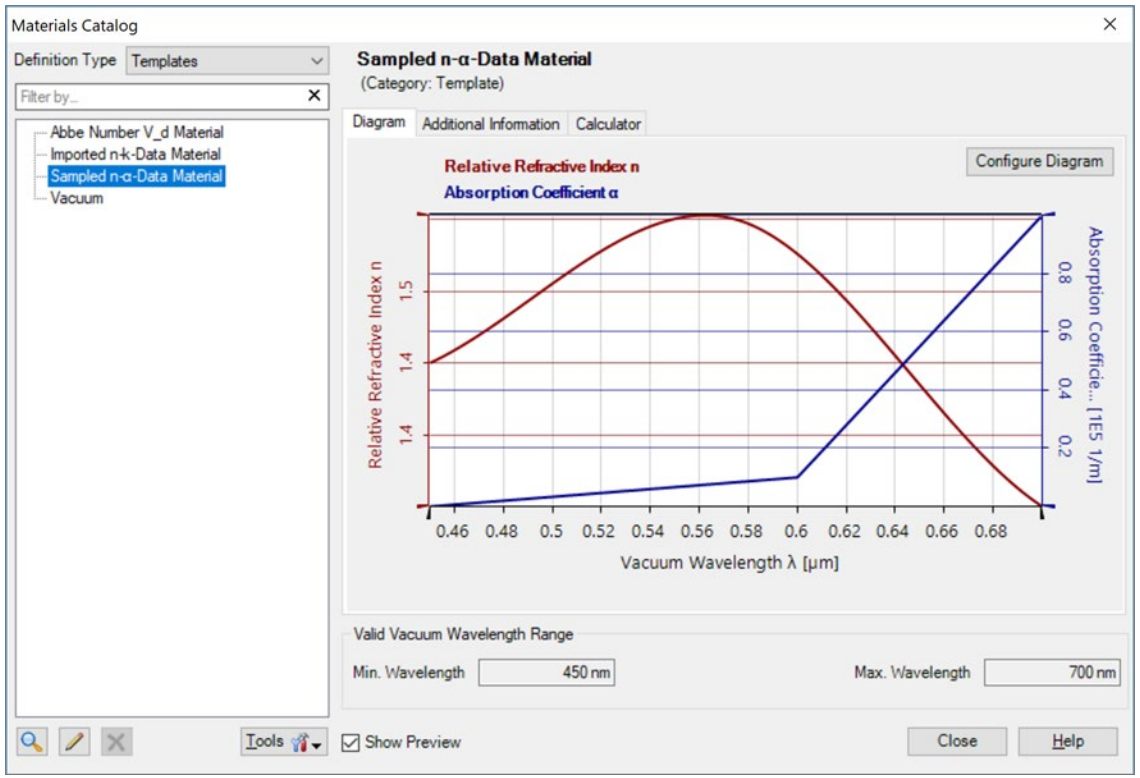
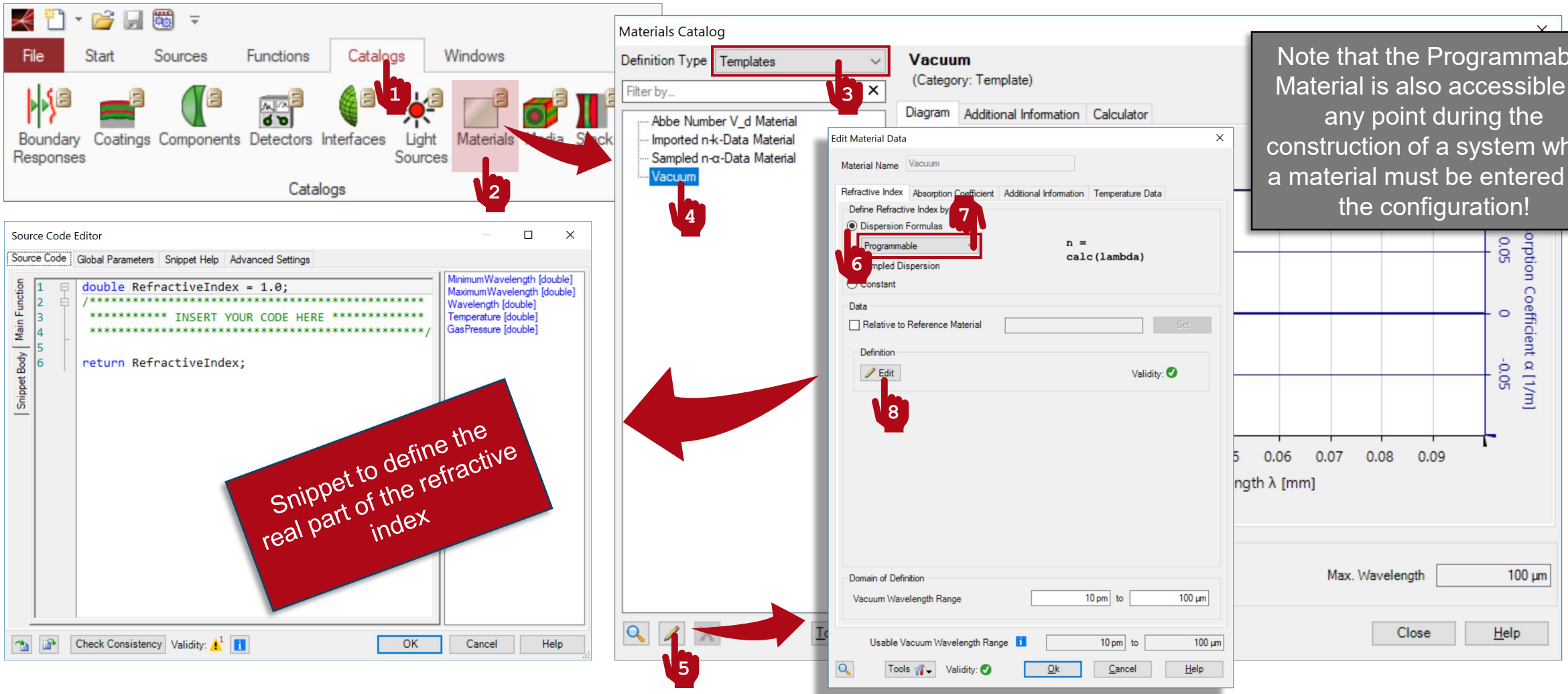
# How to Work with the Programmable Material and Example (Linear Dependence)

