from *pos*.
[float]

'intersection point': point of intersection. [3D vector]

newDir(*inc, nor, n1, n2*)

Computes the refl and refr directions produced by inc at interface n1/n2.

inc: director vector of incoming beam. [3D vector]
 nor: normal to the interface at the intersection point. [3D vector]
 n1: refractive index of the first medium. [float]
 n2: idem.

Returns a dictionary with keys:

'r': normalized direction of reflected beam. [3D vector]
 't': normalized direction of refracted beam. [3D vector]
 'TR': was there total reflection?. [boolean]

Note: if total reflection then refr is None.

rotMatrix(*a, b*)

Provides the rotation matrix which maps a (unit) to b (unit).

a,b: unit 3D vectors. [3D np.arrays]

Returns an np.array such that np.matmul(M,a) == b.

basis(*a*)

Returns two vectors u and v such that (a, u, v) is a direct ON basis.

rectToSph(*array*)

Returns the spherical coordinates of the unitary vector given by array.

array: 3D vector (unitary). [float]

Returns the theta and phi angles in radians with theta in [0, pi] and phi in [-pi, pi]

3.2 Variables

Name	Description
<code>__package__</code>	Value: 'theia.helpers'

4 Module *theia.helpers.interaction*

Module to define interaction functions for *theia*.

4.1 Variables

Name	Description
<code>usage</code>	Value: 'Usage: <i>theia</i> [options] FNAME\n\nArguments:\n FNAME\t\t ...
<code>welcomeString</code>	Value: '\n\ttheia Copyright (C) 2017 R. Duque\n\tLicense: GNU GP...
<code>recursionErrorString</code>	Value: '\n\nIt looks like you reached the maximum recursion dept...
<code>__package__</code>	Value: None

5 Module *theia.helpers.settings*

Module to initiate all global variables for *theia*.

5.1 Functions

init (<i>dic</i>)
Initiate globals with dictionary.
dic: dictionary holding values for globals. [dictionary]

5.2 Variables

Name	Description
<code>__package__</code>	Value: None

6 Module *theia.helpers.tools*

Defines some generic functions for *theia*.

6.1 Functions

timer(*func*)

Decorator function to log execution time of other functions.

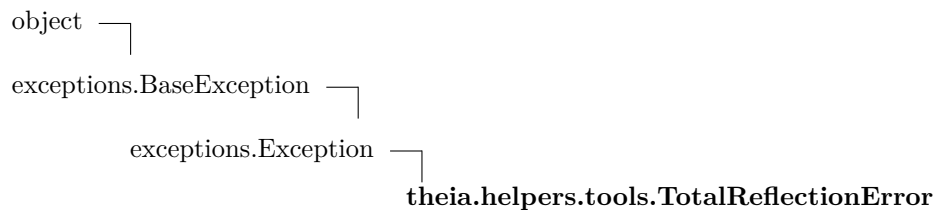
formatter(*stringList*)

Returns a formatted version of the text formed by the list of lines.

6.2 Variables

Name	Description
<code>__package__</code>	Value: <code>'theia.helpers'</code>

6.3 Class *TotalReflectionError*



TotalReflectionError class.

Is raised when an interaction results in total reflection.

== Attributes == Message: exception message. [string]

6.3.1 Methods

__init__(*self*, *message*)

TotalReflectionError exception initializer.

Overrides: *object.__init__*

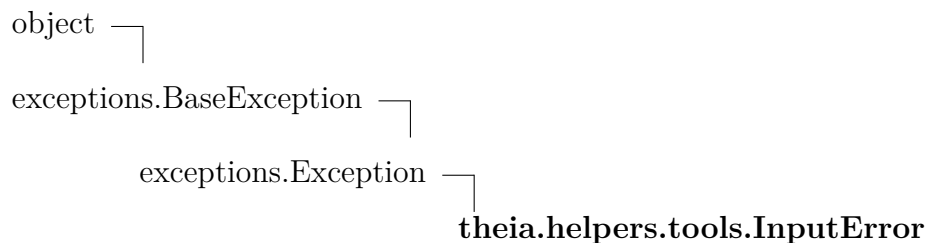
__str__(*self*)

Printing error function.

Overrides: *object.__str__*

Inherited from `exceptions.Exception``__new__()`***Inherited from `exceptions.BaseException`***`__delattr__()`, `__getattr__()`, `__getitem__()`, `__getslice__()`, `__reduce__()`, `__repr__()`, `__setattr__()`, `__setstate__()`, `__unicode__()`***Inherited from `object`***`__format__()`, `__hash__()`, `__reduce_ex__()`, `__sizeof__()`, `__subclasshook__()`**6.3.2 Properties**

Name	Description
<i>Inherited from <code>exceptions.BaseException</code></i>	
<code>args</code> , <code>message</code>	
<i>Inherited from <code>object</code></i>	
<code>__class__</code>	

6.4 Class `InputError`

`InputError` class.

Is raised when the input `.tia` file parsing to input data failed.

==* Attributes == Message: exception message. [string]

6.4.1 Methods

<code>__init__</code> (<i>self</i> , <i>message</i>)
<code>InputError</code> exception initializer.
Overrides: <code>object.__init__</code>

<code>__str__(self)</code>
Printing error function
Overrides: object. <code>__str__</code>

Inherited from `exceptions.Exception`

`__new__()`

Inherited from `exceptions.BaseException`

`__delattr__()`, `__getattr__()`, `__getitem__()`, `__getslice__()`, `__reduce__()`, `__repr__()`, `__setattr__()`, `__setstate__()`, `__unicode__()`

Inherited from `object`

`__format__()`, `__hash__()`, `__reduce_ex__()`, `__sizeof__()`, `__subclasshook__()`

6.4.2 Properties

Name	Description
<i>Inherited from <code>exceptions.BaseException</code></i>	
<code>args</code> , <code>message</code>	
<i>Inherited from <code>object</code></i>	
<code>__class__</code>	

7 Module *theia.helpers.units*

Various units for *theia*.

