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Digital transformation of education & training in photonical measurement engineering & quality assurance (PMQ)

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Abstract.
Aim of the paper is the promotion of the **worldwide new situation** that

- the contactless acquisition of measured quantities becomes more convenient + reliable + affordable (c+r+a) by **photonical** sensor systems,
- the mobile processing of measured values becomes more c+r+a by **mobile** microcomputers for example smartphones,
- the **substantiation** of quality assurance on objective acquired (measured) data becomes more c+r+a by digital transformation,
- the **unified** measurements of physical, physiological and chemo-analytical measurement quantities become more c+r+a by photonical measurement sensor systems with filters on CMOS chips to determine for example
  - **geo-physical** quantities (points, lengthes, areas and spaces of solids which nowadays can be acquired contactless with laser beams),
  - **medico-physiological** quantities (color sensitivities of test persons in accordance with standardized eye color sensitivity curves based on normally 7 Mio red-green-blue eye cuppings which are identifying up to 600.000 color shades) and
  - **chemo-analytical** quantities that means compositions of solids, fluids and gases which are measurable with spectrometers or nowadays with hyperspectral cameras.

1. Introduction into a new situation by historical road mapping

The **19th Century** was the century of mechanical MATTER processing. The social progress driver was the “artificial“ industrial processing of matter. Typical examples are steel factories and heavy machine industry. The clustering of industrial centers has been accomplished by country roads, water ways and rail ways.

The **20th Century** was the century of electrical ENERGY processing. The social progress driver was the “artificial” industrial processing of electrons. Typical examples are electric power stations and electric motors. The clustering of industrial power centers has been accomplished by overhead power lines and urban electricity networks. A parallel development was the dawn of information processing by mechanical, electrical and electronical computers and the information transfer by telephone, radio and television – analogue, wire-bound and wire-less.

The **21st Century** is the century of photonical INFORMATION processing. The social progress driver is the “artificial“ industrial and individual processing of photons. Typical examples are solar power stations and mobile information machines for imaging. The clustering of industrial and personal information centers is accomplished by smartphones with cameras and cloud-based image processing – digital, fiber-bound and fiber-less.

2. Digital and cloud-based education and training in photonical measurement engineering and quality assurance

The **SPIE Press catalog** [1] is the world’s largest collection of information on optics & photonics applied research. It contains > 450.000 research papers and 10 scholarly journals with around 18.000 new papers added each year, and > 250 eBooks. It is a valuable source for education and training in optics & photonics also.

The **SpectroNet** cluster [2] contains > 3.000 papers and > 2.000 videos dealing with photonic measurement engineering and quality assurance.

The **Industry** maintains academies, summer schools, hubs and training centers with valuable contributions for a digital transformed education & training in photonical measurement engineering and quality assurance. Selected examples are:

- European Imaging Academy [3],
- Photonics21 Summer Schools [4],
- Basler AG Imaging Hub [5],
- Fluke Open Imaging Training Center [6].

3. Systematizations in photonical measurement engineering and quality assurance

For easier understanding of new contents in photonical measurement engineering and quality assurance selected HOW’s and HOW-TO’s will be illustrated.

When speaking about photonical measurement engineering every part of the measurement circle must be considered. Applicable solutions for quality assurance through methods, hardware and software are essential (Figure 1).

