RAMAN ACOUSTO-OPTICAL SPECTROMETER TESTING

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ABSTRACT

Comparison of two modifications of Raman acousto-optic spectrometer (RAOS) was carried out. Applicability of such spectrometers for a variety of spectral analytical tasks is demonstrated.

Raman spectroscopy, Acousto-optic spectrometer, chemical characterization

1. INTRODUCTION

Acousto-optic (AO) interaction is adequate physical base for development of small-size optical spectrometers. A series of AO spectrometers of UV, visible and IR range have been developed and produced in Scientific Technological Center of Unique Instrumentation (STC UI) recently.

AO spectrometers exhibit high optical throughput, rather high spectral resolution, ruggedness and spectral agility. Such features combination makes them ideally applicable for Raman spectroscopy, especially for out-door measurements.

Large input pupil and input angle aperture allows easy optical matching of AO spectrometers to various objects. Spectrometers are also supplied with fiber-optical probe for access to objects, which are out of direct sight.

Below, there are presented results of testing of two models of AO spectrometers for Raman spectroscopy.

2. EXPERIMENTS

Raman scattering has very low quantum efficiency, so Raman spectra are often masked by optical noise caused by intense laser radiation. There are two methods of noise suppression: laser radiation rejection with notch filter or utilization of multiple monochromators. Each of these approaches was implemented in two modifications of acousto-optic spectrometers.

<u>Characteristic features of spectrometers</u>

Both spectrometers consist of optical head and computerized control unit. Optical head contains input optics, an acousto-optic tunable filter (AOTF) and a sensitive photomultiplier.

First AO spectrometer (RAOS-1) comprises quartz collinear beam AOTF and notch filter. The second one (RAOS-2) contains two collinear AOTF made of $CaMoO_4$ crystals. Both spectrometers have approximately equal aperture and bandwidth. (For more detailed information, see Ref. 1.)

Most of experiments were made in configuration using fiber-optic probe.

<u>Emission lines measurement</u>

Spectrum of narrow separately located lines reveals instrument function of spectrometer. At fig.1-2 spectra of radiation which was emitted by fluorescent lamp and reflected by a sheet of paper. They show emission lines of mercury vapor.

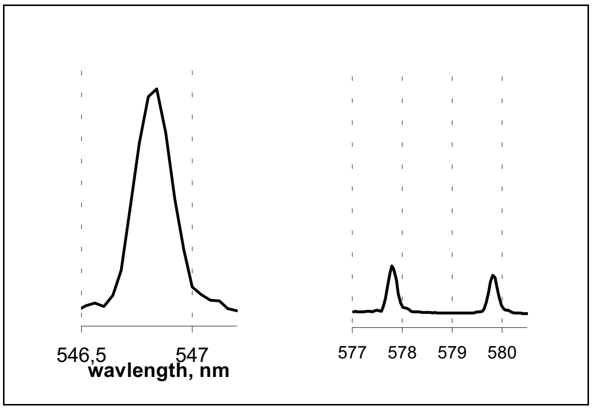

Fig.1. Two intervals of fluorescent lamp spectrum (RAOS-1)

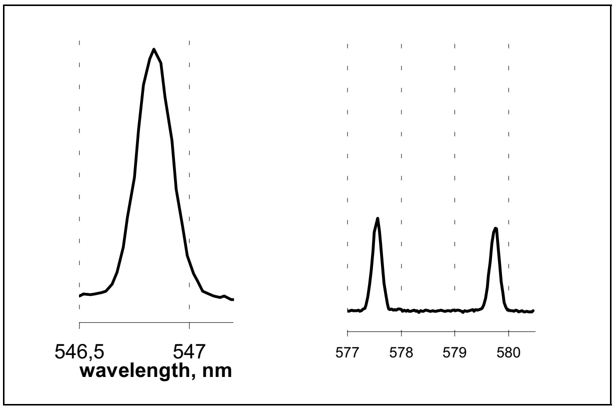

Fig.2: Two intervals of fluorescent lamp spectrum (RAOS-2)

Spectra demonstrate that double monochromator spectrometer (RAOS-2) provides higher signal-to-noise ratio, lower background level, lower sidebands amplitude. All that is in accordance to calculated characteristics of spectrometers. Double monochromator also provides narrower bandwidth than single one. However, that narrowing is compensated by higher spectral resolution of quartz AOTF, so both instruments have approximately equal bandwidth.

