

DISRUPTIVE CHIP-SIZE TECHNOLOGIES PLAY THE DOMINANT ROLE IN THE GROWTH OF COMPACT SPECTROSCOPY

The first aim of development of compact spectrometers was to bring the lab measurements to the field or in the process line. By maintaining required performance level it was accomplished in many **industrial** applications: optical characterization, pharmaceuticals and biotechnology, chemistry etc. It was at the time when **miniature spectrometers** emerged (size <10 000 cm³).

Now it is still **research** and **industrial optical characterization** that possess the biggest shares within the compact spectrometer market. However, the better knowledge of end-users needs results in improving medium series applications (agriculture, environment) and also in developing further solutions for professionals (hair analyzers, textile identifiers, cannabis testers etc.).

INFORMATION SOURCES

- Tematys' in-house knowledge of miniature, micro and chip-size spectrometers technologies and markets.
- Interviews with around 60 key manufacturers of miniature, micro and chip size spectrometers and end-users.
- Bibliographic research.
- Attendance in several international conferences in the field of spectrometers.

Few years later the same spectrometers opened also new applications where spectroscopy **had not been used before**: precision farming, recycling, process control, etc. The range of potential applications became vast.

A **turning point** for the market is coming. It is the arrival of **global leaders** both in the role of manufacturers (**AMS, Osram, VIAVI**) and end-users (**Huawei, Samsung, Bosch, Henkel**). Big players will drive the market towards **consumer** and **biomedical** applications (images enhancement, personal monitoring etc.). This is possible due to the emergence of **chip-size spectral sensors** (<1 cm³).

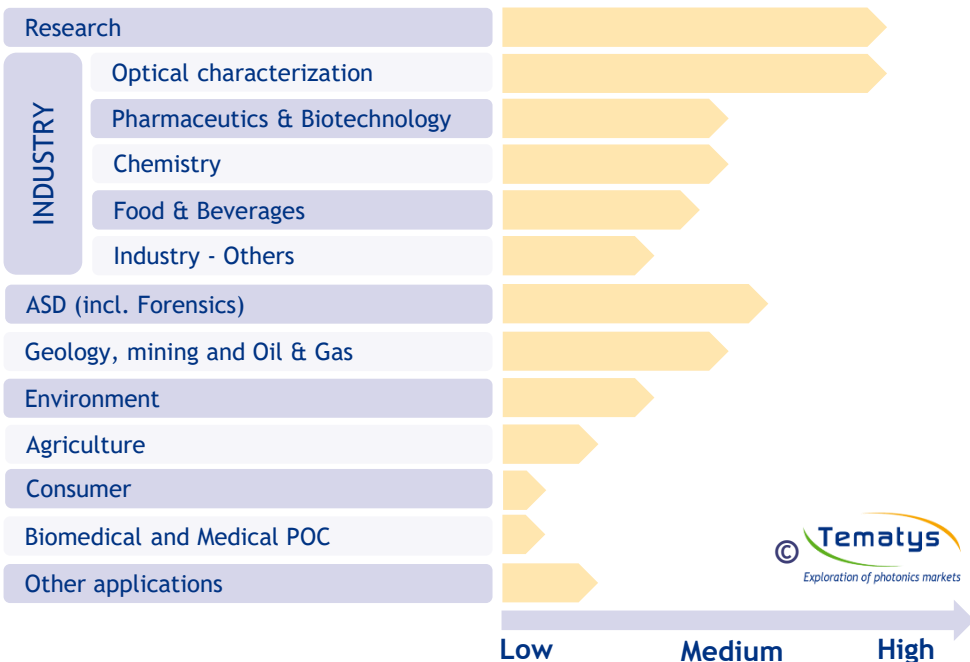
The market started to be split into a wide variety of **niche adoptions**, each having own requirements (performance, costs, design, operating conditions, ...). This implied the development of products specifically to each segment.

The question is to **what extent** this technology will be exploited. The report answers this question by providing **market forecast from 2020 to 2024**.

At the same time **micro spectrometers** were first presented (size between 10 000 cm³ and 100 cm³), offering similar performance to miniature devices but in a handheld, portable design. They enabled to launch new systems for **professional** users.

The study also provides a detailed analysis of most promising applications and describe the end-users needs for widespread adoption of compact spectrometers.

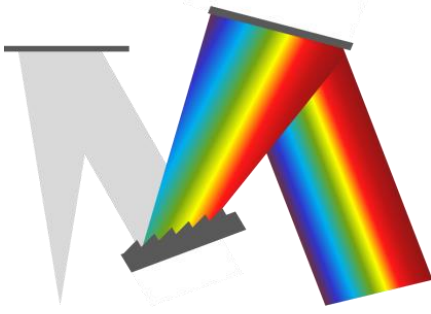
Market penetration rates for compact spectrometers - 2019



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CONTACT

Jacek Kulakowski
jkulakowski@tematys.com
TEMATYS
6 Cité de Tréville
75009 PARIS
Tel: +33 7 54 36 84 54
Fax: +33 9 72 39 44 39
www.tematys.com



ARE THE ACQUISITIONS GOING TO CONSOLIDATE THE MARKET?