# Abstract

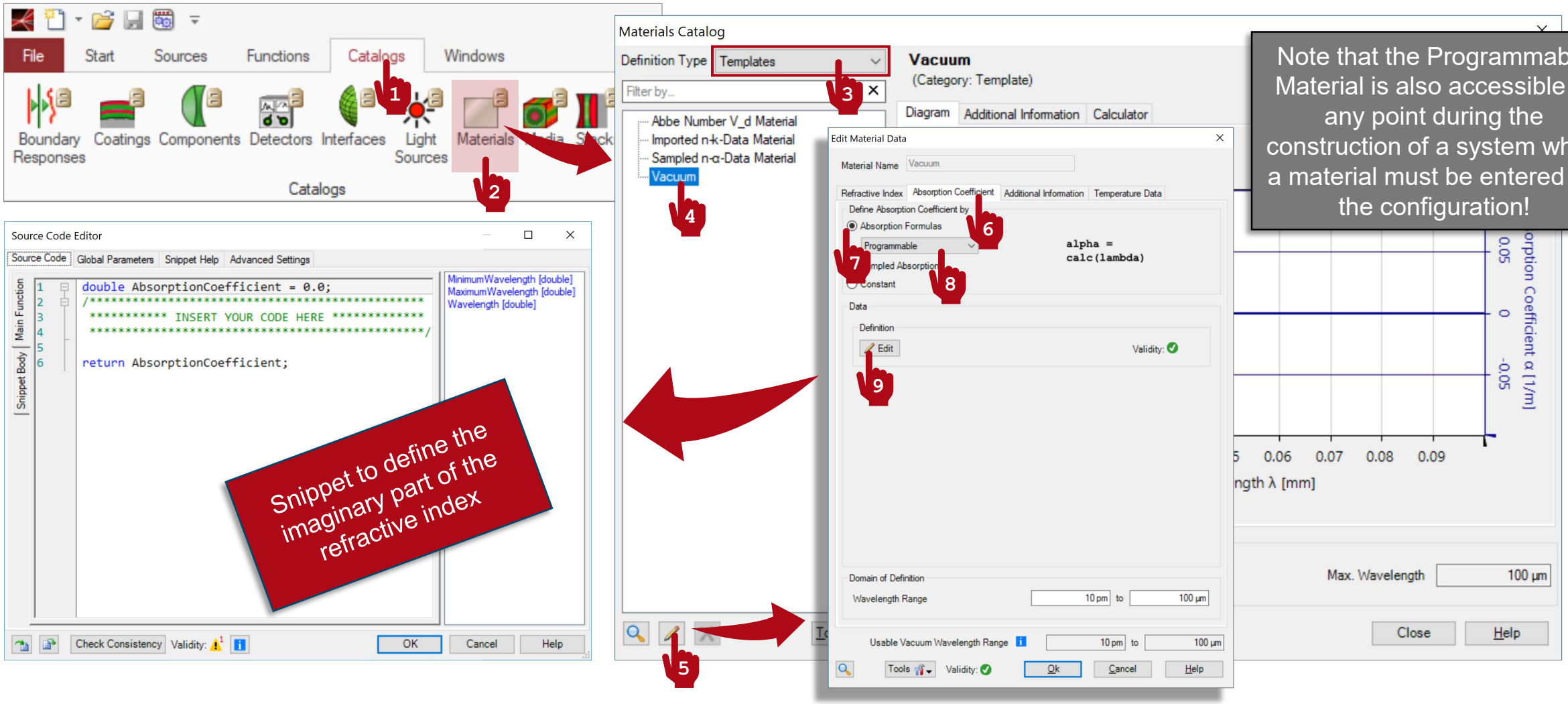



Providing maximum versatility is one of our most fundamental objectives. A key aspect of this aim is to provide a flexible-enough definition mechanism of the refractive index, in order to achieve a realistic characterization of the matter which composes an optical system. In VirtualLab Fusion this role is left to Materials and Media: the first deal with the dependence of the refractive index on wavelength (dispersion), the second group take care of the dependence on position. In what follows we present a tutorial that guides the user in the task of programming their own custom materials.

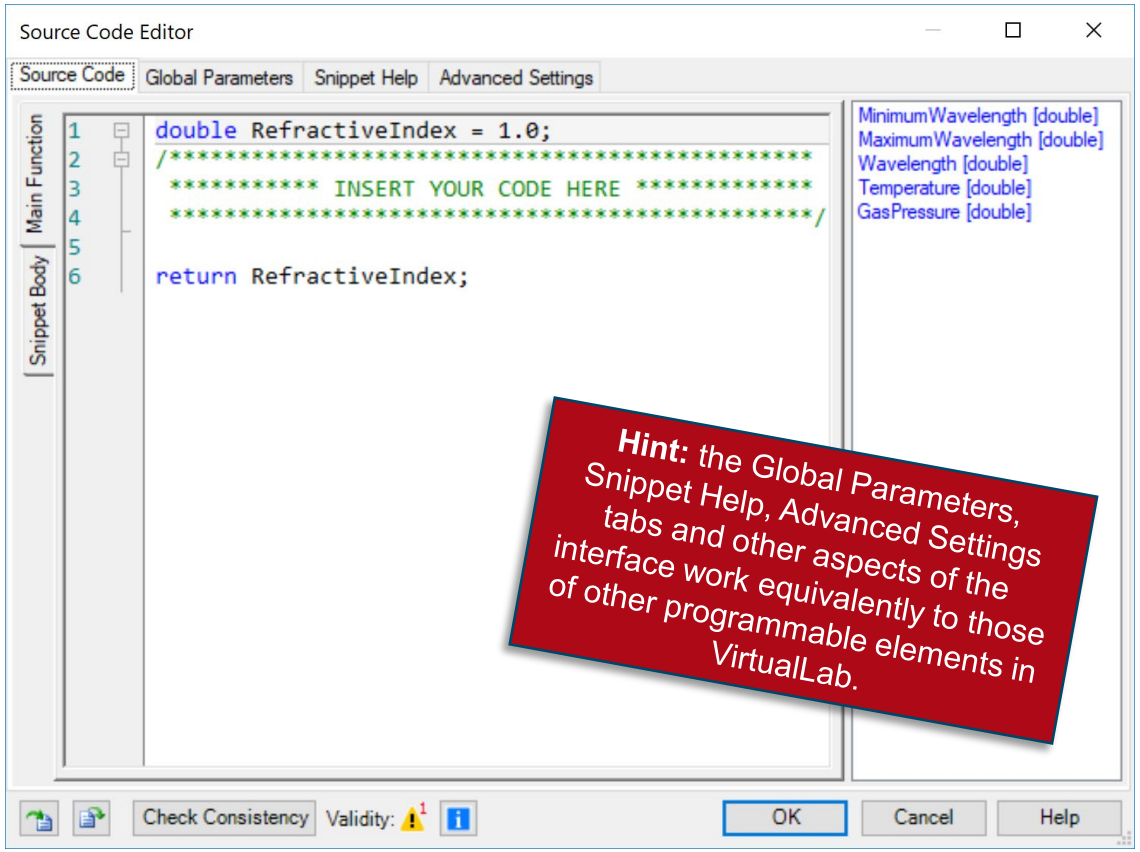
# Where to Find the Programmable Material: Catalog (1)