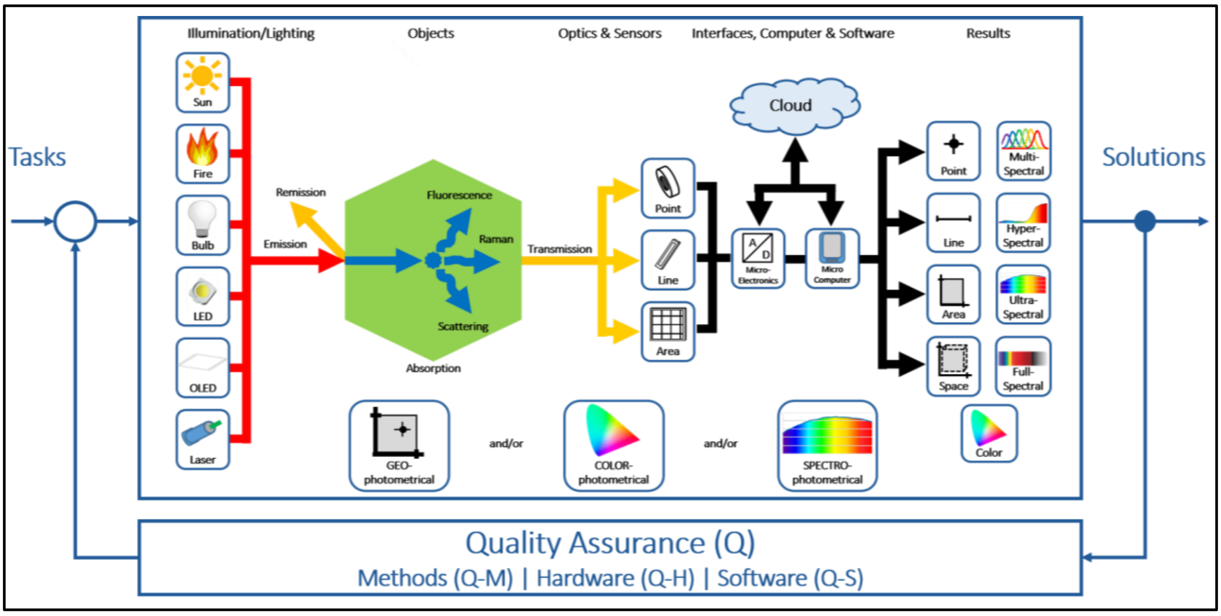

Figure 1. HOW and HOW-TO photonical sensor systems can be systematized.

Nowadays the so called "PhotoSensors 4.0" enable the technical and objective measurement acquisition of geo-, color- and spectro-photometrical information (Figure 2).

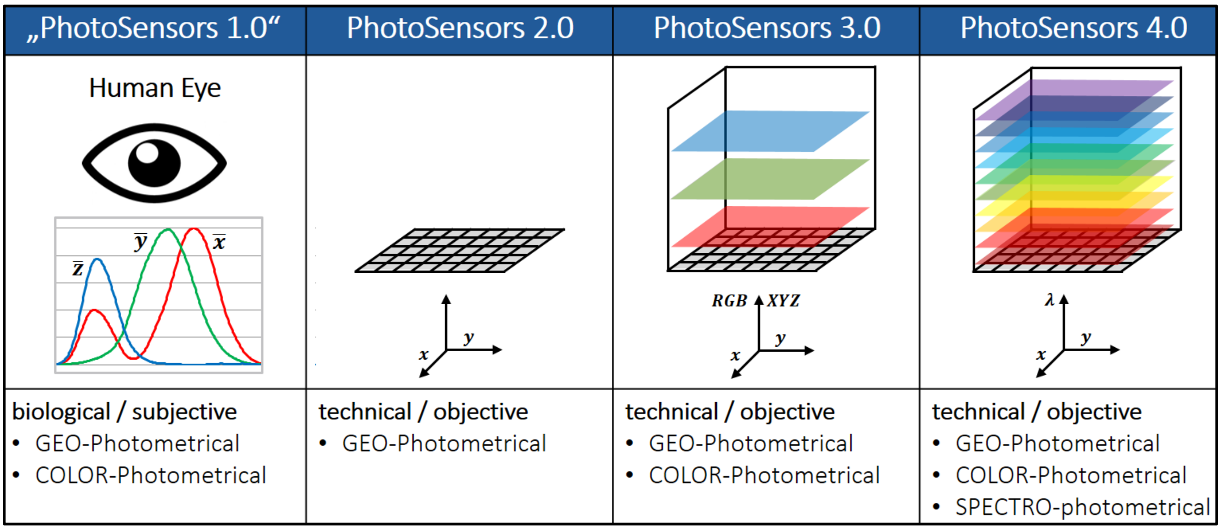

Figure 2. HOW and HOW-TO photo sensors can be arranged.

