QUALITY ASSURANCE WITH SPECTROMETER HARDWARE APPS FOR MOBILE SMART PHOTONIC SPECTRAL MEASUREMENTS

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ABSTRACT & Introduction

An important key factor for the spectral revolution in smart instrumentations for mobile spectral measurement technologies in diagnostics is the entry of Microsoft into the smartphone and smartpad market. The Microsoft Surface smartpad with its standardized PC architecture and Windows 8 operating system can easily be applied for many proven spectral measurement applications without re-inventing or re-adjusting available approved software. Most industrial and laboratory software packages are designed for Microsoft Windows operating systems. They are running directly on Windows smartcomps or indirect virtually or remotely on Apple and Google smartcomps. Another key factor is the reduction of the mass, size and price of the measurement modules.

Aim of the paper is the demonstration of a paradigm shift in measurement engineering and quality assurance. Smartpads, smartphones and smart wearables (smartcomps) in combination with hardware apps (hwapps) and software apps (swapps) are fundamental enablers for the transformation from stationary working places towards innovative mobile working places with in-field measurements and point-of-care (POC) diagnostics for process control and quality assurance. Practical examples for the application of innovative mobile smart photonic spectral measurement systems will be given.

Index Terms **–** smart, mobile, hardware apps, spectral

1. EVOLUTION OF SPECTRAL MEASURMENT SYSTEMS

Looking on the roadmap of spectral measurement systems it is evident that the weight (mass) of the systems has been reduced significantly in the past thirty years (Figure 1) [1]. A new qualitative step in the further development of spectral measurement systems can be expected under the influence of miniaturized spectrometer hardware apps, smartcomps and proven software apps.

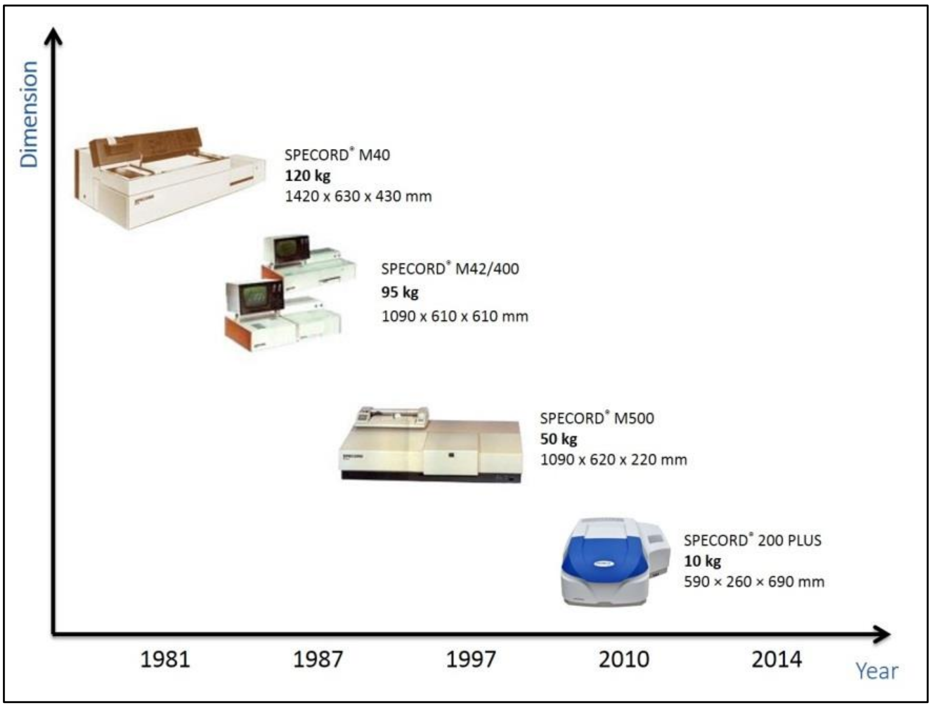

Figure 1: Roadmap of spectral measurement systems

2. MOBILE SMART PHOTONIC SPECTRAL MEASURMENT HARDWARE APPS

Real objects are becoming visible by emitting or reflecting photons. The wavelengths of these photons depend on the object's composition, along with other attributes such as temperature. The human eyes perceive the presence of photons with different wavelengths as different colors. For example, photons with a wavelength of 620 to 750 nanometers are perceived as red. Full spectra are measured with spectral measurement systems. With spectral measurement systems an unknown photonic spectrum is evaluated in terms of known spectra concerning its wavelengths and amplitudes. Spectral measurements are of great importance in industry, biology/medicine, environmental protection and security. Mobile smart photonic spectral measurement system hardware apps are equipped preferably with standardized linear CCD sensors, USB interfaces and SMA connectors (Figure 2) [2].