# Where to Find the Programmable Material: Catalog (2)



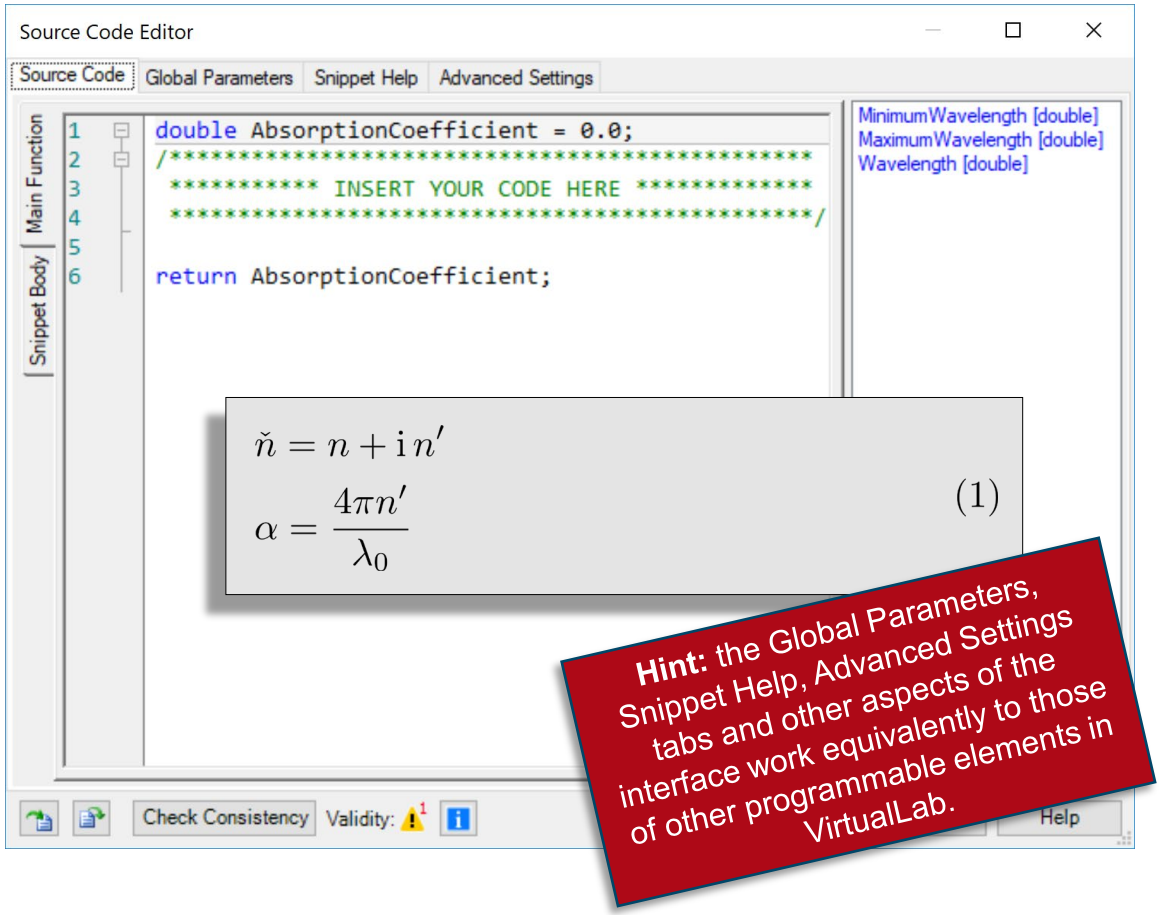
# Writing the Code: Refractive Index




- The refractive index is in general a complex value. This snippet defines its real part.
- The panel on the right shows a list of available independent parameters.
- `MinimumWavelength` and `MaximumWavelength` refer to the boundary values of the range in which this particular function is defined.
- `Wavelength` represents each of the points at which the programmed function is sampled.
- `Temperature` and `GasPressure` retrieve these values from the configuration dialogue, and they can be used in the code, in case the final value of the refractive index depends on them.
- The code must output a `double` value, representing the value of the real part of the refractive index at the wavelength `Wavelength` and for the given values of `Temperature` and `GasPressure`.

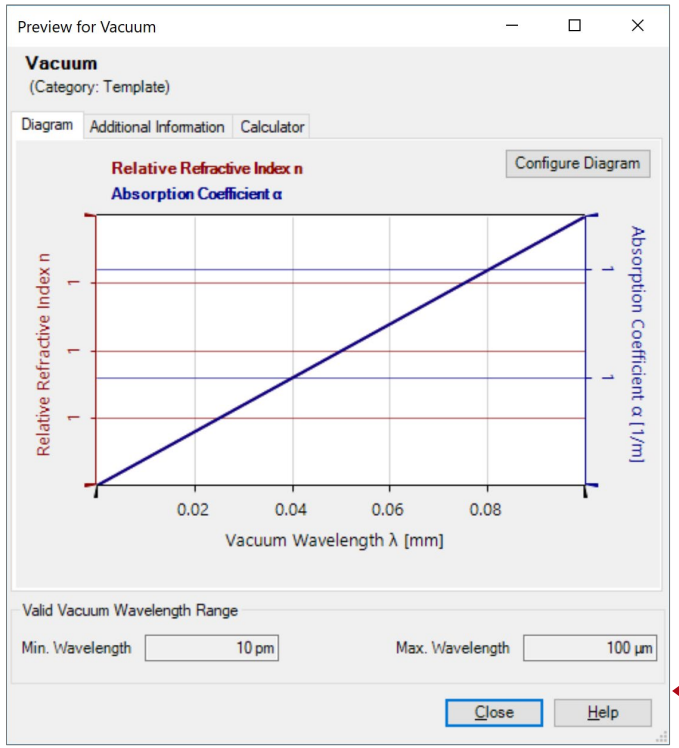
# Writing the Code: Absorption Coefficient

