# Gradient-Index Research Group Metrology Instruments

| Instrument | Wavelength (µm) | Measurement Type | Index Range | Material Type | Comments | Sample Geometry | Sample Prep Requirements |
|---|---|---|---|---|---|---|---|
| **Visible Mach-Zehnder Interferometer** | 0.35 – 1.1 | Relative Index | Any | GRIN | Gives two-dimensional relative index. Accuracy limited by sample preparation and mechanical properties. | Thin (~1mm), plane, parallel slice. Index is constant through sample thickness (exposed gradient). | Figure error < 1λ. Wedge error < 5µm over region of interest. |
| **Schmidt Immersion** | 0.35 – 1.1 | Absolute Index | < 1.7 | GRIN | Same as Mach-Zehnder but uses index fluid that matches the sample at some point. Limited by available fluids. | Thin (~1mm), plane, parallel slice. Index is constant through sample thickness (exposed gradient). | Figure error < 1λ. Wedge error < 5µm over region of interest. |
| **MWIR Mach-Zehnder Interferometer** | 1.1 – 4.6 | Relative Index | Any | GRIN | Gives two-dimensional relative index. Accuracy limited by sample preparation and mechanical properties. Cannot use index fluid. | Thin (~2mm), plane, parallel slice. Index is constant through sample thickness (exposed gradient). | Figure error < 1λ. Wedge error < 5µm over region of interest. |
| **LWIR Mach-Zehnder Interferometer** | 9.3 – 11.3 | Relative Index | Any | GRIN | Gives two-dimensional relative index. Accuracy limited by sample preparation and mechanical properties. Cannot use index fluid. | Thin (~3mm), plane, parallel slice. Index is constant through sample thickness (exposed gradient). | Figure error < 1λ. Wedge error < 5µm over region of interest. |
| **Abbe and Pulfrich Refractometers** | 0.4 – 1.1 | Absolute Index (Surface) | < 1.7 | Homogeneous | Requires index fluid and well-characterized reference prism. Sample must have lower index than prism and fluid. | One polished surface (recommended > 1 cm$^2$) and one polish/fine ground surface at 90°; minimum to no bevel. | Figure error < 3λ |
| **Metricon Refractometer** | 0.4 – 1.7 | Absolute Index (Surface) | < 2.0 | Homogeneous | Critical angle measurement with reference prism. | One polished surface (> 1 cm$^2$) required | Figure error < 3λ |
| **Visible Sagnac Interferometer** | 0.35 – 1.1 | Absolute Index (Bulk) | Any | Homogeneous | Accuracy limited by sample thickness measurement and sample preparation. | Plane parallel window. Diameter > 15mm Thickness > 5mm | Wedge < 5 arcmin Thicker samples reduce measurement uncertainty |
| **MWIR Sagnac Interferometer** | 1.1 – 4.6 | Absolute Index (Bulk) | Any | Homogeneous | Accuracy limited by sample thickness measurement and sample preparation. | Plane parallel window. Diameter > 20mm Thickness > 5mm | Wedge < 5 arcmin Thicker samples reduce measurement uncertainty |

*Instrument under construction or upgrade, expected completion by Fall of 2016

6/23/2016

**www.optics.rochester.edu/workgroups/moore/downloads**

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|---|---|---|---|---|---|---|---|
| **LWIR Sagnac Interferometer** | 9.3 – 11.3 | Absolute Index (Bulk) | Any | Homogeneous | Accuracy limited by sample thickness measurement and sample preparation. | Plane parallel window. Diameter > 25mm Thickness > 5mm | Wedge < 5 arcmin Thicker samples reduce measurement uncertainty |
| **\*Low Coherence Distance Measuring Interferometer** | VIS broadband | Absolute Thickness | N/A | GRIN or Homogeneous | Measures thickness map of plane parallel samples. Expected accuracy around ± 100nm. | Nominally plane parallel sample with polished surfaces | Wedge < 5 arcmin |
| **Beam Deflection** | 0.45-0.66 | Relative Index | Any | GRIN | Calculate relative GRIN profile by measuring laser deflection through GRIN material. | One-dimensional gradient. Plane parallel window or cylinder geometry | Wedge < 2° |
| **\*Thermal Interferometer** | 0.46-0.633 \*3.39 | dn/dT CTE | Any (-40 to 50°C) (\*-40 to 80°C) | GRIN or Homogeneous | Gives two-dimensional measurement of index and thickness change as a function of temperature. | Thin (~1mm), plane, parallel slice. Index is constant through sample thickness (exposed gradient). | Figure error < 1λ Wedge error < 3µm over region of interest. Reflective coating on one half of one surface |
| **\*Mini Mach-Zehnder Interferometer** | 0.6328 \*0.5435 | Relative Index | Any | GRIN | Microscope configuration for small samples or large fringe densities. | Thin (~1mm), plane, parallel slice. Index is constant through sample thickness (exposed gradient). | Figure error < 1λ. Wedge error < 3µm over region of interest. |

| Instrument | Best Case Error Bar | Advantages | Disadvantages |
|---|---|---|---|
| **Mach-Zehnder Interferometer** | $2 \times 10^{-5}$ | - Very versatile and robust measurement method<br>- Schmidt immersion method provides absolute index | - Sample prep problems can limit measurement accuracy<br>- Sample prep is typically destructive |
| **Abbe and Pulfrich Refractometers** | $1 \times 10^{-5}$ | - Robust measurement method | - Limited by reference prism and available index fluids<br>- Surface measurement only |
| **Sagnac Interferometer** | $1 \times 10^{-4}$ | - Average index measurement<br>- Used for any index or wavelength range<br>- Uses plane parallel sample rather than prism | - Limited by sample thickness measurement<br>- Sensitive to scatter and surface shape |
| **Beam Deflection** | $1 \times 10^{-3}$ | - Nondestructive test for certain geometries<br>- Can be implemented in-process | - Limited accuracy<br>- Requires constant index in propagation direction |
| **Thermal Interferometer** | CTE and dn/dT to 2 or 3 digits | - Gives CTE and dn/dT as a function of (x,y)<br>- Useful for GRIN and homogeneous materials | - Double pass (reduces effective fringe resolution)<br>- Requires environmentally controlled chamber |