Differentiating among works

The hyperspectral datacubes of three paintings, seemingly identical except for frame and dimensions, were captured (one large original in a frame, one large unframed copy, and one small unframed copy). The subjects were placed at approximately a 1-m working distance from the hyperspectral imaging system. The imager was mounted on a standard camera tripod for stability. The objective lens presented a 19° field of view to a CMOS sensor that captured images at up to 2.3-MP spatial resolution with demosaicking. A quartz tungsten halogen lamp source and diffuser was positioned to provide uniform illumination over the area of interest.

Quartz tungsten halogen sources cover a broad spectral range from the visible through the near-infrared (250 to 2500 nm) with a relatively flat spectral response, and they complement the response range of the imaging system (400 to 1000 nm). Depending on the nature and sensitivity of the pigments used in the artwork, alternate light sources such as high-brightness white LEDs that also provide broad and relatively flat spectral profiles may be preferred. These LED-based light sources are typically composite systems involving a combination of elements (e.g., RGB, Y, W) (Figure 1).

The paintings were created using different paints, but significant effort was made to make them resemble one another as much as possible in terms of reproduction style and technique. Figure 2 shows the artwork in question, with two randomly selected landmarks indicated.

To confirm that the instruments were capturing repeatable measurements of the samples, multiple measurements of the landmarks were made for each version. Scaled registration of the different size images was applied to ensure that spectra from the same relative locations were identified (Figure 3).

A comparison of the spectra at various landmarks on the images of the three samples reveals that there are clear and distinct differences between the framed original and the copies (Figure 4).

To efficiently assess the authenticity of a work in its entirety, classification algorithms can be applied to the datacubes. Using the spectra from the authentic piece as the reference library for the classification, a spectral angle mapping algorithm was applied to the three works. A threshold value — the spectral angle at which a pixel was considered close enough to the reference or the pixel was rejected — was adjusted and optimized by trial and error. Thus, the process compared spectra pixel by pixel, and if the spectral angle was larger than the threshold, the pixel was identified as bad. This meant the piece was labeled a counterfeit. The bad ratio was defined as the number of bad pixels divided by the total number of pixels. The bad pixels were indicated by a false color map of the artwork image (Figure 5).

Note that some of the areas associated with the two landmarks were flagged as bad (the eye) or good (the apple) on most of the images, even though the spectral points sample demonstrates a difference. This can be attributed to variances that straddle the tolerance of the spectral angle threshold. However, the algorithm positively and reliably distinguishes between the authentic piece and the copy in terms of the entirety of the image. The results are intuitively interpretable. This approach thus provides a means by which nonexperts can use the instrument in the process of authenticating art.

By identifying distinctions in images that are not only invisible to the eye but also to color (RGB) cameras and even multispectral imagers, hyperspectral imaging cameras can provide rapid assessment of the authenticity of artwork. In the examples discussed, an advanced hyperspectral imaging system was able to quickly provide an intuitive means by which to differentiate between the original and the reproductions. This example serves to demonstrate the importance of a turnkey tool for use in art authentication. This solution can be used to augment current methods or it can potentially be used as a primary tool.

The unique combination of portability and the ability to dynamically change spectral range and bandpass capability means that the same hyperspectral instrument can be configured for a wide variety of parameters and points of interest in the field. This both optimizes accuracy and reduces the time to capture the image. The semiconductor manufacturing processes involved in the fabrication of the Fabry-Pérot interferometer means that the technology is not only miniature, yielding a lightweight and compact device, but also scalable and much more economical than competing hyperspectral technologies, such as pushbroom systems, which are manually assembled in a time-consuming manner. Extension farther into the infrared range of the spectrum would enable the platform to detect and analyze hidden layers of paint, possibly unearthing even more valuable cultural treasures such as earlier iterations of the versions of a painting.

Finally, the cost advantages of this technology relative to other hyperspectral imaging solutions also vastly improve access for all such potential uses, making it available to both world-renowned institutions and smaller museums.