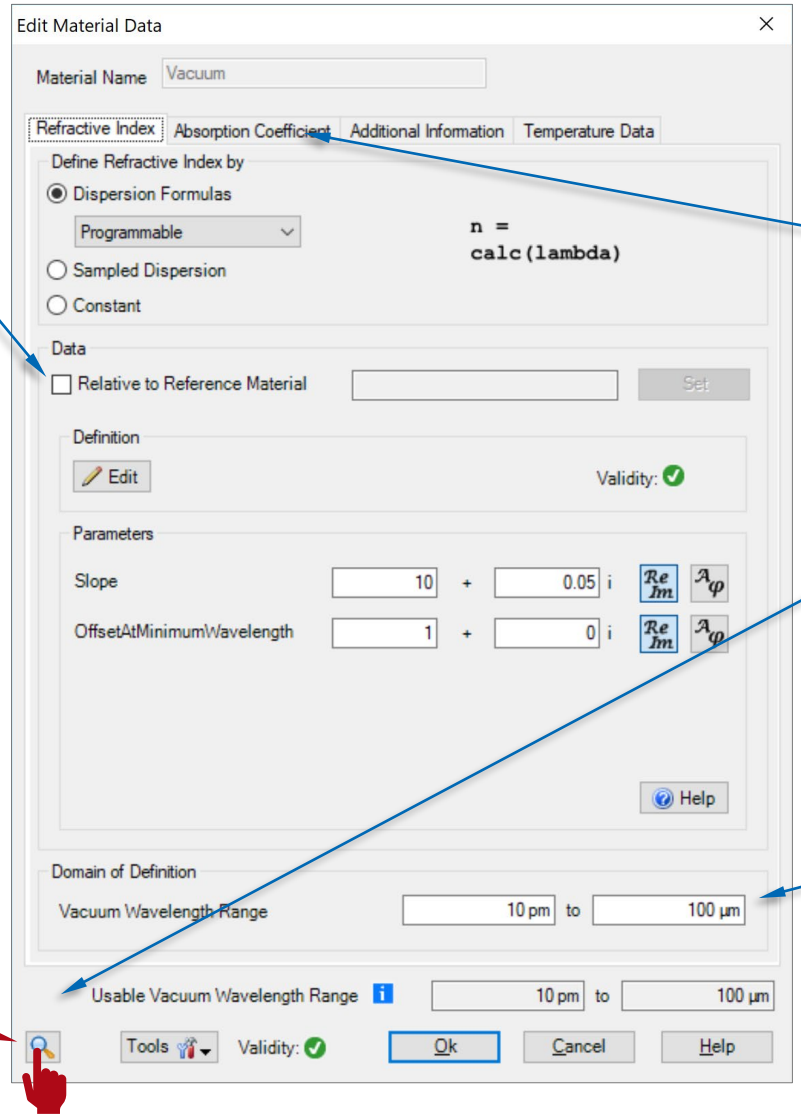
- The refractive index is in general a complex value. This snippet defines the absorption coefficient $\alpha$, which is related to the imaginary part of *n* via Eq. (1).
- The panel on the right shows a list of available independent parameters.
- `MinimumWavelength` and `MaximumWavelength` refer to the boundary values of the range in which this particular function is defined.
- `Wavelength` represents each of the points at which the programmed function is sampled.
- The code must output a `double` value, representing the value of the imaginary part of the refractive index at the wavelength `Wavelength`.



# Wavelength Range

If you wish the final value of the refractive index of your custom material to be defined with respect to another material, tick this option and select the reference material accordingly.




It is possible to combine a programmable real refractive index with, for instance, a constant absorption coefficient. Their snippets are defined independently (except for the user-defined global parameters)

Check the graphical representation of your custom material here!

Enter here the wavelength range for which your custom function will be valid

# Programming a Material with Linear Behaviour

# Linear Dependence of Refractive Index

Let us denote the complex-valued refractive index of our material with

$$\check{n}(\lambda) = n(\lambda) + \mathrm{i}\, n'(\lambda)$$
$$\alpha = \frac{4\pi n'}{\lambda_0} \tag{1}$$

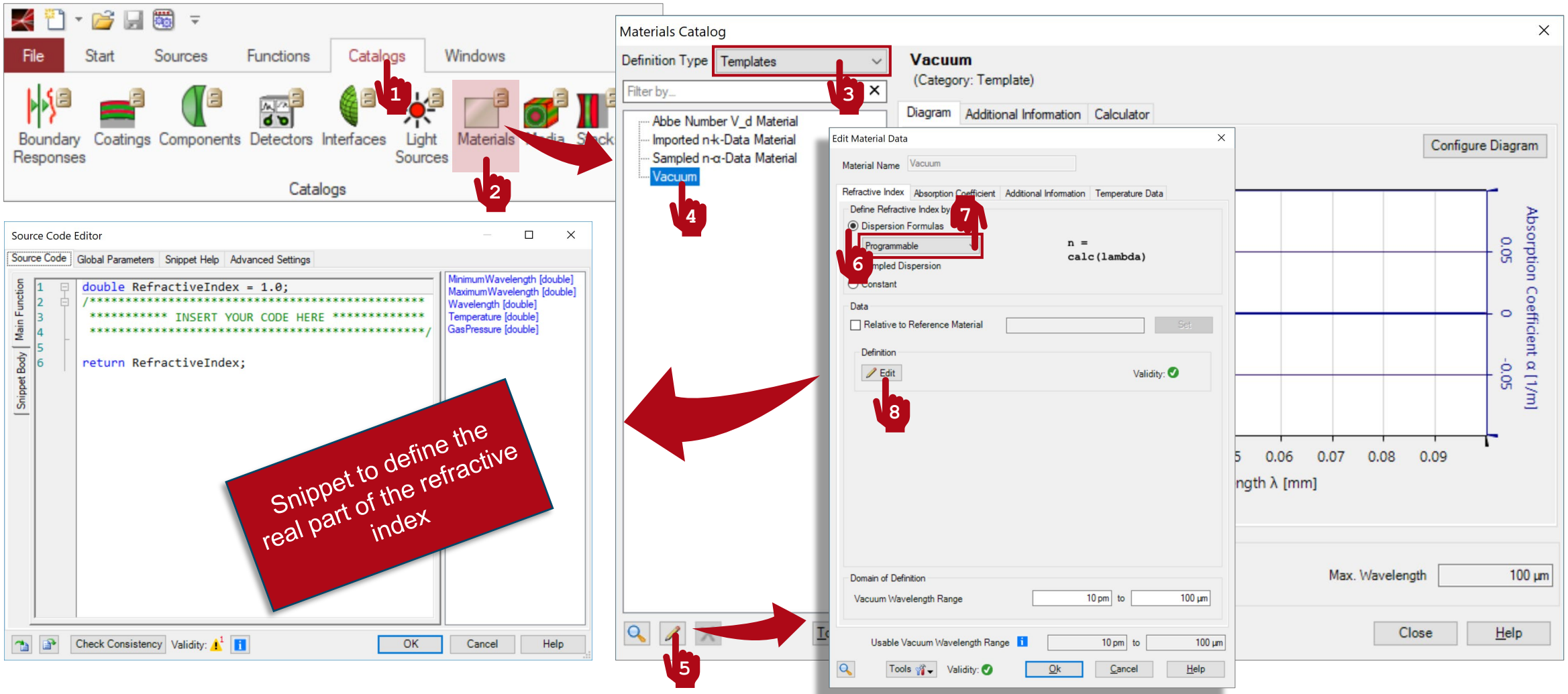
and let us assume that both the real refractive index and the absorption coefficient exhibit a linear dependence on the wavelength

$$n(\lambda) = n_0 + b\lambda$$
$$\alpha(\lambda) = \alpha_0 + b_\alpha \lambda \tag{2}$$

