ADVANTAGES OF LOW - COHERENCE INTERFEROMETRY OVER NUCLEAR - BASED GAUGES

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***Abstract* —Many film manufacturers depend on nuclear gauges (beta, gamma or x-ray) for quality control during manufacturing, e.g. monitoring layer thickness. Low coherence interferometry is a proven measurement technology capable of replacing aging and costly nuclear-based gauging systems. It offers number of advantages with respect to safety, precision, and total cost of ownership.**

***Index Terms* — nuclear, gauge, multiple layers, interferometry, metrology, optics, non-contact thickness measurements.**

In addition to the obvious safety issue, one of the biggest pitfalls of nuclear gauging is its inability to measure multiple layers at once directly. If a film manufacturer wants to know the thickness of a coating on a roll of film using nuclear gauge, it typically has to use an indirect measurement method called subtractive measurement. Subtractive measurement requires two separate nuclear gauges: the first one placed in production line in a location before the coating is applied, and a second gauge placed in a location after the coating is applied. The difference in thickness between those spots is subtracted to calculate the thickness of the coating. It is important that these two nuclear gauges be positioned and timed in such a way that they measure the same location on the film. Therefore, such configuration not only doubles the cost of the measurement system, but requires complex alignment and maintenance.

Lumetrics has developed and commercialized a low-coherence interferometer called OptiGauge II, which uses invisible 1310nm light to measure the thicknesses of multiple layers at the same time in a non-contact manner. In the example of the film manufacturer, a single probe is positioned at a location after the coating is applied. The point-like measurements are conducted at speeds ranging from 50 to 200 times per second.

Nuclear gauges have strict regulatory compliance requirements, special permits are needed to own and operate the equipment. According to the USDA, there are two levels of authorized users. Permit holders and associate users. Not only must these authorized users have their names on the permit for the gauge but also have their own individual permits issued by the Radiation Safety Division. In addition to authorization for the users there are regulations relating to purchasing, transporting, storage and disposal of the gauge itself[1]. This can slow down the deployment process at the time when having proper measurement is critical, as well as require additional company resources to maintain proper documentation and compliance.

The OptiGauge II is classified as a Class 1 laser – the light emitted by the device is considered to be safe. Therefore, OptiGauge II does not result in a burden of regulation.

The decay nature of radioactive materials means that the nuclear gauges must often be recalibrated. At the same time, the calibration of OptiGauge II is maintained internally using single wavelength of a highly stable laser source. Due to the constant nature of the transition energy levels in the atoms for the laser gain medium, recalibration of such low-coherence interferometer therefore is never required.

The large size of the nuclear gauge limits number of locations where such measurements can be accommodated on the production line, and often may require modifications to the line. On the other hand, the optical probe of the low-coherence interferometer is small and can be easily mounted on existing beams. The probe is connected to the main control unit via an optical fiber cable which can be extended by hundreds of meters.

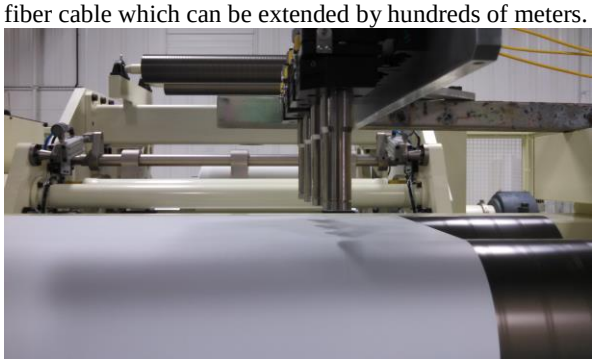

Figure 1: Optical probes mounted on a production line

CONCLUSION

Alternative technologies to nuclear gauging are becoming increasingly popular due to the negative characteristics of nuclear gauging. Optical technologies, such as the one used in the OptiGauge II, offer versatility, safety and added capabilities as compared to the nuclear gauges. For further information review the table on the next page.

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[1] USDA Office of Homeland Security & Emergency Coordination Radiation Safety Division (RSD), Nuclear Gauges, https://www.dm.usda.gov/ohsec/rsd/nucleargauges.htm

Lumetrics OptiGauge	Nuclear-based Gauges
SAFETY	
Based on Class 1 laser source (inherently safe)	Based on radioactive materials Source of ionizing radiation
No safety training needed	Safety training required
No regulatory requirements	Complex permit-based regulatory requirements
MEASUREMENT CAPABILITIES	
On-line, at-line and off-line capabilities	Online measurements only
Accuracy: < 1 micron	Accuracy: +/-0.25% of reading (or $0.1 g/m^2$). Whichever is greater
Rate of measurement: 50 to 200 Hz	Rate of measurement: 200Hz
Point-like measurements: measurement spot of 10 to 80 microns in diameter depending on the probe	Averaged measurement of a large area (15mm diameter)
CONFIGURABILITY	
Small (a cylinder 3" long with 0.85" diameter) and lightweight (60 to 80 grams) probe does not require dedicated space in a production line, e.g. it can be installed at one of the rollers	Probe dimensions vary, with a most common head having a cylindrical shape 13.4" long with 3" diameter requires sufficiently big space availability between the rollers
Measurement probe can be connected to a remote main unit via a long optical fiber (no electrical cabling needed)	Measurement head can be connected to a remote unit via a long wire
Probes compatible with harsh environment (high temperature, caustic chemical vapor, vacuum)	Accessories available to make suitable for harsh environments
Multiplexing capability - multiple inexpensive probes can be connected to a single measurement unit	No multiplexing capability - measurement head is responsible for the majority of the instrument cost
Large available working distance for the probes (from 1 inch to meters)	Fixed close distance (16mm to 32mm) is required between the emitter and receiver portions of the measurement head
MEASUREMENT SETUP	
Single probe positioned on one side of the material (for translucent materials only)	Measurement head has two parts that must be positioned on the opposite sides of the material
Alignment is required to obtain perpendicularity of the measurement beam to the sample	Alignment is required to achieve proper relative positioning of the emitter and receiver
Initial startup time: 1 hour	Initial startup time: 1 day
Continuous operation after the initial startup	Continuous operation after the initial startup
MAINTENANCE	
Re-calibration is not required – calibration is maintained using an internal laser.	Periodic re-calibration is required - nuclear source is continuously degrading
Minimal maintenance of the measurement optical probes (household products can be used to clean the probe)	Measurement head is the primary component that requires maintenance and servicing off-site by qualified technicians
Production line is unperturbed if the main unit requires maintenance off-site – simply disconnect the optical fiber connecting the main unit to the optical probe	Production line must be stopped for removal of the measurement head to be serviced off-site