Concerning the application of PhotoSensors 4.0 there are different sensor principles which enable real-time acquisition (Figure 3).

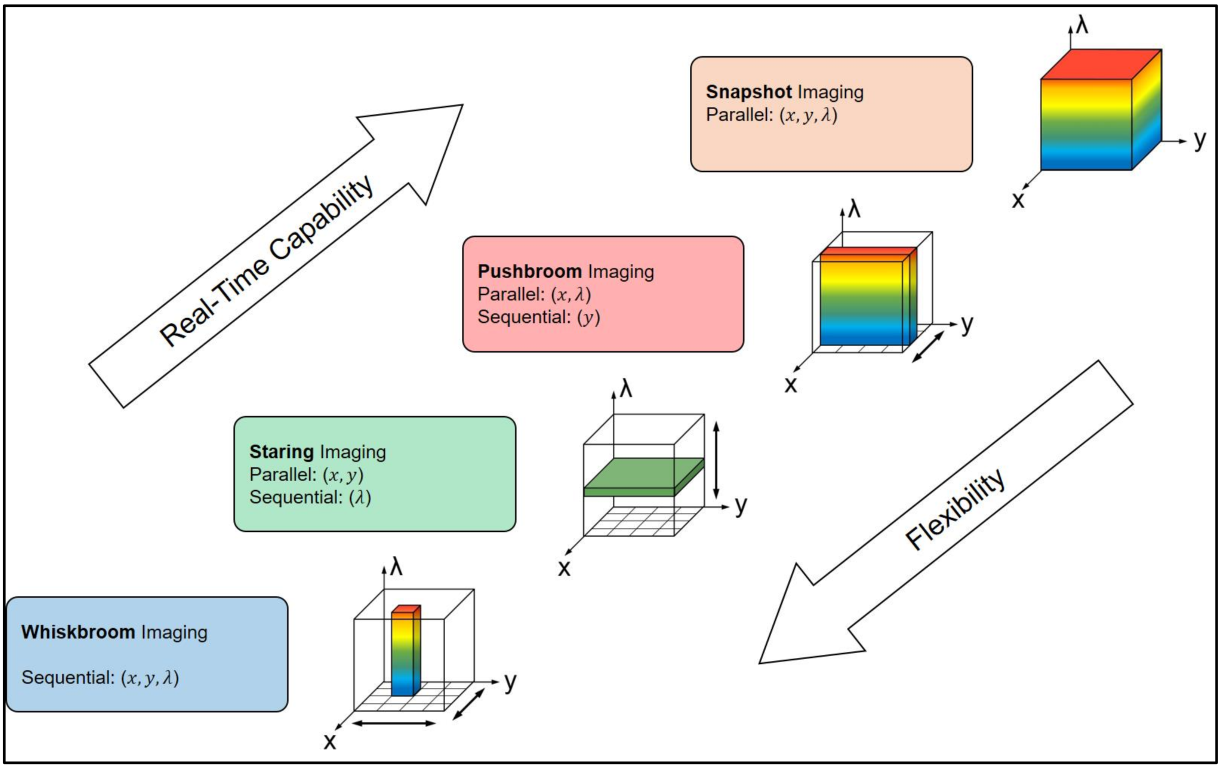

Figure 3. HOW and HOW-TO the real-time capability of photo sensors is construction dependent.

Latest developments of Photosensors 4.0 work with Filter-On-Chip (FOC) CMOS-Sensors. This enables the parallel acquisition of geo-, color- and spectro-photometrical information via video rates (Figure 4).