with

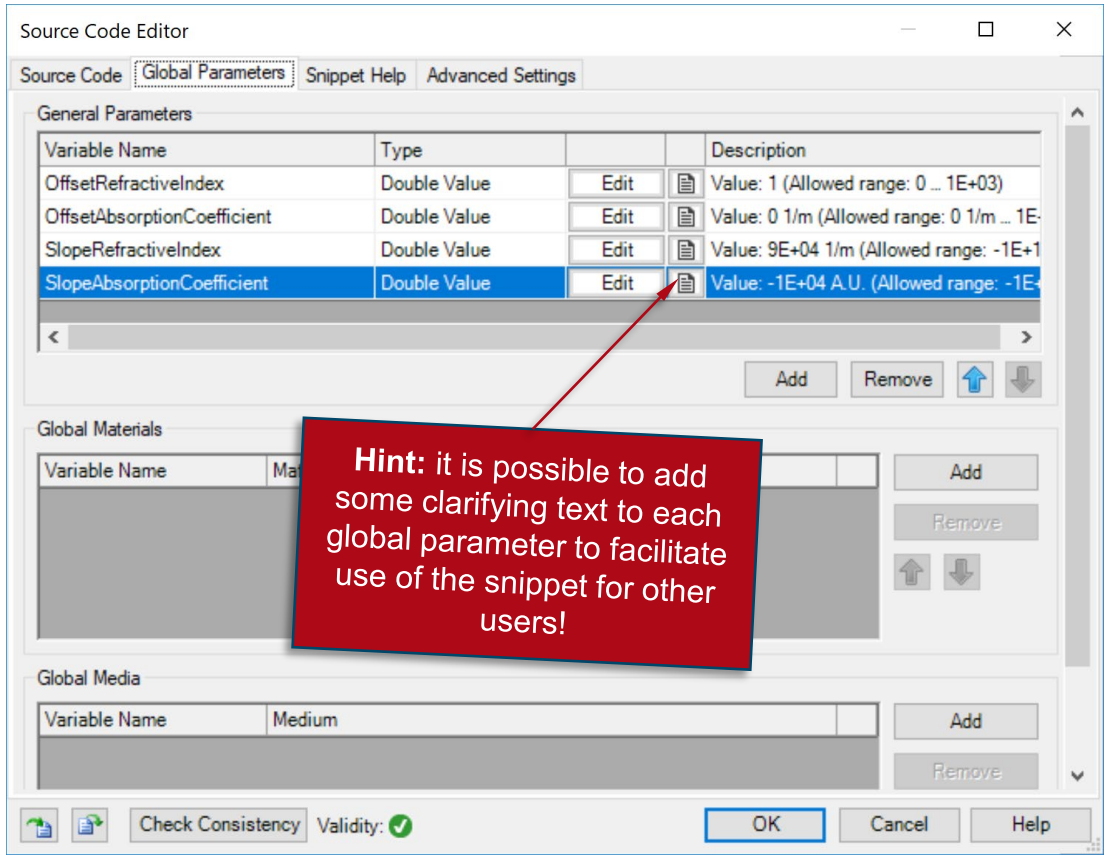
$$n_0 \rightarrow \text{Offset}$$
$$b \rightarrow \text{Slope}$$
$$\alpha_0 \rightarrow \text{Offset} \tag{3}$$
$$b_\alpha \rightarrow \text{Slope}$$

# Where to Find the Programmable Material: Catalog (1)

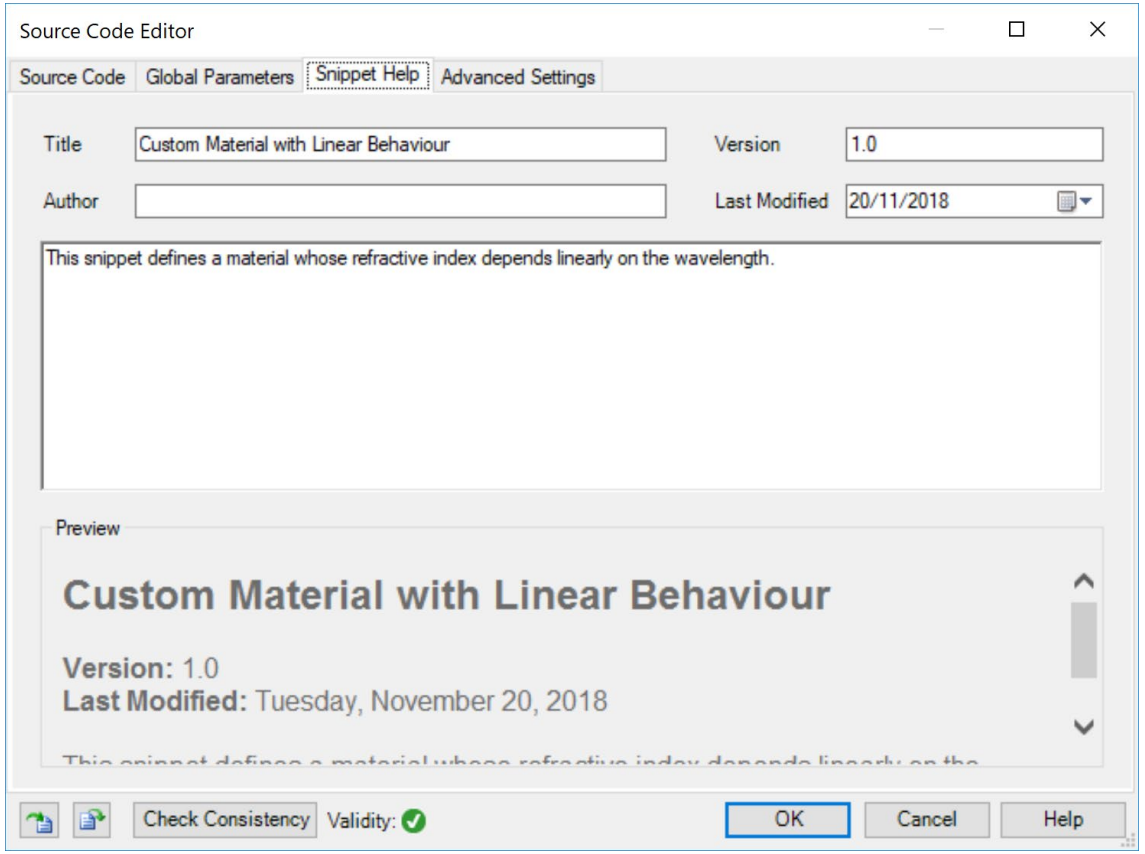


# Programmable Material: Global Parameters

- Once you have triggered open the Edit dialogue, go to the Global Parameters tab.
- There, Add and Edit four global parameters:
  - `double OffsetRefractiveIndex = 1A.U.`: the offset for the linear dependence of the real part of the refractive index.
  - `double OffsetAbsorptionCoefficient = 0A.U`: the offset for the linear dependence of the absorption coefficient.
  - `double SlopeRefractiveIndex = 9e4A.U.`: the slope for the linear dependence of the real part of the refractive index.
  - `double SlopeAbsorptionCoefficient = -1e4A.U.`: the slope for the linear dependence of the absorption coefficient.
- Use the button with the small “notes” icon to add some explanation to your custom global parameters.

