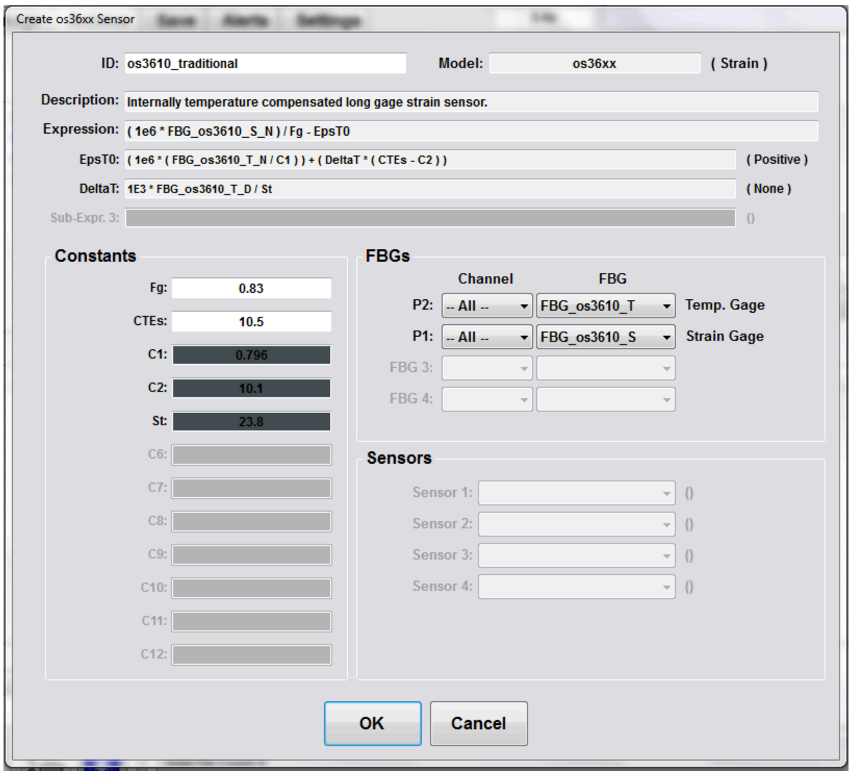
## I. Introduction

This document will demonstrate how to use the generic Create Sensor functions in Micron Optics ENLIGHT to realize the total strain, mechanical/thermal strain, and deviation strain measurements highlighted in MOI Technical Note 1025.

## II. Traditional ENLIGHT templates

Using traditional ENLIGHT expressions, the default measurement output for strain sensors is the mechanical component of strain in which we make assumptions about substrate CTE and the absence thermal gradients between the substrate and the sensor.

**Example 2. os3610 sensor bracket mounted to concrete substrate (with auxiliary os4350 temperature sensor)**




In many cases, these assumptions are inadequate and lead to imprecise or ambiguous strain measurements.

## II. The Five Steps to Meaningful Strain Data in realized in ENLIGHT

This example will show how to realize the Total Strain Expressions from of Technical note 1025 using:

**Example 2. os3610 sensor bracket mounted to concrete substrate (with auxiliary os4350 temperature sensor)**

using the appropriate coefficients from Technical Note 1025, Appendix A.

## Accurate Total Strain Measurements from Micron Optics Optical Strain Gages

**A. COLLOCATION -** *The strain sensing FBG and temperature compensation FBG must be at the same temperature.*

From a gage compensation perspective, the strain and temperature sensing FBGs of the os3610 are intrinsically collocated, so this requirement is generally guaranteed by sensor design.