7.1 Variables

Name	Description
km	Value: 1000.0
m	Value: 1.0
cm	Value: 0.01
mm	Value: 0.001
um	Value: 1e-06
nm	Value: 1e-09
kW	Value: 1000.0
W	Value: 1.0
mW	Value: 0.001
uW	Value: 1e-06
nW	Value: 1e-09
THz	Value: 1e+12
GHz	Value: 1000000000.0
MHz	Value: 1000000.0
kHz	Value: 1000.0
Hz	Value: 1.0
mHz	Value: 0.001
uHz	Value: 1e-06
ppm	Value: 1e-06
rad	Value: 1.0
deg	Value: 0.0174532925199
__package__	Value: None

8 Module **theia.main**

Main module of theia, defines the main function.

8.1 Functions

main (<i>options</i> , <i>args</i>)
Main function of theia.

8.2 Variables

Name	Description
<code>__package__</code>	Value: 'theia'

9 Package *theia.optics*

This is the optics sub-package of *theia*.

It provides the necessary classes and functions in order to calculate the gaussian beams of the setup.

Version: 0.1.0

Author: R. Duque

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9.1 Modules

- **beam:** Defines the *GaussianBeam* class for *theia*.
(Section 10, p. 18)
- **beamdump:** Defines the *BeamDump* class for *theia*.
(Section 11, p. 22)
- **component:** Defines the *SetupComponent* class for *theia*.
(Section 12, p. 25)
- **lens:** Defines the *Lens* class for *theia*.
(Section 13, p. 28)
- **mirror:** Defines the *Mirror* class for *theia*.
(Section 14, p. 32)
- **optic:** Defines the *Optic* class for *theia*.
(Section 15, p. 37)
- **thicklens:** Defines the *ThickLens* class for *theia*.
(Section 16, p. 40)
- **thinlens:** Defines the *ThinLens* class for *theia*.
(Section 17, p. 43)

10 Module *theia.optics.beam*

Defines the *GaussianBeam* class for *theia*.

10.1 Variables

Name	Description
<code>__package__</code>	Value: <code>'theia.optics'</code>

10.2 Class *GaussianBeam*

object  ***theia.optics.beam.GaussianBeam***

GaussianBeam class.

This class represents general astigmatic Gaussian beams in 3D space. These are the objects that are intended to interact with the optical components during the ray tracing and that are rendered in 3D thanks to FreeCAD.

==== Attributes ====

BeamCount: class attribute, counts beams. [integer]

QTens: general astigmatic complex curvature tensor at the origin.
[np. array of complex]

N: Refraction index of the medium in which the beam is placed. [float]

Wl: Wave-length in vacuum of the beam (frequency never changes). [float]

P: Power of the beam. [float]

Pos: Position in 3D space of the origin of the beam. [3D vector]

Dir: Normalized direction in 3D space of the beam axis. [3D vector]

U: A tuple of unitary vectors which along with *Dir* form a direct orthonormal basis in which the *Q* tensor is expressed. [tuple of 3D vectors]

Name: Name of the beam if any. [string]

Ref: Reference to the beam. [string]

OptDist: Optical length. [float]

Length: Geometrical length of the beam. [float]

StrayOrder: Number representing the **strayness** of the beam. If the beams results from a transmission on a HR surface or a reflection on a AR surface, then its *StrayOrder* is the *StrayOrder* of the parent beam + 1.

[integer]

Optic: Ref of optic where the beam departs from (None if laser). [string]

Face: face of the optic where the beam departs from. [string]

10.2.1 Methods

__init__(*self*, *Q*, *N*, *Wl*, *P*, *Pos*, *Dir*, *Ux*, *Uy*, *Name*, *Ref*, *OptDist*, *Length*, *StrayOrder*, *Optic*, *Face*)

Beam initializer.

This is the initializer used internally for beam creation, for user inputed beams, see class method `userGaussianBeam`.

Returns a Gaussian beam with attributes as the parameters.

Overrides: object.__init__

userGaussianBeam(*cls*, *Wx*=0.001, *Wy*=0.001, *WDistx*=0.0, *WDisty*=0.0, *Wl*=1.064e-06, *P*=1.0, *X*=0.0, *Y*=0.0, *Z*=0.0, *Theta*=1.57079632679, *Phi*=0.0, *Alpha*=0.0, *Name*=None, *Ref*=None)

Constructor used for user inputed beams, separated from the class initializer because the internal state of a beam is very different from the input of this user-defined beam.

Input parameters are processed to make arguments for the class constructor and then the corresponding beam is returned.

__str__(*self*)

String representation of the beam, when calling `print(beam)`.

Overrides: object.__str__

lines(*self*)

Returns the list of lines necessary to print the object.

Q(*self*, *d*=0.0)

Return the Q tensor at a distance d of origin.

QParam(*self*, *d*=0.0)

Compute the complex parameters q1 and q2 and theta of beam.

Returns a dictionary with keys: '1': q1 [complex] '2': q2 [complex] 'theta': theta [float]

ROC(*self*, *dist*=0.0)

Return the tuple of ROC of the beam.

waistPos(*self*)

Return the tuple of positions of the waists of the beam along Dir.

rayleigh(*self*)

Return the tuple of Rayleigh ranges of the beam.

width(*self*, *d*=0.0)

Return the tuple of beam widths.

waistSize(*self*)

Return a tuple with the waist sizes in x and y.

gouy(*self*, *d*=0.0)

Return the tuple of Gouy phases.

Inherited from object

`__delattr__()`, `__format__()`, `__getattr__()`, `__hash__()`, `__new__()`,
`__reduce__()`, `__reduce_ex__()`, `__repr__()`, `__setattr__()`, `__sizeof__()`,
`__subclasshook__()`

10.2.2 Properties

Name	Description
<i>Inherited from object</i>	
<code>__class__</code>	

10.2.3 Class Variables

Name	Description
BeamCount	Value: 0

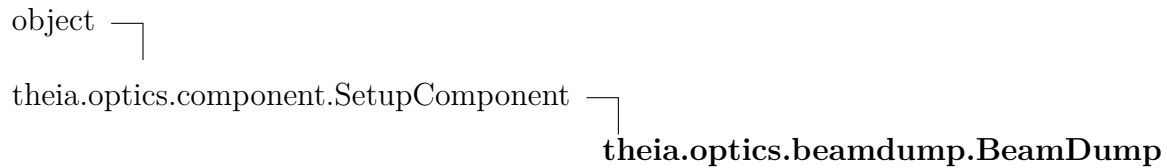
11 Module theia.optics.beamdump

Defines the BeamDump class for theia.