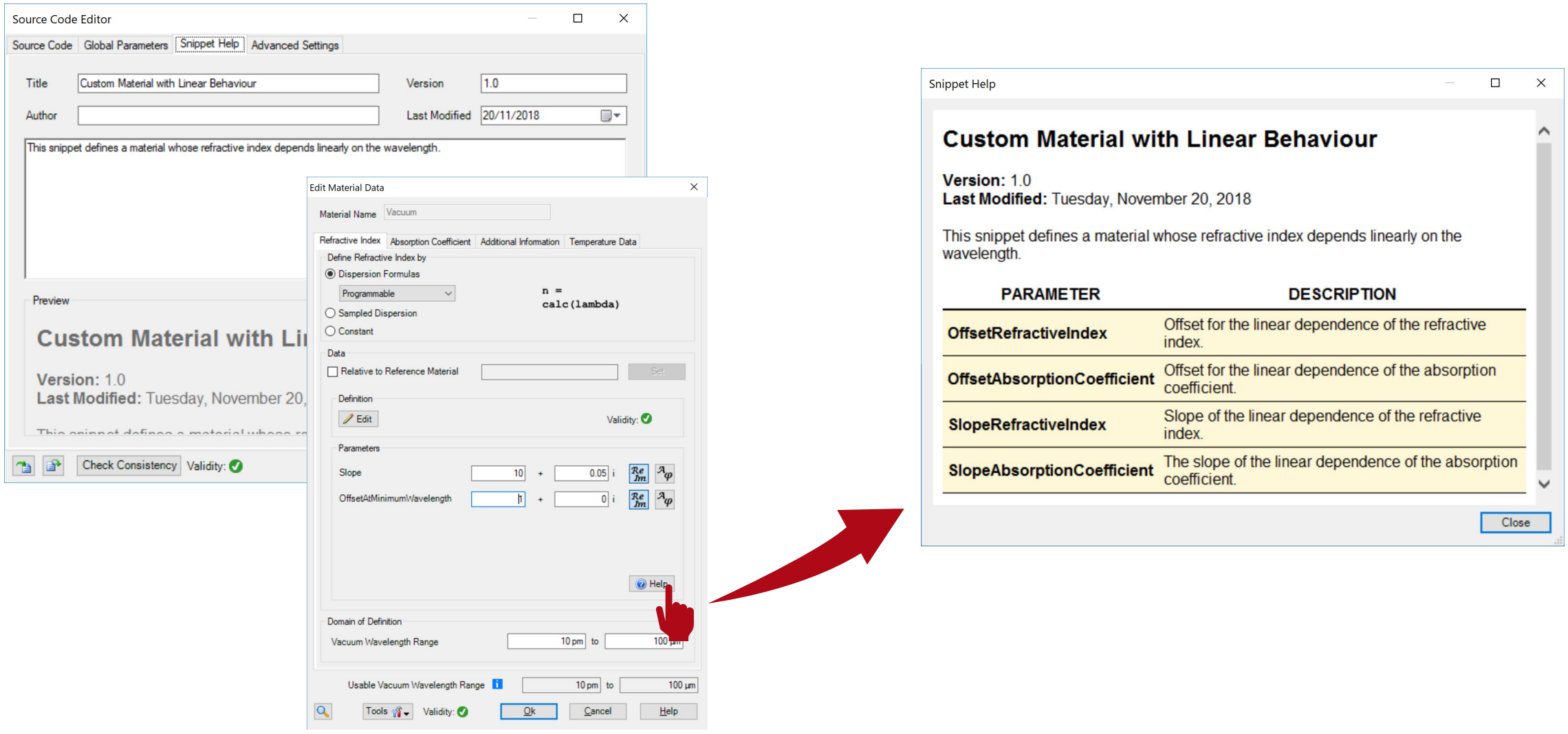


# Programmable Material: Snippet Help

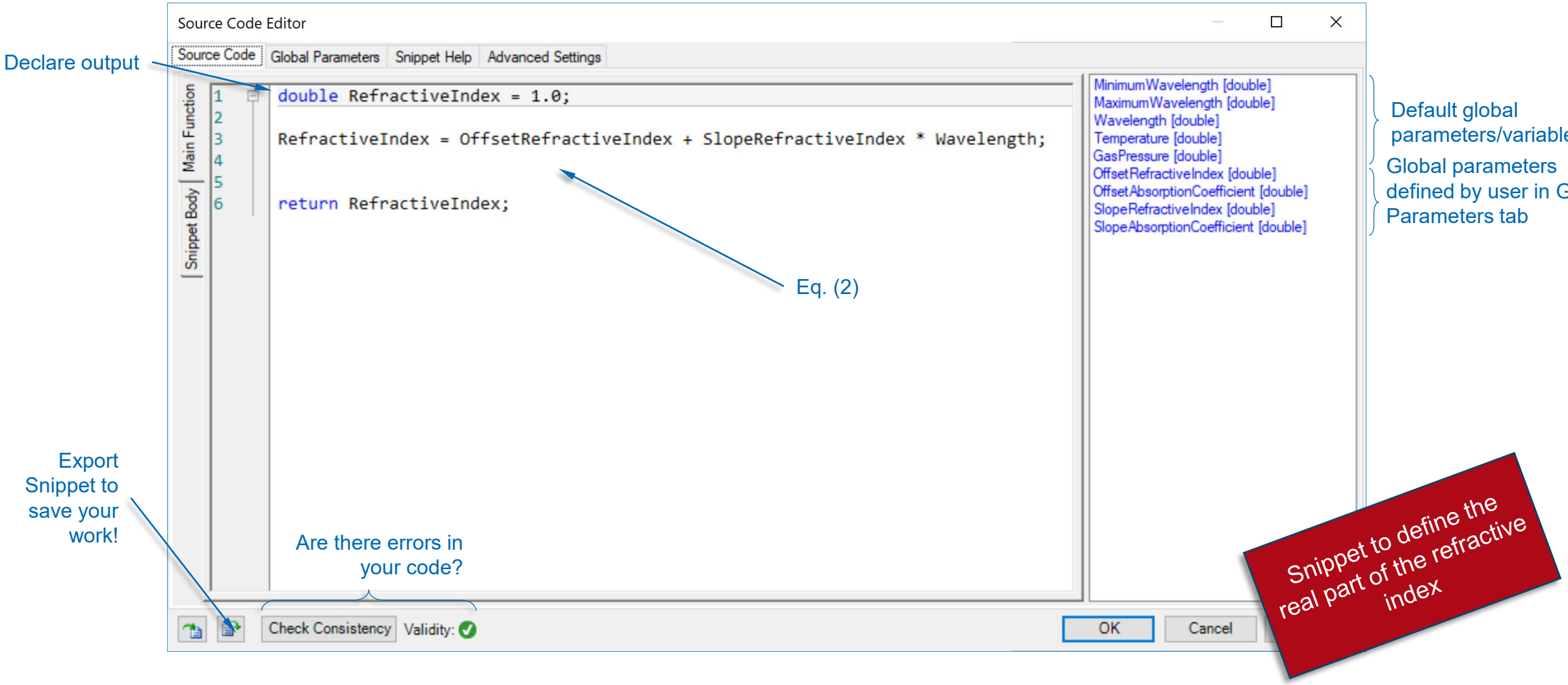



- **Optional:** you can use the Snippet Help tab to write instructions, clarifications, and some metadata associated to your snippet.
- This option is very helpful to keep track of your progress with a programmable element.
- It is especially useful when the programmable element is later disseminated to be handled by other users!