**B. TOTAL STRAIN -** *Total strain can be accurately calculated by first subtracting out thermally induced optical gage effects.*

From Tech Note 1025, Equation 1:

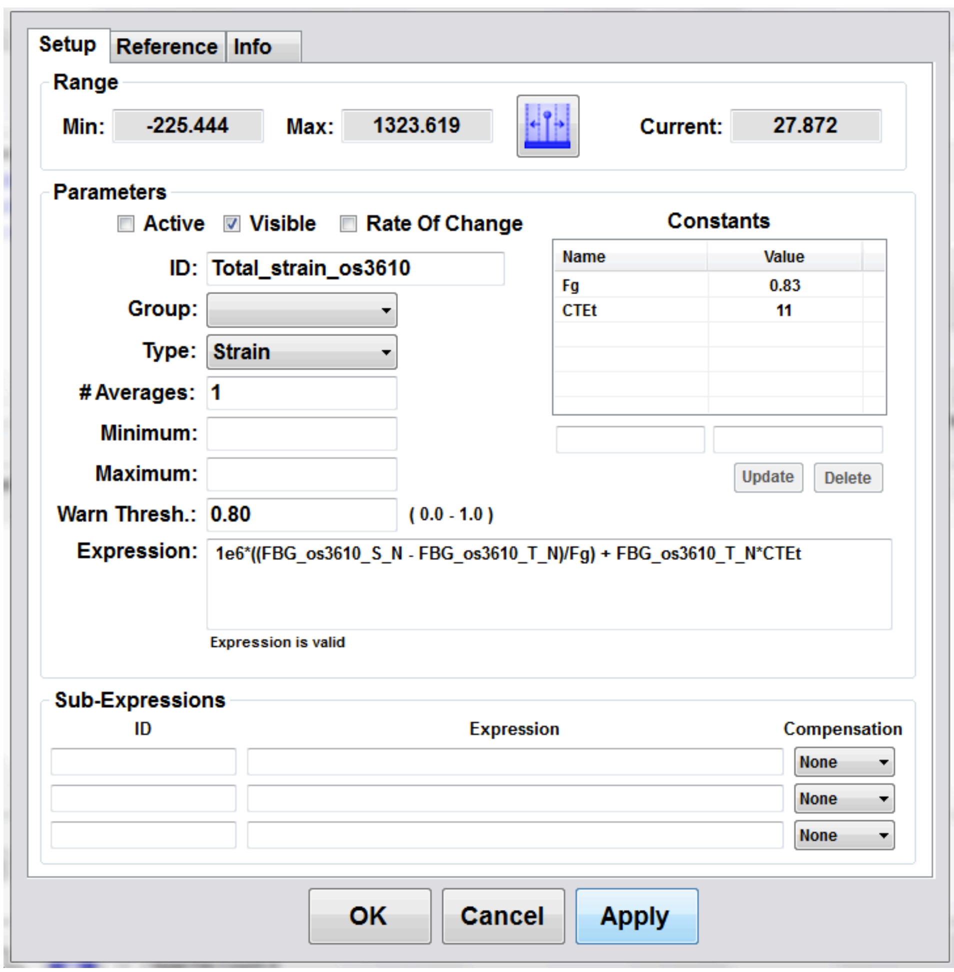
$$\varepsilon_{Total} = 10^6 \left[ \frac{(\Delta\lambda/\lambda_0)_S - (\Delta\lambda/\lambda_0)_T}{F_G} \right] + \frac{(\Delta\lambda/\lambda_0)_T}{S_T} CTE_T$$

where,

$CTE_T$ is the coefficient of thermal expansion for the temperature compensation FBG mount,

$F_G$ is the gage factor for the optical strain gage in units, and is specified in the attached appendix, and

$S_T$ is the temperature compensator thermal response, and is specified in the attached appendix.




Now we have an accurate, gage temperature corrected account of total strain from both thermal and load induced sources.