11.1 Variables

Name	Description
<code>__package__</code>	Value: 'theia.optics'

11.2 Class BeamDump



BeamDump class.

This class represents components on which rays stop. They have cylindrical symmetry and stop beams on all their faces. They can represent baffles for example.

```

*=== Attributes ===*
SetupCount (inherited): class attribute, counts all setup components.
    [integer]
HRCenter (inherited): center of the principal face of the BeamDump in space.
    [3D vector]
HRnorm (inherited): normal unitary vector the this principal face,
    supposed to point outside the media. [3D vector]
Thick (inherited): thickness of the dump, counted in opposite direction to
    HRNorm. [float]
Dia (inherited): diameter of the component. [float]
Name (inherited): name of the component. [string]
Ref (inherited): reference string (for keeping track with the lab). [string]
  
```

11.2.1 Methods

__init__(*self*, *X*=0.0, *Y*=0.0, *Z*=0.0, *Theta*=1.57079632679, *Phi*=0.0, *Name*='BeamDump', *Ref*=None, *Thickness*=0.02, *Diameter*=0.05)

BeamDump initializer.

Parameters are the attributes.

Returns a BeamDump.

Overrides: object.__init__

lines(*self*)

Return the list of lines needed to print the object.

Overrides: theia.optics.component.SetupComponent.lines

isHit(*self*, *beam*)

Determine if a beam hits the BeamDump.

This uses the line***Inter functions from the geometry module to find characteristics of impact of beams on beamdumps.

beam: incoming beam. [GaussianBeam]

Returns a dictionary with keys:

 'isHit': whether the beam hits the dump. [boolean]

 'intersection point': point in space where it is first hit.
 [3D vector]

 'face': to indicate which face is first hit, can be 'HR', 'AR' or
 'side'. [string]

 'distance': geometrical distance from beam origin to impact. [float]

Overrides: theia.optics.component.SetupComponent.isHit

```

hit(self, beam, order, threshold)

```

Compute the refracted and reflected beams after interaction.

BeamDumps always stop beams.

beam: incident beam. [GaussianBeam]
order: maximum strayness of daughter beams, which are not returned if
their strayness is over this order. [integer]
threshold: idem for the power of the daughter beams. [float]

Returns a dictionary of beams with keys:

```

    't': None
    'r': None

```

Inherited from theia.optics.component.SetupComponent(Section 12.2)

```

__str__()

```

Inherited from object

```

__delattr__(), __format__(), __getattr__(), __hash__(), __new__(),
__reduce__(), __reduce_ex__(), __repr__(), __setattr__(), __sizeof__(),
__subclasshook__()

```

11.2.2 Properties

Name	Description
<i>Inherited from object</i> __class__	

11.2.3 Class Variables

Name	Description
__abstractmethods__	Value: frozenset([])
<i>Inherited from theia.optics.component.SetupComponent (Section 12.2)</i> SetupCount	

12 Module *theia.optics.component*

Defines the *SetupComponent* class for *theia*.

12.1 Variables

Name	Description
<code>__package__</code>	Value: <code>'theia.optics'</code>

12.2 Class *SetupComponent*

object —
 theia.optics.component.SetupComponent

Known Subclasses: *theia.optics.beamdump.BeamDump*, *theia.optics.optic.Optic*

SetupComponent class.

This is an Abstract Base Class for all the components (optical or not) of the setup. Its methods may be implemented in daughter classes.

== Attributes ==

SetupCount: class attribute, counts setup components. [integer]

HRCenter: center of the principal face of the component in space.
 [3D vector]

HRnorm: normal unitary vector the this principal face, supposed to point
 outside the media. [3D vector]

Thick: thickness of the component, counted in opposite direction to
 HRNorm. [float]

Dia: diameter of the component. [float]

Name: name of the component. [string]

Ref: reference string (for keeping track with the lab). [string]

12.2.1 Methods

__init__ (<i>self</i> , <i>HRCenter</i> , <i>HRNorm</i> , <i>Name</i> , <i>Ref</i> , <i>Thickness</i> , <i>Diameter</i>)
SetupComponent initializer.
Parameters are the attributes of the object to construct.
Returns a setupComponent.
Overrides: object.__init__

__str__ (<i>self</i>)
String representation of the component, when calling print(object).
Overrides: object.__str__

isHit (<i>self</i> , <i>beam</i>)
Method to determine if component is hit by a beam.
Abstract (pure virtual) method.

lines (<i>self</i>)
Method to return the list of strings to __str__.
Abstract (pure virtual) method.

Inherited from object

__delattr__(), __format__(), __getattr__(), __hash__(), __new__(),
 __reduce__(), __reduce_ex__(), __repr__(), __setattr__(), __sizeof__(),
 __subclasshook__()

12.2.2 Properties

Name	Description
<i>Inherited from object</i>	
__class__	

12.2.3 Class Variables

Name	Description
SetupCount	Value: 0

continued on next page

Name	Description
<code>__abstractmethods__</code>	Value: <code>frozenset(['isHit', 'lines'])</code>

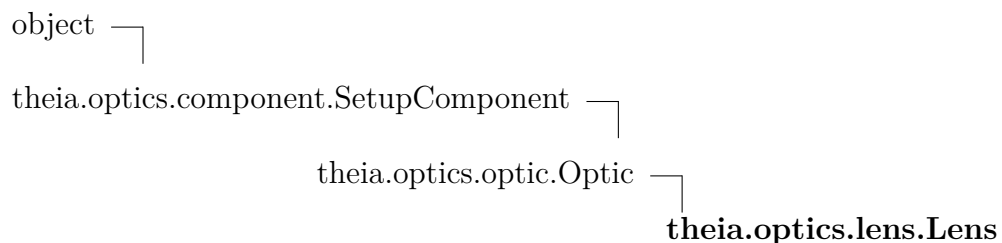
13 Module theia.optics.lens

Defines the Lens class for theia.

13.1 Variables

Name	Description
<code>__package__</code>	Value: <code>'theia.optics'</code>

13.2 Class Lens



Known Subclasses: `theia.optics.thicklens.ThickLens`, `theia.optics.thinlens.ThinLens`

Lens class.

This class is a base class for lenses. It implements the `hit` and `hitActive` methods for all lenses.

==== Attributes ====

`SetupCount` (inherited): class attribute, counts all setup components.

