LUMETRICS®
Precision Measurement Solutions

Application Note AP-110-01

REAL-TIME GROUP REFRACTIVE INDEX MEASUREMENT OF FLUIDS USING INTERFEROMETRY

Jeremy Crouse, *Opto-Mechanical Engineer*, *Lumetrics*

***Abstract* — Maintaining proper chemical composition of fluids is an important control parameter for a variety of different production processes. This is especially critical in the medical device manufacturing to maintain high quality standards. One method to monitor fluid composition is to measure its refractive index.**

Lumetrics offers a commercial low-coherence interferometer, the OptiGauge II. Combined with custom software, the group refractive indices of fluids can be quickly and accurately measured, on- or off-line.

I. Introduction

Medical grade fluids must be held to extremely tight compositions. Manufacturers need a system that has repeatable measurements, high accuracy, ease of use, and could be used either online or offline. Refractive index of the solution offers one such indicator, which is directly correlated with the chemical composition of a solution mix. There are two types of the refractive index – phase refractive index (PRI) and group refractive index (GRI). PRI and GRI are in general very close to each other in value. While PRI is more difficult to measure, GRI can easily be measured using a time-domain low-coherence interferometer.

Lumetrics offers off-the-shelf low-coherence interferometer (OptiGauge II) to address the measurement needs associated with these fluids. When combined with opto-mechanical or software development, it offers powerful custom metrology solution to multiple online manufacturing and quality control applications.

II. Description of the Experiment

The GRI is measured online utilizing the OptiGauge II and the OptiGauge Control Center software. Figure 1 shows the setup of the fluid GRI measurement experiment.

The 1310nm wavelength light from the OptiGauge is directed into the measurement probe via optical fiber. The probe refocuses the light into a plastic tube, positioned directly underneath the optical probe. The reflected light is then collected by the probe, and is analyzed by the interferometer located inside the OptiGauge. The interferometer then extracts the value for the inner diameter (ID) of the tube.

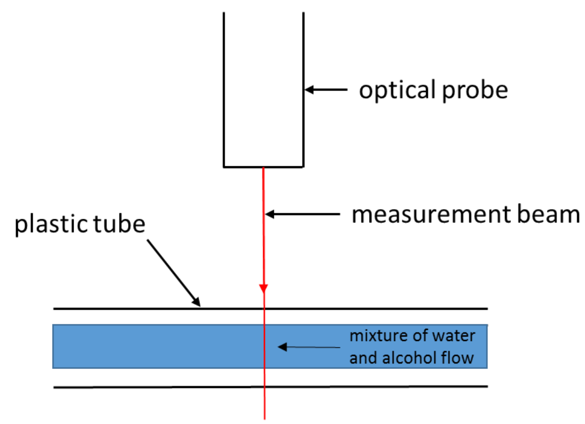

Figure 1: Fluid GRI measurement experiment setup

The extracted thickness value is so-called optical thickness – it is equal to the inner diameter of the tube multiplied by the GRI of the air or liquid filling the tube.

At first, the tube is measured empty to extract its actual physical dimensions, since the GRI of air is approximately equal to one[1]. Then, the fluid is pumped through the tubing, and the optical thickness of the ID is measured in real-time. The GRI of the fluid is then calculated using:

$$GRI_{liquid} = ID_{liquid}/ID,$$

[1] See www.refractiveindex.info for refractive indices of air, water, isopropyl alcohol and many other materials.

where ID_{liquid} is the optical thickness of the inner diameter of the tube with liquid present.

III. Results

The real-time liquid measurements are first conducted by pumping pure water through the tubing. Then, the isopropyl-alcohol was added to the water, and its concentration slowly increased, while continually pumping the solution through the tubing.

The initial GRI measurements are expected to be close to the GRI of water at room temperature (1.330 at 20°C), and slowly increase as the concentration of the alcohol increases. The group refractive index of pure isopropyl alcohol is 1.378.

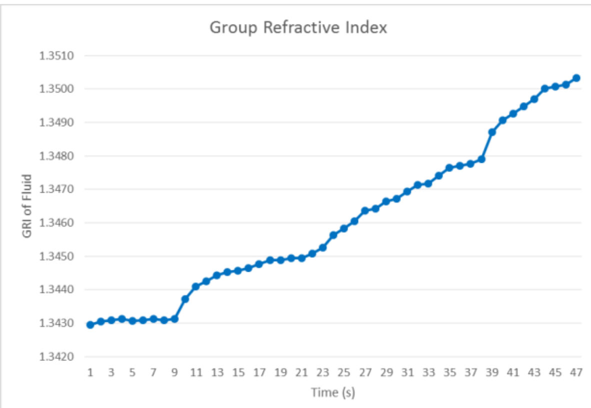

Figure 2: Measured GRI of a mixture of water and alcohol, alcohol concentration is increased over time

Figure 2 shows obtained measurements. At first, only water was flowing through the tubing for the first 9 seconds, as shown by the flat portion of the graph. The measured GRI is 1.343, close to the expectations.

Around the 9 second mark, the isopropyl alcohol is added to the solution and its concentration slowly increased. In agreement with the expected behavior, the measured GRI is slowly increasing. Thus, using the GRI, one can control the rate of the addition of the alcohol to the water solution to stabilize the concentration at the certain set point.

Please note that the refractive index also depends on other environmental factors, such as the temperature and pressure. With proper precautions, the GRI measurements can also be used to maintain these parameters at a preset level. Temperature dependence of the GRI will be addressed in another application note.

IV. Conclusion

The OptiGauge II is a powerful non-contact optical measurement instrument. It can precisely measure wall thickness, ID, and OD of transparent and even some visually opaque materials, including tubing. This can be utilized to calculate the measured group refractive index of fluids. The OptiGauge II can be integrated onto production lines for fast inspection of fluids for instant feedback, which can be tied into the control system of the fluid's composition.

Lumetrics engineers can quickly answer any questions pertaining to software communication with these products, mechanical mounting, or any other technical question to help you evaluate an application.

Contact Lumetrics for additional information

Email: sales@lumetrics.com or engineering@lumetrics.com