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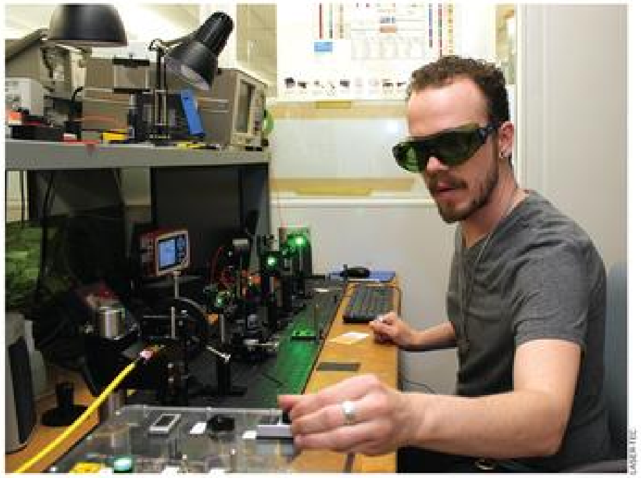
Springfield Technical Community College, Springfield, Massachusetts

LASER-TEC is the Center for Laser and Fiber Optics Education, founded in 2013 by the National Science Foundation (NSF) and headquartered at Indian River State College in Florida. It was established to help meet the goals of educating and sourcing domestic talent in the areas of optics and photonics. As a service to students, recent graduates, and prospective employers, Photonics Spectra *runs a profile of one of the 35 LASER-TEC colleges each month.*



A Springfield Technical Community College student measures laser beam characteristics.

LASER-TEC

Springfield Technical Community College (STCC) offers a one-year Optics and Photonics Technology certificate and a two-year Optics and Photonics Technology Associate of Science degree. The programs give engineering technicians knowledge of lasers and optics, and provide the electronics skills needed to design, test, and maintain complex optical and photonic systems. Graduates work side by side with engineers and scientists involved with cutting-edge applications in a wide variety of highly technical applications. Applications include laser materials processing, fiber optic communications, precision optical manufacturing and metrology, aerospace and defense, homeland security, medical device fabrication, nanotechnology, and integrated photonic devices.

As the only program of its kind in New England, STCC's Optics and Photonics Technology program graduates are highly sought after by industry and have enjoyed excellent job placement and salaries since 1976. Companies that hire STCC graduates include MIT Lincoln Lab, Northrop Grumman, Coherent, Lumentum, TRUMPF, OFS, IPG Photonics, Convergent Photonics, Viavi Solutions, II-VI Inc., L3Harris, and Zygo.

Programs

One-year Optics and Photonics Technology certificate

Two-year Optics and Photonics Associate of Science degree

These one- and two-year programs with strong interdisciplinary core curriculum provide extensive hands-on training in state-of-the-art optics and photonics labs. The one-year certificate program, which serves as the first year of the associate degree program, provides students with extensive theoretical and hands-on training in lasers and laser systems, fiber optics, geometric optics, electronics, and SolidWorks, along with other manufacturing essentials. The associate degree program builds on the certificate program by providing additional advanced coursework in industrial laser applications, wave optics, advanced topics, and a yearlong senior capstone project. The curriculum is heavily project- and problem-based, and the majority of students have paid internship opportunities with local laser and optics companies.

Graduates of the associate degree program will have the skills to:

- Align, clean, build, and test complex optical systems.
- Strip, cleave, clean, and align multimode, single-mode, and dual-clad fiber.
- Calculate and measure fiber optic power loss in decibels and power in decibels per milliwatt.
- Determine modal dispersion, chromatic dispersion, and system bandwidth.

- Terminate and test fiber optic cables for connector and insertion loss.
- Operate optical time-domain reflectometers, fusion splicers, optical spectrum analyzers, fiber inspection microscopes, and fiber optic loss test sets.
- Identify fiber loss mechanisms and create fiber optic power budgets.
- Align, operate, and characterize LEDs, laser diodes, and photodetectors.
- Operate, test, and troubleshoot erbium-doped fiber amplifiers, wavelength-division multiplexers, add/drop multiplexers, circulators, thin-film filters, and fiber Bragg gratings.
- Design, build, and test electronic circuits and devices.
- Use oscilloscopes, multimeters, signal generators, spectrum analyzers, and laboratory power supplies.
- Apply electrical and laser safety standards and practices.
- Operate, test, and maintain ytterbium- and erbium-doped fiber lasers.
- Operate, test, and maintain CO_2, argon-krypton, and HeNe gas lasers.
- Use a laser power and energy meter to measure the output power and energy of a laser.
- Use a laser beam profiler to measure the spatial output characteristics of a laser.
- Use an optical spectrum analyzer to measure the temporal output characteristics of a laser.
- Test, maintain, and troubleshoot basic laser components.