[integer]

`OptCount` (inherited): class attribute, counts optical components. [string]

`HRCenter` (inherited): center of the 'chord' of the HR surface. [3D vector]

`HRNorm` (inherited): unitary normal to the 'chord' of the HR (always pointing towards the outside of the component). [3D vector]

`Thick` (inherited): thickness of the optic, counted in opposite direction to `HRNorm`. [float]

`Dia` (inherited): diameter of the component. [float]

`Name` (inherited): name of the component. [string]

`Ref` (inherited): reference string (for keeping track with the lab). [string]

`ARCenter` (inherited): center of the 'chord' of the AR surface. [3D vector]

`ARNorm` (inherited): unitary normal to the 'chord' of the AR (always pointing

towards the outside of the component). [3D vector]
 N (inherited): refraction index of the material. [float]
 HRK, ARK (inherited): curvature of the HR, AR surfaces. [float]
 HRr, HRt, ARr, ARt (inherited): power reflectance and transmission coefficients of the HR and AR surfaces. [float]
 KeepI (inherited): whether or not to keep data of rays for interference calculations on the HR. [boolean]

****Note****: the curvature of any surface is positive for a concave surface (coating inside the sphere).
 Thus $\text{kurv} \cdot \text{HRNorm} / |\text{kurv}|$ always points to the center of the sphere of the surface, as is the convention for the lineSurfInter of geometry module. Same for AR.

*****	HRK > 0 and ARK > 0	*****	HRK > 0 and ARK < 0
*****		*****	and ARK > HRK
H***A		H*****A	
*****		*****	
*****		*****	

13.2.1 Methods

isHit(*self*, *beam*)

Determine if a beam hits the Lens.

This is a generic function for all lenses, using their geometrical attributes. This uses the line***Inter functions from the geometry module to find characteristics of impact of beams on lenses.

beam: incoming beam. [GaussianBeam]

Returns a dictionary with keys:

- 'isHit': whether the beam hits the optic. [boolean]
- 'intersection point': point in space where it is first hit.
[3D vector]
- 'face': to indicate which face is first hit, can be 'HR', 'AR' or 'side'. [string]
- 'distance': geometrical distance from beam origin to impact. [float]

Overrides: theia.optics.component.SetupComponent.isHit

hit(*self*, *beam*, *order*, *threshold*)

Compute the refracted and reflected beams after interaction.

This function is valid for all types of lenses.

The beams returned are those selected after the order and threshold criterion.

beam: incident beam. [GaussianBeam]

order: maximum strayness of daughter beams, which are not returned if their strayness is over this order. [integer]

threshold: idem for the power of the daughter beams. [float]

Returns a dictionary of beams with keys:

 't': refracted beam. [GaussianBeam]

 'r': reflected beam. [GaussianBeam]

hitActive(*self*, *beam*, *point*, *faceTag*, *order*, *threshold*)

Compute the daughter beams after interaction on HR or AR at point.

AR and Hr are the 'active' surfaces of the lens.

This function is valid for all types of lenses.

beam: incident beam. [GaussianBeam]

point: point in space of interaction. [3D vector]

faceTag: either 'AR' or 'HR' depending on the face. [string]

order: maximum strayness of daughter beams, which are not returned if their strayness is over this order. [integer]

threshold: idem for the power of the daughter beams. [float]

Returns a dictionary of beams with keys:

 't': refracted beam. [GaussianBeam]

 'r': reflected beam. [GaussianBeam]

Inherited from theia.optics.optic.Optic(Section 15.2)

__init__(), collision(), geoCheck(), hitSide()

Inherited from theia.optics.component.SetupComponent(Section 12.2)

__str__(), lines()

Inherited from object

__delattr__(), __format__(), __getattr__(), __hash__(), __new__(),

`__reduce__()`, `__reduce_ex__()`, `__repr__()`, `__setattr__()`, `__sizeof__()`,
`__subclasshook__()`

13.2.2 Properties

Name	Description
<i>Inherited from object</i> <code>__class__</code>	

13.2.3 Class Variables

Name	Description
<code>__abstractmethods__</code>	Value: <code>frozenset(['lines'])</code>
<i>Inherited from <code>theia.optics.optic.Optic</code> (Section 15.2)</i> <code>OptCount</code>	
<i>Inherited from <code>theia.optics.component.SetupComponent</code> (Section 12.2)</i> <code>SetupCount</code>	

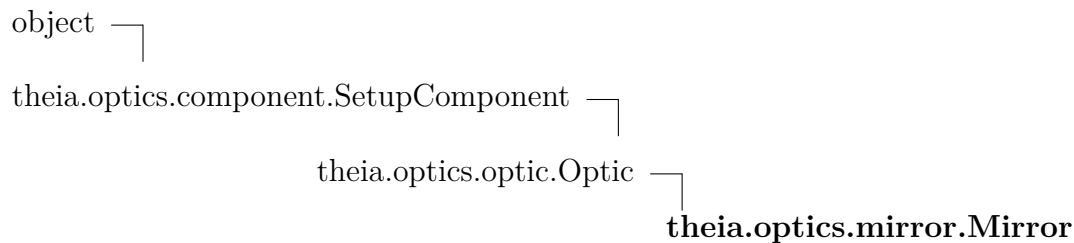
14 Module theia.optics.mirror

Defines the Mirror class for theia.

14.1 Variables

Name	Description
<code>__package__</code>	Value: 'theia.optics'

14.2 Class Mirror



Mirror class.

This class represents semi reflective mirrors composed of two faces (HR, AR) and with a wedge angle. These are the objects with which the beams will interact during the ray tracing. Please see the documentation for details on the geometric construction of these mirrors.