		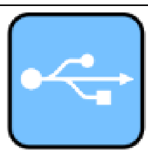	
Linear CCD sensors	Hardware modules	USB interfaces	SMA connectors
	Sensor: 2500 pixel linear CCD, 360 - 740 nm, 1.2 nm FWHM Digital interface and power requirements: 5V USB 2.0, 150 mA Dimensions and Weight WxHxD: 85.7 × 22.0 × 10.0 mm, 10 g		

Figure 2: Mobile smart photonic spectral measurement hardware apps

3. EXAMPLES FOR MOBILE SMART PHOTONIC SPECTRAL MEASUREMENT HARDWARE APPS

Examples for photonic spectral measurement hardware apps are shown (Figure 3) [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14]. They are already on the market. All these hardware apps are different concerning traditional spectral measurement systems by their size, weight and price. Nevertheless their precision and spectral resolution is comparable with conventional spectral measurement systems. These new types of spectrometers are available in the spectral range from UV to NIR.

logo	lasersystems LEADING PHOTONICS	lasersystems LEADING PHOTONICS	Ocean Optics	Ocean Optics
spectrometer module				
spectral range	360 - 740 nm	220 - 1100 nm	350 - 800 nm 650 - 1100 nm	900 - 1700 nm
logo	zbs	ZEISS	THORLABS	ASENSETEK
spectrometer module				
spectral range	340 - 1100 nm	190 - 1000 nm	200 - 1000 nm	380 - 780 nm
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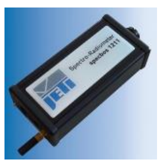
spectrometer module				
spectral range	900 - 1700 nm	350 - 950 nm	250 - 1000 nm	360 - 830 nm

Figure 3: Mobile smart photonic measurement hardware apps

4. CALIBRATION OF MOBILE SMART PHOTONIC SPECTRAL MEASURMENT SYSTEMS

As mentioned above, to get an information about an unknown spectrum the spectral measurement system has to be evaluated in terms of known spectra concerning its wavelengths and amplitudes.

For that purpose reference measurements with calibration lamps are necessary. High pressure mercury vapor arc-discharge lamps and incandescent lamps such as tungsten-halogen lamps can provide intense illumination over selected wavelength bands throughout the visible spectral region when combined with appropriate filters. These illumination sources are highly reliable, produce high flux densities, and have historically been widely used in fluorescence microscopy. However, compared to traditional incandescent lamps the significant increase in brightness afforded by mercury arc lamps is accompanied by the inconvenience of critical mechanical alignment, shorter lifetime, decreased temporal and spatial homogeneity, specialized lamp houses and power supply requirements, potential explosion hazards, and higher cost (Figure 4) [15].

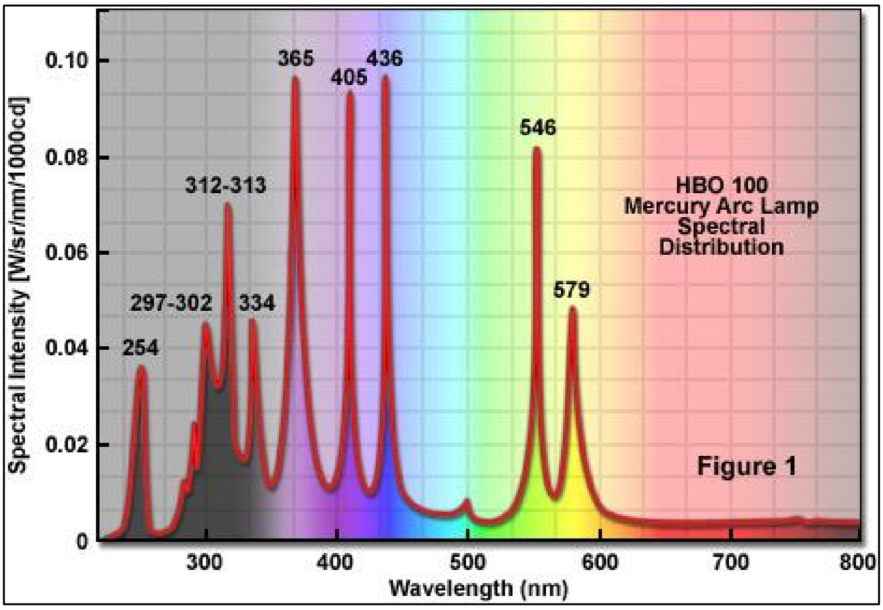


Figure 4: Calibration spectra of mercury vapor arc-discharge lamps

5. APPLICATIONS OF MOBILE SMART PHOTONIC SPECTRAL MEASURMENT SYSTEMS

Huge numbers in applications of smart computers for private life support their applications also in working life.

The new combinations of autonomous function modules for spectral measurements with smartphones and smartpads offer new possibilities for mobile spectral measurements in:

- Agriculture/Horticulture
- Automotive Industry
- Beauty and Cosmetic Industry
- Chemical Industry

- Displays/Projectors
- Electrical Industry
- Pharma Industry
- Petrochemical Industry
- Lighting Industry
- Metal industry
- Polymer Industry
- Printing Industry
- Production Industry
- Textile Industry

LEDs are configured to stimulate plant growth in greenhouse environments. Horticulturists are interested in the effects of light on the growth of their crops. Investigations have shown that especially blue and red light of LEDs affects both the growth rate and blossoming of various floral crops. The idea is to better tune the spectral content to match the needs of the crops. Continuously monitoring the LED emission spectrum with a miniature spectrometer enables growth patterns to be correlated with the illumination spectra (Figure 5) [16], [17].

