Gaussian Beam Focused by a Thermal Lens
Thermal lens effect describes the inhomogeneity of refractive index of medium, which is induced by thermal gradient of a high-power incident laser beam. For a Gaussian beam with specified parameters, the refractive index is mathematically represented as a function of temperature and input power [W. Koechner, Appl. Opt. 9, 2548–2553 (1970)]. This use case shows the variation of the focal length of the thermal lens, as well as the focus beam diameter when the input power changes. This example is published in [H. Zhong, J. Opt. Soc. Am. A 35].
Modeling Task

**task 1:** evaluation of the variation of focal length with varying $P_{in}$

**task 2:** evaluation of the variation of beam size with varying $P_{in}$

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**Fundamental Gaussian mode**

- **wavelength**: 632.8 nm
- **polarization**: linear in $x$-direction
- **waist radius**: 760 $\mu$m
- **input power $P_{in}$**: 8 to 20 kW

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**Thermal lens refractive index distribution**

$$n(x, y) = n_0 - \frac{\eta P_{in}}{4K\pi d} \cdot \frac{\delta n}{\delta T} \cdot \frac{r^2}{r_0^2}$$

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<table>
<thead>
<tr>
<th>$\delta n / \delta T$</th>
<th>7.3 $\times$ 10$^{-6}$ $\degree$C$^{-1}$</th>
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</thead>
<tbody>
<tr>
<td>$\eta$</td>
<td>0.05</td>
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<tr>
<td>$K$</td>
<td>11.1 W/(cm$^2$)$\degree$C$^{-1}$</td>
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<tr>
<td>$r_0$</td>
<td>0.31 cm</td>
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</tbody>
</table>

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**Input parameters**

- $d = 7.5$ cm
- $\tau_0 = 0.31$ cm
- $\frac{\delta n}{\delta T} = 7.3 \times 10^{-6} \degree$C$^{-1}$
- $\eta = 0.05$
- $K = 11.1$ W/(cm$^2$)$\degree$C$^{-1}$
Results

- When input power $P_{in}$ increases, thermal lens effect becomes stronger and the focal length reduces;
- When NA of thermal lens increases, beam diameter in focal plane reduces.
Peek into VirtualLab Fusion

customizable graded-index media

detector for Gaussian beam parameters
Workflow in VirtualLab Fusion

• Set up input Gaussian field
  - Basic Source Models [Tutorial Video]

• Customize the graded-index medium
  - How to Work with the Programmable Medium and Example (Thermal Lens) [Use Case]

• Use the Parameter Run
  - Usage of Parameter Run [Use Case]
VirtualLab Fusion Technologies

beam waist  thermal lens  focal plane

Field Solver

1. crystals & anisotropic components
2. diffractive, Fresnel, meta lenses
   HOE, CGH, DOE

- waveguides & fibers
- scatterer
- diffusers
- diffractive beam splitters
- SLM & adaptive components
- micro lens & freeform arrays
- free space
- prisms, plates, cubes, ...
- lenses & freeforms
- apertures & boundaries
- gratings

# idealized component
## Document Information

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<th>Gaussian Beam Focused by a Thermal Lens</th>
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<td>Application Use Case</td>
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| further reading | - Construction and Modeling of a Graded-Index Lens  
- Modeling of Graded-Index (GRIN) Multimode Fiber |