==== Attributes ====

SetupCount (inherited): class attribute, counts all setup components.
[integer]

OptCount (inherited): class attribute, counts optical components. [string]

HRCenter (inherited): center of the 'chord' of the HR surface. [3D vector]

HRNorm (inherited): unitary normal to the 'chord' of the HR (always pointing towards the outside of the component). [3D vector]

Thick (inherited): thickness of the optic, counted in opposite direction to HRNorm. [float]

Dia (inherited): diameter of the component. [float]

Name (inherited): name of the component. [string]

Ref (inherited): reference string (for keeping track with the lab). [string]

ARCenter (inherited): center of the 'chord' of the AR surface. [3D vector]

ARNorm (inherited): unitary normal to the 'chord' of the AR (always pointing

towards the outside of the component). [3D vector]
 N (inherited): refraction index of the material. [float]
 HRK, ARK (inherited): curvature of the HR, AR surfaces. [float]
 HRr, HRt, ARr, ARt (inherited): power reflectance and transmission coefficients of the HR and AR surfaces. [float]
 KeepI (inherited): whether or not to keep data of rays for interference calculations on the HR. [boolean]
 Wedge: wedge angle of the mirror, please refer to the documentation for detail on the geometry of mirrors and their implementation here. [float]
 Alpha: rotation angle used in the geometrical construction of the mirror (see doc, it is the angle between the projection of Ex on the AR plane and the vector from ARCenter to the point where the cylinder and the AR face meet). [float]

****Note****: the curvature of any surface is positive for a concave surface (coating inside the sphere).
 Thus $\text{kurv} \cdot \text{HRNorm} / |\text{kurv}|$ always points to the center of the sphere of the surface, as is the convention for the lineSurfInter of geometry module. Same for AR.

*****	HRK > 0 and ARK > 0	*****	HRK > 0 and ARK < 0
*****		*****	and ARK > HRK
H***A		H*****A	
*****		*****	
*****		*****	

14.2.1 Methods

```
__init__(self, Wedge=0.0, Alpha=0.0, X=0.0, Y=0.0, Z=0.0,
          Theta=1.57079632679, Phi=0.0, Diameter=0.1, HRr=0.99, HRt=0.01,
          ARr=0.1, ARt=0.9, HRK=0.01, ARK=0, Thickness=0.02, N=1.4585,
          KeepI=False, Name='Mirror', Ref=None)
```

Mirror initializer.

Parameters are the attributes and the angles theta and phi are spherical coordinates of HRNorm.

Returns a mirror.

Overrides: object.__init__

lines(*self*)

Returns the list of lines necessary to print the object.

Overrides: theia.optics.component.SetupComponent.lines

isHit(*self*, *beam*)

Determine if a beam hits the Optic.

This is a function for mirrors, using their geometrical attributes. This uses the `line**Inter` functions from the `geometry` module to find characteristics of impact of beams on mirrors.

beam: incoming beam. [GaussianBeam]

Returns a dictionary with keys:

 'isHit': whether the beam hits the optic. [boolean]

 'intersection point': point in space where it is first hit.
 [3D vector]

 'face': to indicate which face is first hit, can be 'HR', 'AR' or
 'side'. [string]

 'distance': geometrical distance from beam origin to impact. [float]

Overrides: theia.optics.component.SetupComponent.isHit

hit(*self*, *beam*, *order*, *threshold*)

Compute the refracted and reflected beams after interaction.

The beams returned are those selected after the order and threshold criterion.

beam: incident beam. [GaussianBeam]

order: maximum strayness of daughter beams, which are not returned if
 their strayness is over this order. [integer]

threshold: idem for the power of the daughter beams. [float]

Returns a dictionary of beams with keys:

 't': refracted beam. [GaussianBeam]

 'r': reflected beam. [GaussianBeam]

```
hitHR(self, beam, point, order, threshold)
```

Compute the daughter beams after interaction on HR at point.

```
beam: incident beam. [GaussianBeam]
point: point in space of interaction. [3D vector]
order: maximum strayness of daughter beams, which are not returned if
      their strayness is over this order. [integer]
threshold: idem for the power of the daughter beams. [float]
```

Returns a dictionary of beams with keys:

```
  't': refracted beam. [GaussianBeam]
  'r': reflected beam. [GaussianBeam]
```

```
hitAR(self, beam, point, order, threshold)
```

Compute the daughter beams after interaction on AR at point.

```
beam: incident beam. [GaussianBeam]
point: point in space of interaction. [3D vector]
order: maximum strayness of daughter beams, which are not returned if
      their strayness is over this order. [integer]
threshold: idem for the power of the daughter beams. [float]
```

Returns a dictionary of beams with keys:

```
  't': refracted beam. [GaussianBeam]
  'r': reflected beam. [GaussianBeam]
```

Inherited from *theia.optics.optic.Optic*(Section 15.2)

```
collision(), geoCheck(), hitSide()
```

Inherited from *theia.optics.component.SetupComponent*(Section 12.2)

```
__str__()
```

Inherited from object

```
__delattr__(), __format__(), __getattr__(), __hash__(), __new__(),
__reduce__(), __reduce_ex__(), __repr__(), __setattr__(), __sizeof__(),
__subclasshook__()
```

14.2.2 Properties

Name	Description
<i>Inherited from object</i> __class__	

14.2.3 Class Variables

Name	Description
__abstractmethods__	Value: frozenset([])
<i>Inherited from theia.optics.optic.Optic (Section 15.2)</i> OptCount	
<i>Inherited from theia.optics.component.SetupComponent (Section 12.2)</i> SetupCount	

15 Module *theia.optics.optic*

Defines the *Optic* class for *theia*.

15.1 Variables

Name	Description
<code>__package__</code>	Value: <code>'theia.optics'</code>

15.2 Class *Optic*



Known Subclasses: *theia.optics.lens.Lens*, *theia.optics.mirror.Mirror*

Optic class.

This class is a base class for optics which may interact with Gaussian beams and return transmitted and reflected beams (mirrors, lenses, etc.)

```

*=== Attributes ===
SetupCount (inherited): class attribute, counts all setup components.
    [integer]
OptCount: class attribute, counts optical components. [string]
HRCenter (inherited): center of the 'chord' of the HR surface. [3D vector]
HRNorm (inherited): unitary normal to the 'chord' of the HR (always pointing
    towards the outside of the component). [3D vector]
Thick (inherited): thickness of the optic, counted in opposite direction to
    HRNorm. [float]
Dia (inherited): diameter of the component. [float]
Name (inherited): name of the component. [string]
Ref (inherited): reference string (for keeping track with the lab). [string]
ARCenter: center of the 'chord' of the AR surface. [3D vector]
ARNorm: unitary normal to the 'chord' of the AR (always pointing
    towards the outside of the component). [3D vector]
  
```

N: refraction index of the material. [float]
 HRK, ARK: curvature of the HR, AR surfaces. [float]
 HRr, HRt, ARr, ARt: power reflectance and transmission coefficients of the HR and AR surfaces. [float]
 KeepI: whether of not to keep data of rays for interference calculations on the HR. [boolean]

****Note****: the curvature of any surface is positive for a concave surface (coating inside the sphere).
 Thus $\text{kurv} \cdot \text{HRNorm} / |\text{kurv}|$ always points to the center of the sphere of the surface, as is the convention for the `lineSurfInter` of geometry module. Same for AR.