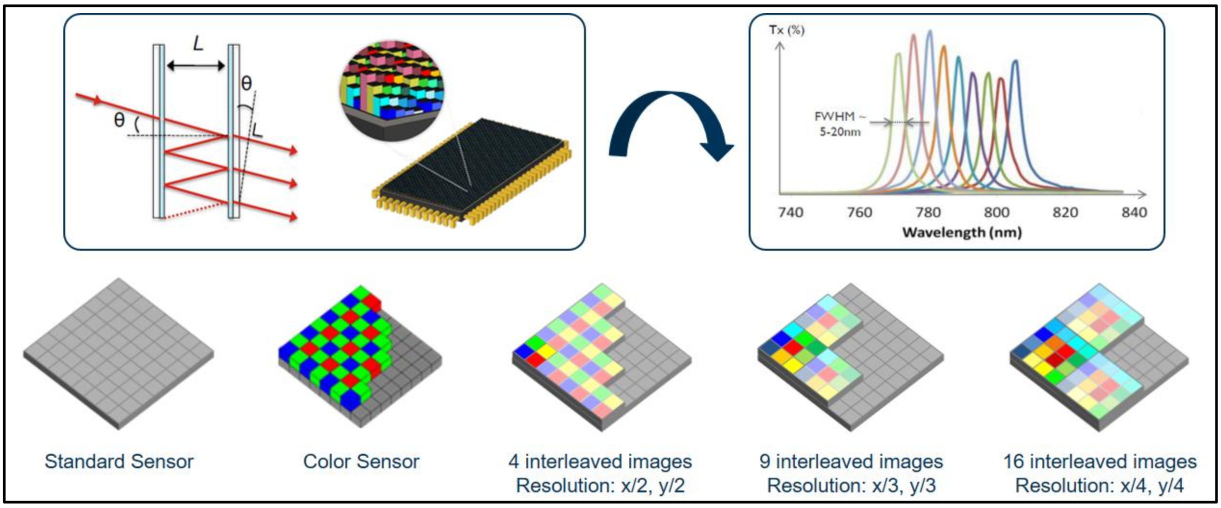

Figure 4. HOW and HOW-TO filter-on-chip solutions can be classified [7], [8].

Every developments in measurement engineering and quality assurance need their time to become usable as mass products. The current breakthrough of PhotoSensors 4.0 as multispectral Filter-On-Chip CMOS-camera systems started 40 years ago, by the “MKF 6” first multispectral camera which was developed and manufactured by Carl Zeiss Jena in 1976. The essential difference between latest developments and the first multispectral camera in 1976 is the reduction of mass (Figure 5).