## Decomposition of Total Strain into Thermal and Non-Thermal Components

**C. SUBSTRATE TEMPERATURE -** *The substrate temperature $T_{subst}$ can sometimes be accurately represented by the strain sensor's temperature compensation FBG, measured as $\lambda_T$, but sometimes requires an auxiliary temperature sensor.*

In this working example, it is known that the os4350 is a better measure of substrate temperature than the os3610 temperature compensation FBG and will be used for total strain decomposition. We could correct using

From Tech Note 1025, Equation 2:

$$\Delta T_{subst} = \frac{(\Delta\lambda / \lambda_0)_{os4350}}{S_T}$$

which we will realize a s a sub-expression in subsequent steps.

**D. SUBSTRATE CTE -** *Thermal and mechanical components of total strain can be accurately decoupled if the exact substrate CTE and the substrate temperature are known.*

From Tech Note 1025, Total strain $\varepsilon_{Total}$ is defined in as follows:

Equation 3: $$\varepsilon_{Total} = \varepsilon_{therm} + \varepsilon_{mech}$$

where,

$\varepsilon_{therm}$ is the thermal strain response, and

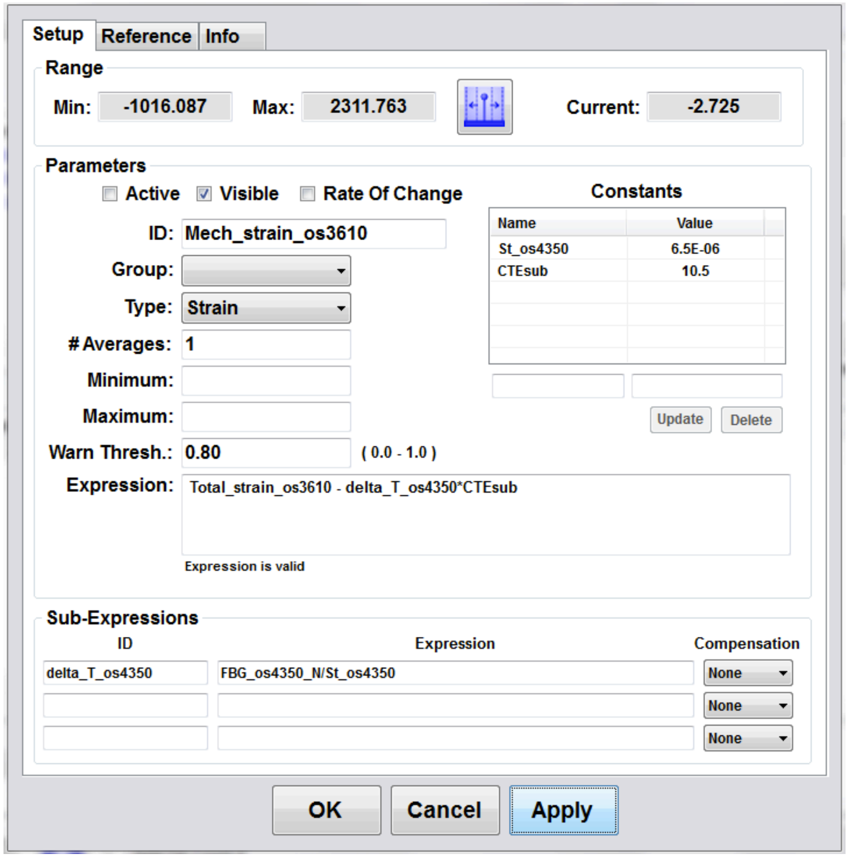
$\varepsilon_{mech}$ is the substrate non-thermal strain response, and may comprised of load-induced, creep, shrinkage or other strains, depending upon the material nature of the measurement substrate.

Once total strain is calculated, the thermal strain $\varepsilon_{therm}$ and the non-thermal strain $\varepsilon_{mech}$ can be decoupled through a measurement of the change in substrate temperature $\Delta T_{subst}$ multiplied by the exact coefficient of thermal expansion of the substrate $CTE_{subst}$ as in Equation 4 below:

Equation 4: $$\varepsilon_{therm} = \Delta T_{subst} CTE_{subst}$$

Equation 5: $$\varepsilon_{mech} = \varepsilon_{Total} - \Delta T_{subst} CTE_{subst}$$

Plugging these expressions into ENLIGHT with an assumed substrate CTE of 10.5 ppm/degC results is shown in the following image. The accuracy of the resulting mechanical strain will depend directly upon the accuracy of the estimated CTE.