*****	HRK > 0 and ARK > 0	*****	HRK > 0 and ARK < 0
*****		*****	and ARK > HRK
H***A		H*****A	
*****		*****	
*****		*****	

15.2.1 Methods

__init__(*self*, *ARCenter*, *ARNorm*, *N*, *HRK*, *ARK*, *ARr*, *ARt*, *HRr*, *HRt*, *KeepI*, *HRCenter*, *HRNorm*, *Thickness*, *Diameter*, *Name*, *Ref*)

Optic base initializer.

Parameters are the attributes of the object to construct.

Returns an Optic.

Overrides: object.__init__

collision(*self*)

Determine whether the HR and AR surfaces intersect.

Returns True if there is an intersection, False if not.

geoCheck(*self*, *word*)

Makes geometrical checks on surfaces and warns when necessary.

hitSide(*self*, *beam*)

Compute the daughter beams after interaction on Side at point.

Generic function: all sides stop beams.

beam: incident beam. [GaussianBeam]

Returns {'t': None, 'r': None}

Inherited from theia.optics.component.SetupComponent (Section 12.2)

__str__(), isHit(), lines()

Inherited from object

__delattr__(), __format__(), __getattr__(), __hash__(), __new__(),
__reduce__(), __reduce_ex__(), __repr__(), __setattr__(), __sizeof__(),
__subclasshook__()

15.2.2 Properties

Name	Description
<i>Inherited from object</i> __class__	

15.2.3 Class Variables

Name	Description
OptCount	Value: 0
<i>Inherited from theia.optics.component.SetupComponent (Section 12.2)</i> SetupCount, __abstractmethods__	

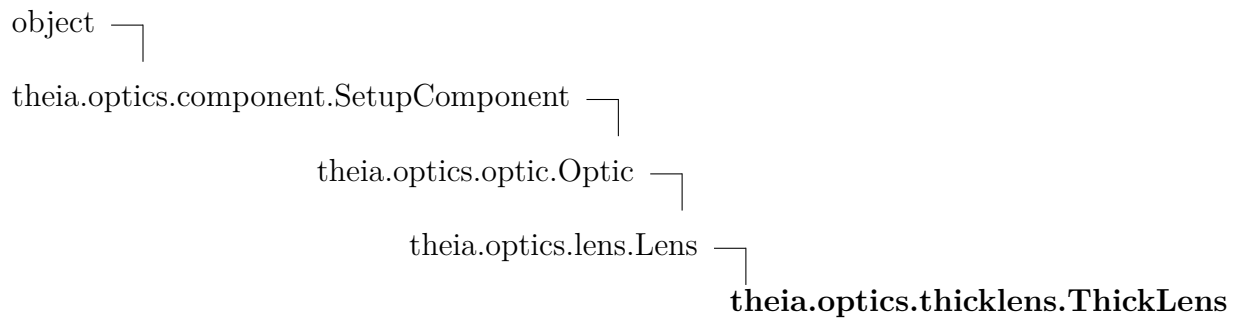
16 Module theia.optics.thicklens

Defines the ThickLens class for theia.

16.1 Variables

Name	Description
<code>__package__</code>	Value: <code>'theia.optics'</code>

16.2 Class ThickLens



ThickLens class.

This class represents thick lenses, specified by curvatures and thickness instead of focal length.

==== Attributes ====

SetupCount (inherited): class attribute, counts all setup components.
[integer]

OptCount (inherited): class attribute, counts optical components. [string]

HRCenter (inherited): center of the 'chord' of the HR surface. [3D vector]

HRNorm (inherited): unitary normal to the 'chord' of the HR (always pointing towards the outside of the component). [3D vector]

Thick (inherited): thickness of the optic, counted in opposite direction to HRNorm. [float]

Dia (inherited): diameter of the component. [float]

Name (inherited): name of the component. [string]

Ref (inherited): reference string (for keeping track with the lab). [string]

ARCenter (inherited): center of the 'chord' of the AR surface. [3D vector]

ARNorm (inherited): unitary normal to the 'chord' of the AR (always pointing

towards the outside of the component). [3D vector]
 N (inherited): refraction index of the material. [float]
 HRK, ARK (inherited): curvature of the HR, AR surfaces. [float]
 HRr, HRt, ARr, ARt (inherited): power reflectance and transmission
 coefficients of the HR and AR surfaces. [float]
 KeepI (inherited): whether of not to keep data of rays for interference
 calculations on the HR. [boolean]

****Note****: the curvature of any surface is positive for a concave surface
 (coating inside the sphere).
 Thus $\text{kurv} \cdot \text{HRNorm} / |\text{kurv}|$ always points to the center
 of the sphere of the surface, as is the convention for the lineSurfInter of
 geometry module. Same for AR.

*****	HRK > 0 and ARK > 0	*****	HRK > 0 and ARK < 0
*****		*****	and ARK > HRK
H***A		H*****A	
*****		*****	
*****		*****	

****Note****: in the case of thicklenses, the thickness provided to and by the
 initializer is the thickness *on the optical axis*, and not the thickness
 on the side of the component (like mirrors).

****Note****: in the case of thicklenses, the center provided to the initializer
 is the *apex* of the principal face, and not the chord of the HR surface.

16.2.1 Methods

```
__init__(self, K1=0.01, K2=0.01, X=0.0, Y=0.0, Z=0.0,
Theta=1.57079632679, Phi=0.0, Thickness=0.02, N=1.4585,
KeepI=False, Diameter=0.05, R=0.1, T=0.9, Name='Thicklens',
Ref=None)
```

Thicklens initializer.

Parameters are the attributes.

Returns a Thicklens.