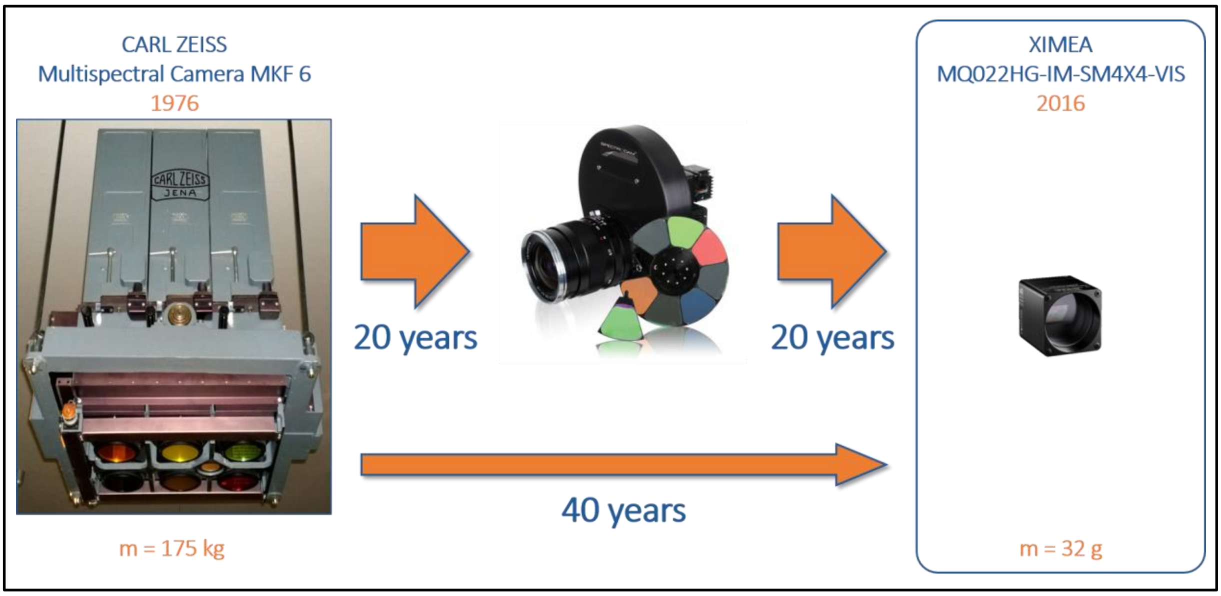

Figure 5. HOW and HOW-TO multispectral cameras lost their mass (weight) as a function of time.

Another main thing to realize is that photonical measurement engineering and quality assurance becomes applicable via hand-held photonical measuring systems and move into the mass markets (Figure 6).

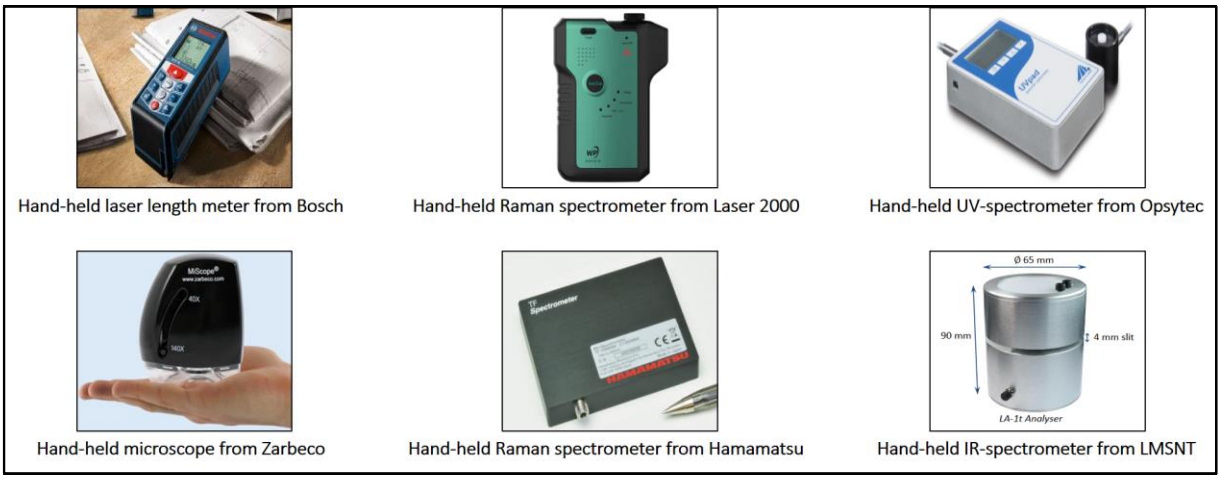

Figure 6. HOW and HOW-TO hand-held photonical measuring systems move into the mass market [9], [10], [11], [12], [13], [14].

Through latest developments in photonical sensors and their usable detector ranges as well as optical materials show the extension of the measurement regions from UV via VIS to NIR (Figure 7).