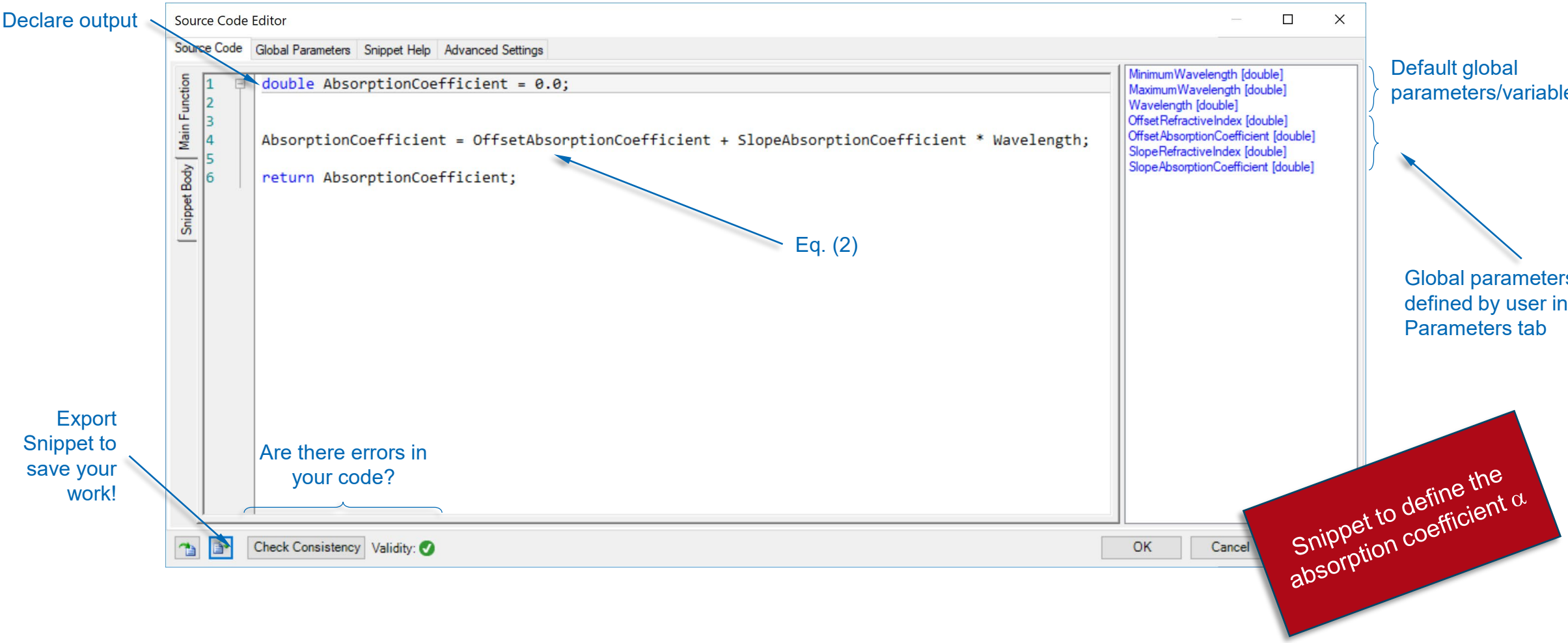
# Programmable Material: Snippet Help



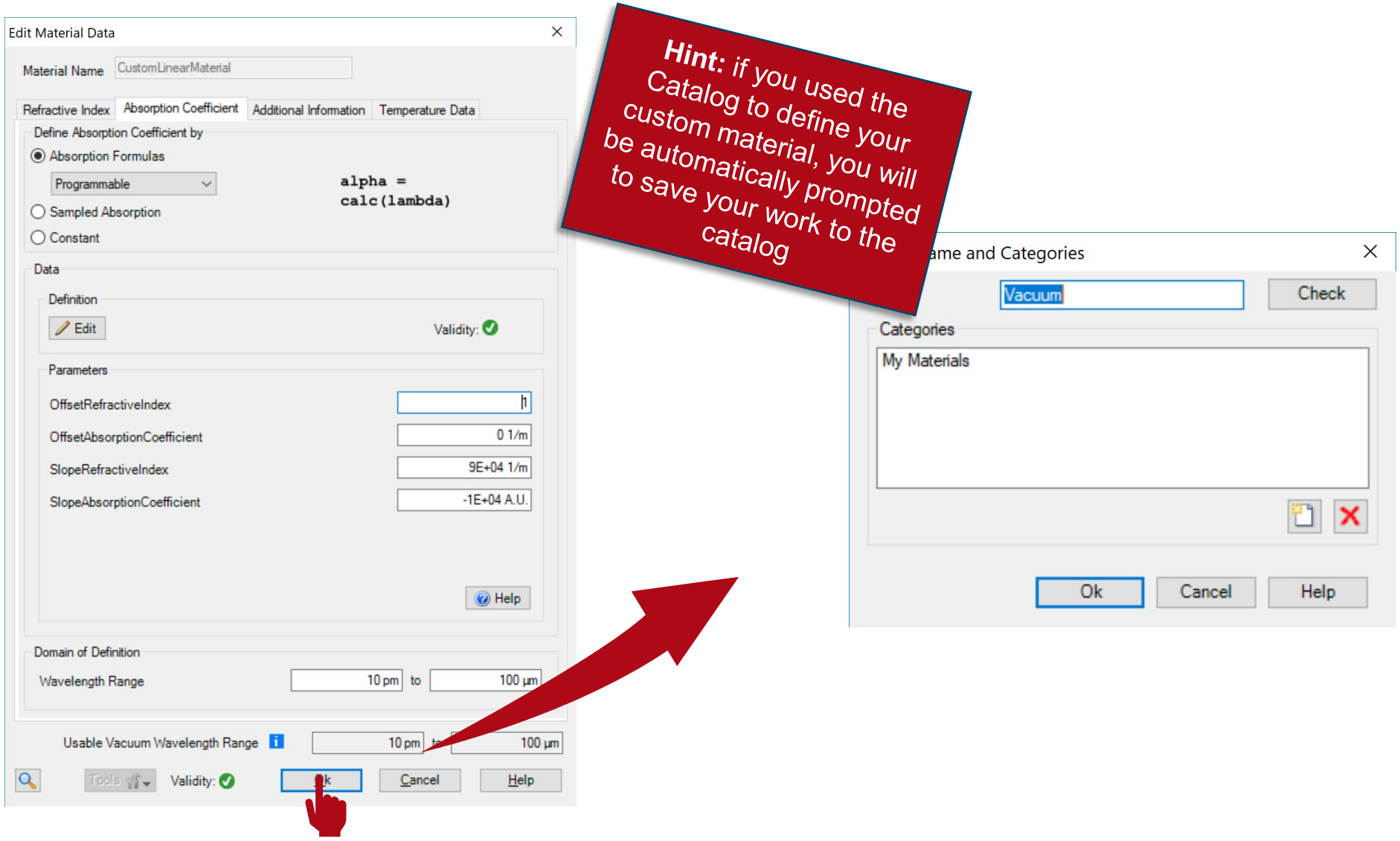
# Programmable Material: Writing the Code (1)