Overrides: object.__init__

lines (<i>self</i>)

Returns the list of lines necessary to print the object.
--

Overrides: theia.optics.component.SetupComponent.lines
--

Inherited from theia.optics.lens.Lens(Section 13.2)

hit(), hitActive(), isHit()

Inherited from theia.optics.optic.Optic(Section 15.2)

collision(), geoCheck(), hitSide()

Inherited from theia.optics.component.SetupComponent(Section 12.2)

__str__()

Inherited from object

__delattr__(), __format__(), __getattr__(), __hash__(), __new__(),
 __reduce__(), __reduce_ex__(), __repr__(), __setattr__(), __sizeof__(),
 __subclasshook__()

16.2.2 Properties

Name	Description
<i>Inherited from object</i> __class__	

16.2.3 Class Variables

Name	Description
__abstractmethods__	Value: frozenset([])
<i>Inherited from theia.optics.optic.Optic (Section 15.2)</i> OptCount	
<i>Inherited from theia.optics.component.SetupComponent (Section 12.2)</i> SetupCount	

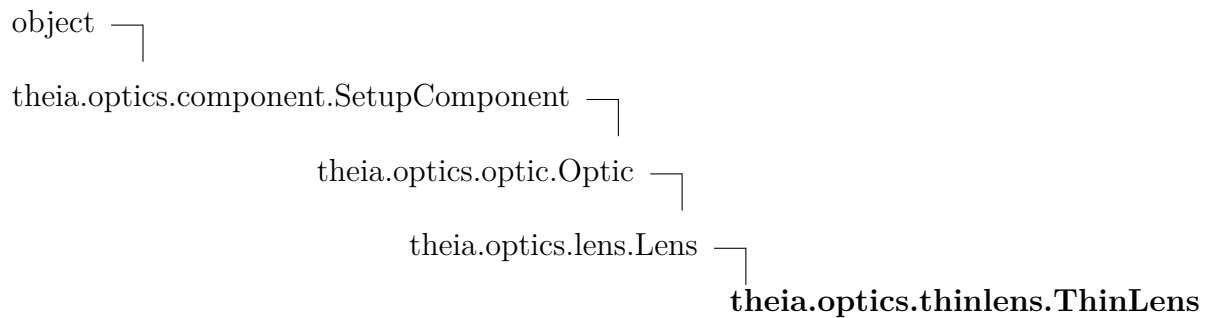
17 Module *theia.optics.thinlens*

Defines the *ThinLens* class for *theia*.

17.1 Variables

Name	Description
<code>__package__</code>	Value: <code>'theia.optics'</code>

17.2 Class *ThinLens*



ThinLens class.

This class represents thin lenses, which are specified only by their focal lengths, diameter, position and orientation. Only the initializer and the printing distinguishes thin lenses (in implementation) from other lenses.

==== Attributes =====

SetupCount (inherited): class attribute, counts all setup components.

[integer]

OptCount (inherited): class attribute, counts optical components. [string]

HRCenter (inherited): center of the 'chord' of the HR surface. [3D vector]

HRNorm (inherited): unitary normal to the 'chord' of the HR (always pointing towards the outside of the component). [3D vector]

Thick (inherited): thickness of the optic, counted in opposite direction to *HRNorm*. [float]

Dia (inherited): diameter of the component. [float]

Name (inherited): name of the component. [string]

Ref (inherited): reference string (for keeping track with the lab). [string]

ARCenter (inherited): center of the 'chord' of the AR surface. [3D vector]

ARNorm (inherited): unitary normal to the 'chord' of the AR (always pointing towards the outside of the component). [3D vector]
 N (inherited): refraction index of the material. [float]
 HRK, ARK (inherited): curvature of the HR, AR surfaces. [float]
 HRr, HRt, ARr, ARt (inherited): power reflectance and transmission coefficients of the HR and AR surfaces. [float]
 KeepI (inherited): whether of not to keep data of rays for interference calculations on the HR. [boolean]
 Focal: Focal length of the lens. [float]

****Note****: the curvature of any surface is positive for a concave surface (coating inside the sphere).
 Thus $\text{kurv} \cdot \text{HRNorm} / |\text{kurv}|$ always points to the center of the sphere of the surface, as is the convention for the lineSurfInter of geometry module. Same for AR.

*****	HRK > 0 and ARK > 0	*****	HRK > 0 and ARK < 0
*****		*****	and ARK > HRK
H***A		H*****A	
*****		*****	
*****		*****	

17.2.1 Methods

__init__ (self, Focal=0.1, KeepI=False, Theta=1.57079632679, Phi=0.0, Diameter=0.05, R=0.1, T=0.9, X=0.0, Y=0.0, Z=0.0, Name='ThinLens', Ref=None)

ThinLens initializer.

Parameters are the attributes.

Returns a ThinLens.

Overrides: object.__init__

lines (self)

Returns the list of lines necessary to print the object.

Overrides: theia.optics.component.SetupComponent.lines

Inherited from theia.optics.lens.Lens(Section 13.2)

hit(), hitActive(), isHit()

Inherited from theia.optics.optic.Optic(Section 15.2)

collision(), geoCheck(), hitSide()

Inherited from theia.optics.component.SetupComponent(Section 12.2)

__str__()

Inherited from object

__delattr__(), __format__(), __getattr__(), __hash__(), __new__(),
 __reduce__(), __reduce_ex__(), __repr__(), __setattr__(), __sizeof__(),
 __subclasshook__()

17.2.2 Properties

Name	Description
<i>Inherited from object</i>	
__class__	

17.2.3 Class Variables

Name	Description
__abstractmethods__	Value: frozenset([])
<i>Inherited from theia.optics.optic.Optic (Section 15.2)</i>	
OptCount	
<i>Inherited from theia.optics.component.SetupComponent (Section 12.2)</i>	
SetupCount	

18 Package theia.rendering

This is the rendering sub-package of theia.

It allows to write the physical objects to FreeCAD format files for 3D rendering.

Version: 0.1.0

Author: R. Duque

Copyright: Copyright 2017, R. Duque

License: GNU GPLv3+

19 Package **theia.running**

This is the running sub-package of *theia*.

It provides the necessary classes and functions to allow the input, output and encapsulation of simulation data.

Version: 0.1.0

Author: R. Duque

Copyright: Copyright 2017, R. Duque

License: GNU GPLv3+

19.1 Modules

- **parser:** Module for the parsing on input data from *m.tia* file.
(Section 20, p. 48)
- **simulation:** Defines the *Simulation* class for *theia*.
(Section 21, p. 50)

20 Module *theia.running.parser*

Module for the parsing on input data fro m.tia file.