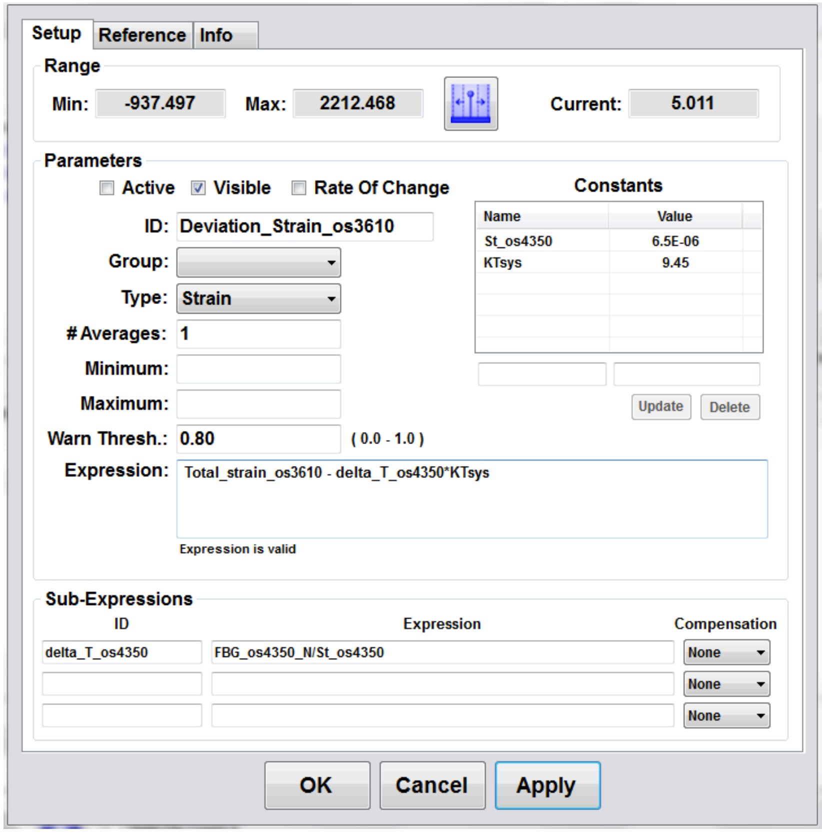

**E. SYSTEM THERMAL RESPONSE -** *Strain deviations from typical structural system thermal response can be observed by knowing the substrate temperature and deducing an effective thermal response coefficient of the system.*

From Tech Note 1025, Equation 6: $\varepsilon_{dev} = \varepsilon_{Total} - \Delta T_{subst} KT_{sys}$

where,

$KT_{sys}$ is the effective thermal response coefficient of the structural system within the gage length of the sensor and can be deduced as the slope of the total strain versus substrate temperature plots over time.

For this example, post processing of Total strain vs substrate temperature yields a value for $KT_{sys}$ of 9.45. Thus, deviation strains can be realized in ENLIGHT as the following.




And of course, the os4350 can output absolute temperature, these steps result in the following measurement outputs from the os3600/os4350.

| ID | | Relative T | Range Min. | Alarm Min. | Current | Alarm Max. | Range Max. |
|---|---|---|---|---|---|---|---|
| ✓Total_strain_os3610 | με | ------ | -225.444 | ------ | 57.460 | ------ | 1323.619 |
| ✓Mech_strain_os3610 | με | ------ | -166.052 | ------ | 13.517 | ------ | 1213.574 |
| ✓Deviation_Strain_os3610 | με | ------ | -164.298 | ------ | 17.435 | ------ | 1215.327 |