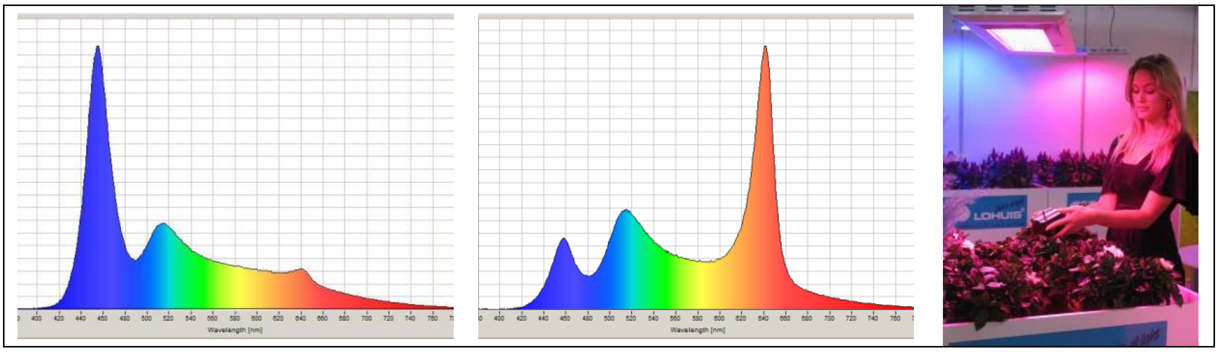


Figure 5: Monitoring of illuminations in greenhouses

In another example mobile smart spectral measurement hardware apps enable small Unmanned Aerial Vehicle (UAV) to collect spectral data in the visible or near-infrared wavelength range. They are equal in quality to ground based-spectrometers. They are also less complex and lower in cost than traditional hyperspectral imaging cameras (Figure 6) [17].

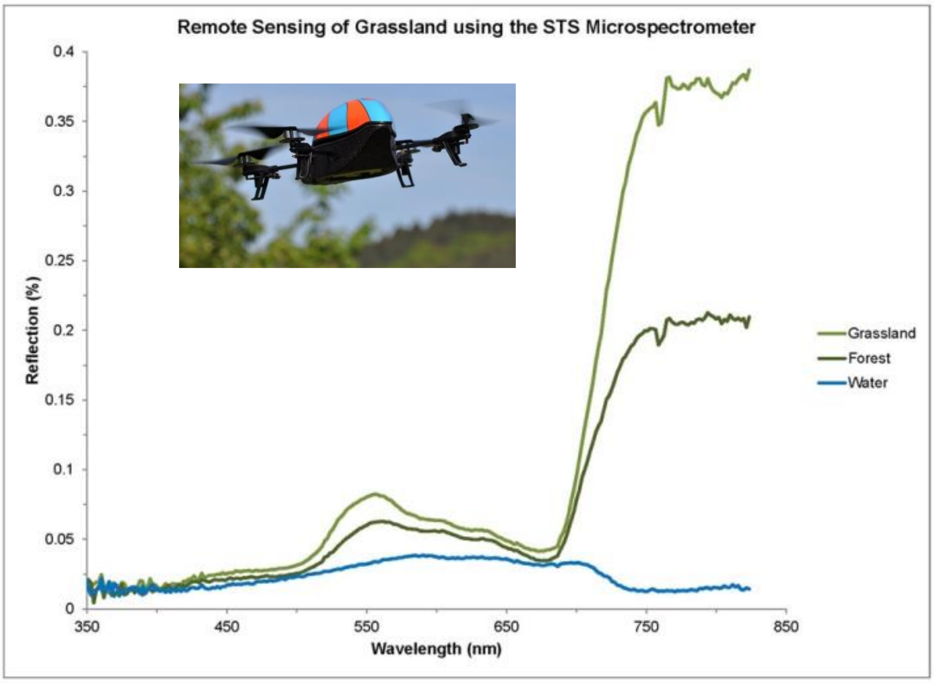


Figure 6: Spectral analysis of vegetation and ground cover

6. FUTURE DEVELOPMENTS OF MOBILE SMART PHOTONIC SPECTRAL MEASURMENT SYSTEMS

Nowadays mobile smart photonic spectral measurement systems can be designed by miniaturized spectrometer hardware apps and miniaturized smartcomps supported by proven software apps for Microsoft Windows operating systems (Figure 7) [18].

Figure 7: Hardware apps and software apps for mobile spectral measurements

7. CONCLUSIONS

The paper has shown significant elements of a paradigm shift in measurement engineering and quality assurance for mobile smart photonic spectral measurement systems. Details have been explained in detail.

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