RAMAN AOTF-BASED SPECTROMETERS

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ABSTRACT

Raman AOTF-based spectrometers are described, which are compact, rugged, and quite sensitive. Double monochromator modification is presented. Characteristic features, technical characteristics, and potential applications are described.

Raman spectroscopy, Acousto-optic spectrometer

1. INTRODUCTION

Raman spectroscopy is powerful modern method of structure and composition analysis of substances. It based upon spectral analysis of optical radiation scattered by the sample, which is illuminated by monochromatic light. Characteristic lines appearing in such spectra correspond to energy level structure of substance molecules and, thus, make possible chemical characterization of samples. This contactless analytical method does not require sample preparation. Moreover, it would not require sampling if there is an optical connection of the spectrometer with the inspected object (e.g. through a fiber-optic probe). The main problem is the extremely low quantum efficiency of Raman scattering (~10^{-8}), which requires high-sensitivity instruments for detection. That is why Raman spectrometers are usually too bulky and heavy for transportation.

In the report, a portable Raman spectrometer comprised an acousto-optical tunable filter (AOTF) (Ref. 1) and a compact laser is described. Spectrometer structure, operation principle and characteristic features are described, applications are discussed.

2. SPECTROMETER COMPOSITION

Spectrometer contains monochromatic source and receiving spectral optical part (fig.1). Optical source is diode pumped solid-state laser with frequency doubling. Receiving part consists of optical unit and computerized control unit. Spectral selection is effected by AOTF, and radiation detection – by cooled photomultiplier (PMT) operating in photon counting mode. Y-shaped fiber-optic bundle is served for radiation transmission from laser to sample and from sample to optical unit.

Two types of Raman -based spectrometers are developed now: based on single and double monochromator. Single monochromator uses quasi-collinear crystal quartz AOTF. Double monochromator is made of two collinear AOTFs based on $CaMoO_4$-crystal cells (fig.2).

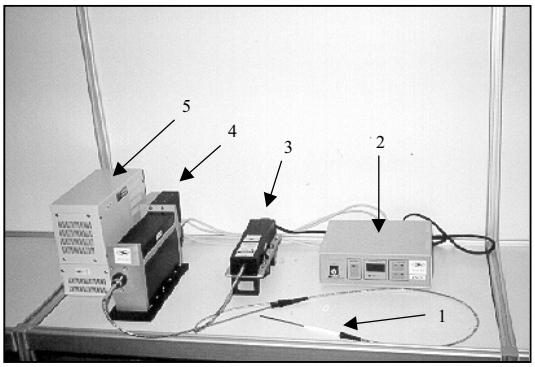

Fig. 1. Raman acousto-optic spectrometer "RAOS-2":
1 – fiber-optic probe;
2 – laser power supply;
3 – laser head;
4 – optical unit;
5 – control unit.

3. TECHNICAL CHARACTERISTICS

- AOTF Spectral range 535 - 750 nm.
- Laser wavelength 532 nm.
- Frequency shift range 100 – 5500 cm^{-1}.
- Spectral resolution 9 cm^{-1} (0.4 nm at 660 nm).
- Laser power 0.2 W.
- AOTF geometric factor ∅9 mm × 4°.
- Photomultiplier "Hamamatzu R-6060".
- Sizes, weight:

optical unit	35×12×17 cm^3	4 kg
control unit	25×12×23 cm^3	4 kg
laser head	25×10×9 cm^3	2 kg
laser power supply	25×19×9 cm^3	2 kg
fiber-optic probe	1.5 m	0.3 kg.

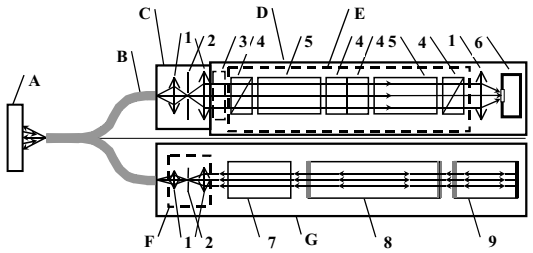

Fig.2. Optical diagram of Raman double-AOTF monochromator spectrometer "RAOS-2":
A – sample; B – fiber-optic probe; C – optical objective;
D – optical unit; E – double-AOTF monochromator;
F – laser head output lenses; G – laser head;
1 – lenses; 2 – objective aperture; 3 – location for rejection filter; 4 – polarizers; 5 – acousto-optic cells;
6 – photomultiplier; 7 – frequency doubler;
8 – solid-state laser; 9 – diode pumping.

4. OPERATION PRINCIPLE

Laser radiation is supplied via central fibre of the bundle to the analysed sample. Scattered radiation is collected by peripheral fibres and transmitted to the optical unit input. Radiation frequency is shifted at the value corresponding to the transition energy between electron levels. The scattered radiation is transmitted through a set of filters. Single monochromator spectrometer contains a notch filter for suppression of direct and reflected laser radiation. AOTF is used for selection of characteristic lines. Transmitted radiation is focused to PMT and the pulse rated is calculated by pulse counter.

Double monochromator spectrometer “RAOS-2” (fig.2) contains a pair of AOTFs, which provide rather high spectral contrast. In a contrast to ordinary monochromator spectrometer, “RAOS-2” can be used with any laser, which wavelength belong to AOTF spectral range (0,5-0,7 mcm). It is important for highly luminescent samples for suppression this effect by shifting exciting wavelength from green to red subrange.

AOTF is tuned by changing of RF control signal frequency. The signal is generated by RF programmable synthesizer according to commands of computerized control unit. The last is directed from user computer via serial port RS-232. The program running on that computer enables parameter and operation mode specification, displays and saves spectral information. Analysis of Raman spectral (i.e. samples identification) is fulfilled manually with help of reference tables and databases on Raman lines.

5. CHARACTERISTIC FEATURES

- Small sizes and weight of all the units due to AOTF and laser compactness.
- Rugged design, insensitivity to shocks and vibrations as there are no moveable or adjustable elements.
- High optical throughput of AOTF, sensitivity to low-level optical signals.
- Fiber-optic probe simplifies on-site analysis of hard-to-reach samples.
- Programmability: various operation modes are available as the control unit is based on single-board computer.

6. APPLICATIONS

Spectrometer is developed for spectral contactless chemical analysis of samples on site.

It can be used in those applications,

- where sampling is difficult or impossible,
- where express-analysis is necessary;
- where continuous or periodical monitoring is required (e.g. in technological control systems or quality assurance systems).

Some dedicated applications:

- scientific researches;
- mineralogy, petrology;
- microelectronics;
- criminalistics, customs inspection;
- chemical and petrochemical industry;
- food industry;
- medicine;
- pharmacology;
- environment monitoring.

Examples of samples:

- new materials;
- minerals;
- coatings;
- drugs;
- fuel;
- chemicals;
- food;
- polymers.

7. CONCLUSION

A couple of AOTF-based spectrometer was developed and produced. Due to unique features of AOTFs, they exhibit high sensitivity, adequate spectral resolution, spectral agility, rugged design and small sizes. Thus, they ideally suited for out-of-door measurements, and for integration into industrial automated systems or apparatus. Such an apparatus produced for underwater spectral chemical analysis is described in Ref. 2.

8. LITERATURE

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2. V.E.Pozhar. «Spectral optical apparatus for undersea measurements». V Int. Conf. «Modern methods and instruments for oceanological researches» (Moscow, 1999), p.229-230.