Consolidation is now more evident trend on the spectrometers market.

Due to the transactions made by Nynomic Group (acquisitions of Avantes and tec5 before 2016, Spectral Engines in 2018), Metrohm (B&W Tek in 2018, Snowy Range Instrument in 2016, earlier IPS) and Halma (owner of Ocean Insight since 2004) only this three companies accounted for 1/3 of the total market revenue (2019).

The gap between the biggest entities and small competitors is **widening**, it is also harder to enter the market. Older companies are trusted, can provide many references and offer mature products.

It is still an open question who is going to **catch the value** on the current compact spectrometer sub-systems market out of the main players. This report analyzes key elements for a successful adoption of a spectroscopy product.

INNOVATIVE SOLUTIONS

To reach new applications, technological breakthrough is necessary. That is why miniaturization of spectrometers exploits **new designs** and **novel ideas**.

Recent progress in the development of compact spectrometers follow this path and takes an advantage of micro-technologies such as **MEMS** and **MOEMS**. This reduces the cost and offers large production capabilities while maintaining high performance.

In case of new, chip-size spectrometers, the dominant technologies are: ultra-small gratings, multispectral filters, plasmonic filters, photonic crystals and organic semiconductors.

This study consists a detailed description of all key technologies of the compact spectrometers market with examples of manufacturers. Advantages and trade-offs for each technology have been also discussed.

KEY IMPORTANCE OF MODERN ALGORITHMS

Data analysis is becoming crucial for developing new applications in spectral analysis, especially those based on ultra small spectrometers.

Global IT environment helps in the progress - development of Cloud Solutions, Big Data, Machine Learning and Artificial Intelligence is very extensive all around the world. There is a massive funding for Machine Learning companies (\$ **16.5B** in 2019 globally, driven by **695** deals).

Modern algorithms become the **key element** of the spectroscopic system - even if there is a lot of stray light in the spectrometer one can correct it with proper data processing. Algorithms allow to **reduce the cost** of extracting useful information from the spectra. This helps to bring spectroscopy **out of the lab**.

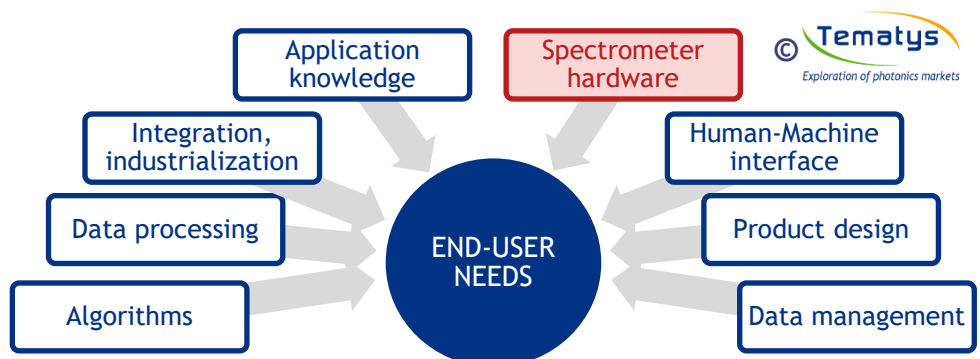
The report helps to understand the role of modern algorithms in compact spectroscopy.

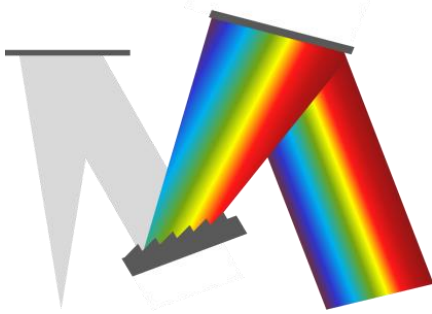
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CONTACT

Jacek Kulakowski
jkulakowski@tematys.com
TEMATYS
6 Cité de Tréville
75009 PARIS
Tel: +33 7 54 36 84 54
Fax: +33 9 72 39 44 39
www.tematys.com

Essential components of compact spectrometer system





AUTHORS



Jacek Kulakowski is Analyst at Tematys. He holds a Master Degree in Physics. He is experienced application and sales engineer for high-end semiconductor devices. In TEMATYS he is in charge of the production and promotion of market reports.



Benoît d'Humières is an expert in Optics, Electronics and Instrumentation for industrial and research applications. He has run many marketing and technological studies for major companies (THALES, ESSILOR, EDF...), SMEs and research institutes. He is Partner and Strategy Consultant in TEMATYS.

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CONTACT

Jacek Kulakowski

jkulakowski@tematys.com

Tel: +33 7 54 36 84 54

NAF 7490B - Siret 528 943 616 00011

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