How to recruit from this college

Come to our college to present your company and employment opportunities to our students. We will make available, free of charge, a private room to interview interested students. Please contact the person below to make arrangements for a recruiting visit. Interns and graduates are available every summer.

Contact information

Nicholas Massa
+1 413-755-4579
massa@stcc.edu
1 Armory Square
Springfield, MA 01102

Program websites

www.stcc.edu/explore/programs/leot.as
www.stcc.edu/explore/programs/leot.coc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1 3D Printer

The Quantum X shape 3D printer from **Nanoscribe GmbH & Co.** is designed for rapid prototyping and wafer-scale batch production in life science, materials engineering, and microfluidics applications, among others. With a galvo system and smart electronic system control units on a sturdy granite-based platform, the printer uses an industry-grade pulsed femtosecond laser to provide microfabrication processes for nano- to mesoscale-size structures. The Quantum X shape features size control down to 100 nm in all spatial directions for nano- and microscale printing. Mesoscale printing for objects with sizes up to 50 mm is possible.
info@nanoscribe.com

2 Laser Power Sensor

The Ophir F80(120)A-CM-17 laser power sensor from **MKS Instruments Inc.** is a thermal sensor for measuring high-repetition-rate lasers with short pulses in the nanosecond, picosecond, and femtosecond ranges. The F80(120)A-CM-17 is a compact, calibrated, fan-cooled sensor that can withstand higher power densities. It measures average power up to 80 W and intermittent power up to 120 W. The device can be used for micromachining and materials microprocessing applications in the semiconductor, display, and medical industries.
sales.ophir.usa@mksinst.com

3 Autonomous Laser Scanning

BLK ARC, from **Leica Geosystems AG**, is an autonomous laser scanning module for robots. The device can be integrated with multiple types of robotic carriers to enable autonomous mobile laser scanning. Fully autonomous and repeatable scan missions are possible. BLK ARC captures 3D point clouds and panoramic imagery as the robot moves through an environment.
info@leica-geosystems.com

4 UAV Lidar

The YellowScan Explorer long-range multi-platform lidar from **YellowScan** is a compact device designed for use with unmanned aerial vehicles or lightly manned aircraft. Its high-power laser scanner can catch points up to 600 m away, and its 2.3-kg weight enables an integrable system. When the Explorer is combined with YellowScan's software suite, users can easily extract and process point cloud data to meet the needs of the surveying, environmental research, archaeology, utilities, industrial inspection, civil engineering, and mining sectors.
contact@yellowscan-lidar.com

5 3D Sensor

The reflectCONTROL sensor from **Micro-Epsilon UK** is a compact, 3D noncontact surface inspection system that enables fast, reliable defect detection on shiny and reflecting surfaces such as polished or painted metals, glass, and mirrors; painted plastics; and galvanized surfaces. Based on the deflectometry principle, the reflectCONTROL sensor can be used in a stationary mode for assembly lines or mounted on a robot to perform inline inspection. Inspection cycles are <2 s per measuring position, and the sensor provides a large measuring field.
info@micro-epsilon.co.uk

6 LED Line Illuminators

The LTLNC series of ultrahigh-power LED line illuminators from **Opto Engineering SRL** are designed for line-scan applications. The illuminators' design provides a powerful and homogeneous beam of light that is sharply focused onto the object that must be inspected via a condenser lens. The devices dissipate the generated heat due to the fins machined in the aluminum housing and the air-cooling ports designed to inject compressed air into the illuminator. The LTLNC series features industrial M8 connectors and can be easily installed into any machine vision system through its four M3 threads in the rear part of the aluminum housing.
info@opto-e.com