20.1 Functions

dicOf(*st*, *line*, *fileName*, *lineNumber*)

Extract the initializer dictionary from a line.

st: object tag, 'bm', 'th', ... [string] *line*: line of data in .tia format (supposed no spaces nor tabs nor comments) and without the object tag. [string]
fileName: name of file (used to write errors). [string] *lineNumber*: number fo this line in the file (used to write errors). [int] Returns a dictionary ready for construction.

readIn(*name*)

Finds the input data in a file.

Returns a list of tuples where tuple[0] identifies the object of which data has been found and tuple[1] the data itself. tuple[1] may be a simple value or a dictionary for constructors, etc.

Example return value: [('bd', {'X': 0., 'Y': 0., 'Z': 1.}), #constructor
('LName', 'foo')] #string data.

name: file to read. [string]

May raise an `InputError`.

Returns a list of tuples.

20.2 Variables

Name	Description
GHz	Value: 1000000000.0
Hz	Value: 1.0
MHz	Value: 1000000.0
THz	Value: 1e+12
W	Value: 1.0
__package__	Value: 'theia.running'

continued on next page

Name	Description
arccos	Value: <ufunc 'arccos'>
arcsin	Value: <ufunc 'arcsin'>
arctan	Value: <ufunc 'arctan'>
cm	Value: 0.01
cos	Value: <ufunc 'cos'>
deg	Value: 0.0174532925199
exp	Value: <ufunc 'exp'>
kHz	Value: 1000.0
kW	Value: 1000.0
km	Value: 1000.0
m	Value: 1.0
mHz	Value: 0.001
mW	Value: 0.001
mm	Value: 0.001
nW	Value: 1e-09
nm	Value: 1e-09
pi	Value: 3.14159265359
ppm	Value: 1e-06
rad	Value: 1.0
sin	Value: <ufunc 'sin'>
sqrt	Value: <ufunc 'sqrt'>
tan	Value: <ufunc 'tan'>
uHz	Value: 1e-06
uW	Value: 1e-06
um	Value: 1e-06

21 Module theia.running.simulation

Defines the Simulation class for theia.

21.1 Variables

Name	Description
<code>__package__</code>	Value: 'theia.running'

21.2 Class Simulation

object  **theia.running.simulation.Simulation**

Simulation class.

This class is a wrapper for all the metadata (names of setup and of files, etc.) as well as for the high level functions of a simulation.

== Attributes ==

LName: name of the simulation [string]
 FName: name of the file for outputs (without extension) [string]
 OptList: list of optical components of the setup [list of optics]
 InBeams: list of input beams [list of beams]
 BeamTreeList: list of binary trees of beams [list of BeamTree]
 Order: order of the simulation, beams transmitted by HRs or reflected by ARs
 have their orders augmented by 1, and simulation calculates only until
 this Order attribute. [int]
 Threshold: Power under which beams are no longer traced. [float]
 Date: string of the date-time when the simulation was created (not run).
 [string]

21.2.1 Methods

__init__(*self*, FName='simulationinput')

Simulation initializer.

FName: output files name without extension. [string]

Overrides: object.__init__

__str__(*self*)

String representation of the simulation, for print(simulation).

Overrides: object.__str__

numberOfOptics(*self*)

Calculate the number of optics of OptList.

Returns the number of optics (not components, optics).

load(*self*)

Initialize simulation attributes by input from .tia file.

See documantation for the format of the input file.

No return value.

run(*self*)

Run simulation with input as read by load.

threshold: power of beam below which the simulation stops tracing child
beams. [float]

order: maximum order to keep daughter beams. [integer]

No return value.

writeOut(*self*)

Write the results from the simulation in the .out file.

writeCAD(*self*)

Inherited from object

```
__delattr__(), __format__(), __getattr__(), __hash__(), __new__(),  
__reduce__(), __reduce_ex__(), __repr__(), __setattr__(), __sizeof__(),  
__subclasshook__()
```

21.2.2 Properties

Name	Description
<i>Inherited from object</i>	
__class__	

22 Package `theia.tree`

This is the tree sub-package of `theia`.

It provides the necessary classes and functions to allow the reverse ray tracing and stray light hunting features of `theia`.

Version: 0.1.0

Author: R. Duque

Copyright: Copyright 2017, R. Duque

License: GNU GPLv3+

22.1 Modules

- **beamtree:** Defines the `BeamTree` class for `theia`.
(Section 23, p. 54)

23 Module theia.tree.beamtree

Defines the BeamTree class for theia.

23.1 Functions

treeOfBeam(*srcBeam*, *optList*, *order*, *threshold*)

Function to calculate the tree of daughter beams of srcBeam.

srcBeam: Input beam. [GaussianBeam] optList: List of optical components of the setup. [list of OpticalComponent] order: order of simulation. [integer] threshold: power threshold for daughter beams. [float]

Returns a BeamTree.

23.2 Variables

Name	Description
__package__	Value: 'theia.tree'

23.3 Class BeamTree

object —
theia.tree.beamtree.BeamTree

BeamTree class.

A BeamTree is a binary tree which allows to keep track of the beams as they are traced throughout the optical setup. The Root of the tree is a Gaussian beam and the other attributes are the daughter trees and all the data of the interaction producing these with the Root beam

== Attributes == Root: beam of this node of the tree. [GaussianBeam] T: beam resulting from the transmission of the Root beam. [BeamTree] R: beam resulting from the reflection of the Root beam. [BeamTree]

23.3.1 Methods

__init__ (<i>self</i> , Root=None, T=None, R=None)
BeamTree initializer.
Overrides: object.__init__

__str__ (<i>self</i>)
String representation of a BeamTree, for print(tree).
Overrides: object.__str__

lines (<i>self</i>)
Returns the list of lines necessary to print the object.

beamList (<i>self</i>)
Returns the string representation the tree of beams.

beamLines (<i>self</i>)
Returns the list of lines necessary to print the list of beams.

numberOfBeams (<i>self</i>)
Return the total number of beams.

outputLines (<i>self</i>)
Return the list of lines necessary to write the output of simulation.

Inherited from object

__delattr__(), __format__(), __getattr__(), __hash__(), __new__(),
 __reduce__(), __reduce_ex__(), __repr__(), __setattr__(), __sizeof__(),
 __subclasshook__()

23.3.2 Properties

Name	Description
<i>Inherited from object</i>	
__class__	

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