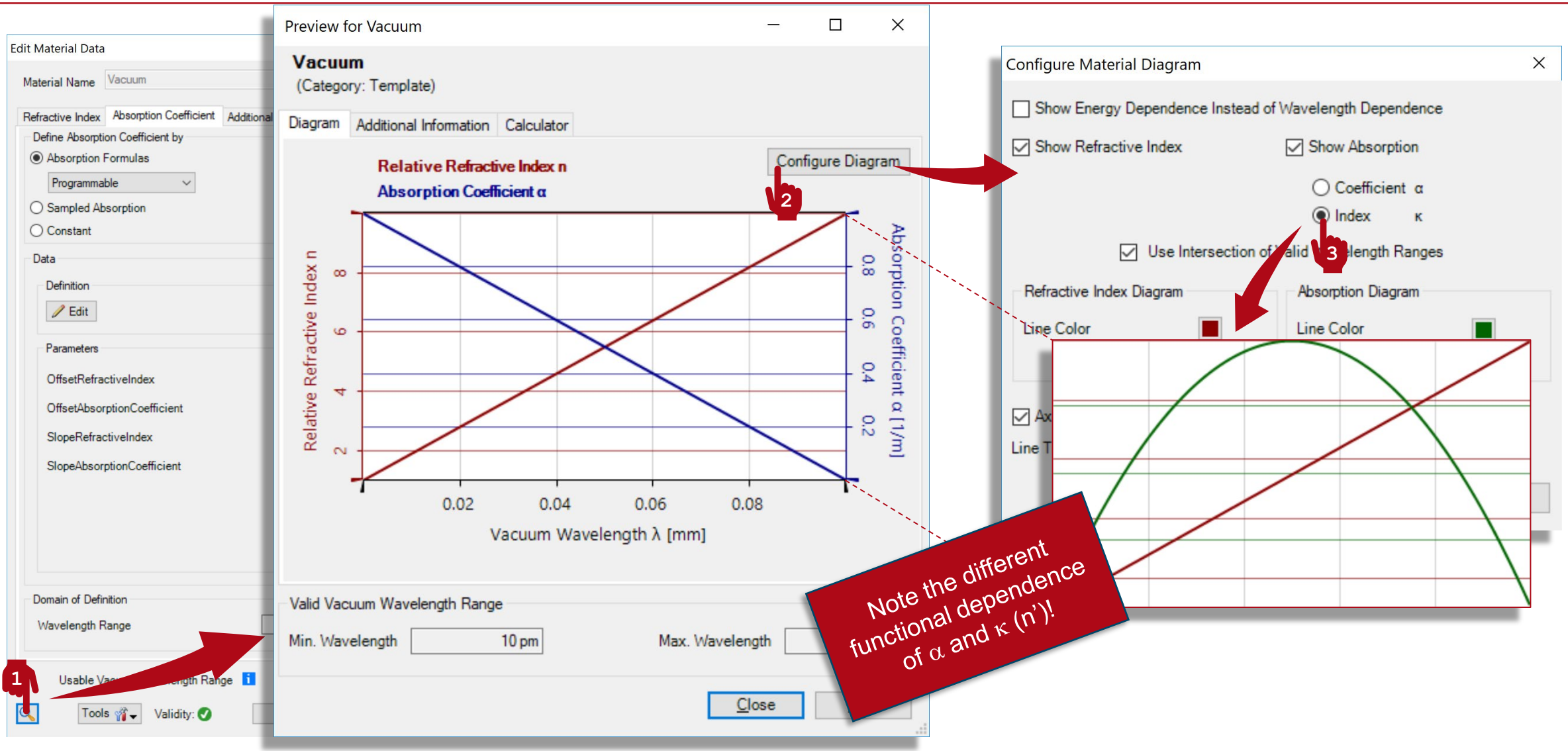
# Programmable Material: Writing the Code (2)



# Save the Custom Material to the Catalog



# Output


Edit Material Data
Material Name
Vacuum
Refractive Index
Absorption Coefficient
Define Absorption Coefficient by
Absorption Formulas
Programmable
Sampled Absorption
Constant
Data
Definition
Edit
Parameters
OffsetRefractiveIndex
OffsetAbsorptionCoefficient
SlopeRefractiveIndex
SlopeAbsorptionCoefficient
Domain of Definition
Wavelength Range
Tools
Validity:
1
Preview for Vacuum
Vacuum
(Category: Template)
Diagram
Additional Information
Calculator
Configure Diagram
2
Relative Refractive Index n
Absorption Coefficient α
Relative Refractive Index n
Absorption Coefficient α [1/m]
Vacuum Wavelength λ [mm]
0.02
0.04
0.06
0.08
Valid Vacuum Wavelength Range
Min. Wavelength
10 pm
Max. Wavelength
Close
Configure Material Diagram
Show Energy Dependence Instead of Wavelength Dependence
Show Refractive Index
Show Absorption
Coefficient α
Index κ
3
Refractive Index Diagram
Absorption Diagram
Line Color
Line Color
Note the different functional dependence of α and κ (n')!

# Test the Code!

**Main Function (Refractive Index)**

```
// Declare output:
double RefractiveIndex = 1.0;

// Apply equation for linear dependence:
RefractiveIndex = OffsetRefractiveIndex + SlopeRefractiveIndex * Wavelength;

// Return output:
return RefractiveIndex;
```

# Test the Code!

**Main Function (Absorption Coefficient)**

```
// Declare output:
double AbsorptionCoefficient = 0.0;

// Apply equation for linear dependence:
AbsorptionCoefficient = OffsetAbsorptionCoefficient + SlopeAbsorptionCoefficient * Wavelength;

// Return output:
return AbsorptionCoefficient;
```

# Document Information

| | |
|---|---|
| title | How to Work with the Programmable Material and Example (Linear Dependence) |
| document code | CZT.0103 |
| version | 1.0 |
| toolbox(es) | Starter Toolbox |
| VL version used for simulations | 7.4.0.49 |
| category | Feature Use Case |
| further reading | - How to Work with the Programmable Medium and Example (Thermal Lens) |