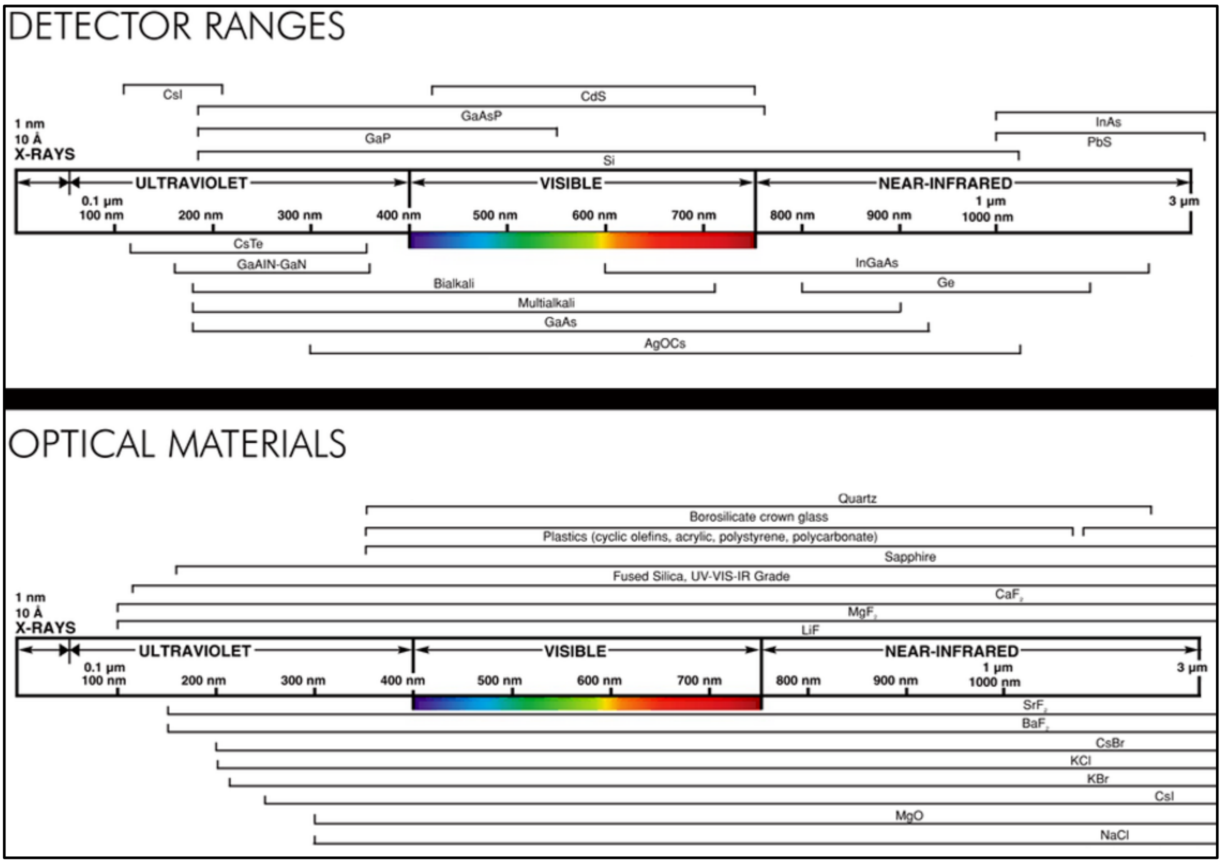

Figure 7. HOW and HOW-TO the measuring ranges are extended from visible to ultraviolet (left) and infrared (right) [15].

To overcome higher sensor complexity and the necessary complex data interpretation a big amount of software packages can be used for image processing (Figure 8).

Figure 8. HOW and HOW-TO image processing can be done.

When tackling complex sensors and systems education and training in photonical measurement engineering for employees, partners and customers is becoming more and more important. To tackle these facts one digital platform for self-service-learning by online accessible presentations and videos can be mentioned (Figure 9).

Figure 9. HOW and HOW-TO an individual digital education & training program can be done.

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4. Summary & Conclusions

Due to the well-known and accepted proverb "A picture is worth a thousand words" the 21st Century as Century of Photonics will be full of "enlightenments" in pictures. Selected HOW's and HOW-TO's have been illustrated to facilitate the understanding of the significant influence of photonics on daily life.

The digital transformation proves to be also a valuable assistant for education and training in photonical measurement engineering and quality assurance. The digital transformation makes education and training both self-controllable and c+r+a (convenient + reliable + affordable).

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