Raman scattering measurement

However, due to notch filter RAOS-1 has an important advantage in measurements of Raman spectra. Fig.3-4 shows Raman scattering spectra of lithium niobate crystal. They demonstrate that RAOS-1 provides appreciably higher signal-to-noise ratio than RAOS-2 does. As Raman line intensity is many orders lower than laser illumination, it looks very noisy (fig.4). Notch filter rejects laser radiation, so detected Raman line is rather smooth (fig.3).

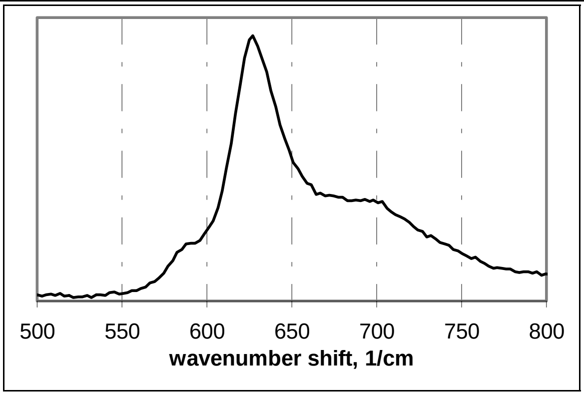

Fig.3. Raman scattering spectrum of $LiNbO_3$ (RAOS-1)

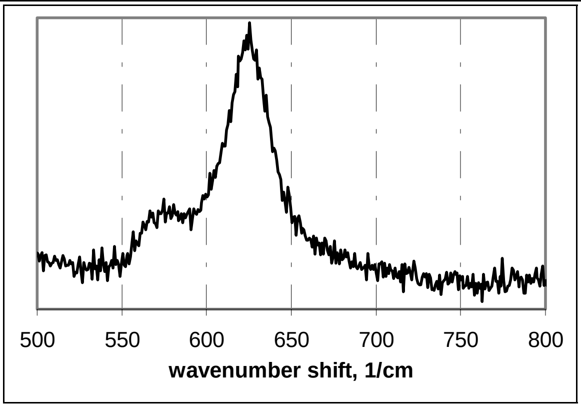

Fig.4. Raman scattering spectrum of $LiNbO_3$ (RAOS-2)

Raman spectra of crystals

Crystals are ordered structure and as a rule Raman scattering of such objects is rather strong. A variety of crystal samples spectra (TeO_2, $LiNbO_3$, diamonds, fianit, CdS, etc.) were obtained by these spectrometers. Both of them are able to reliable detect Raman scattering of crystals. Although "quality" of those spectra differs for two instruments, but it primarily depends on optical configuration, accumulation time, and laser power.

Measurements have shown that spectral location of Raman lines does not depend on spectrometer type, exiting laser wavelength, or optical configuration. Also they demonstrate that the spectrometers are capable of crystal identification. For example, fig.5 illustrates clear distinction of Raman spectra of diamond and fianit.

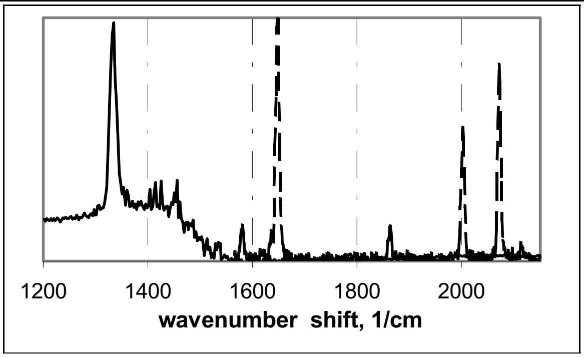

Fig.5. Raman scattering spectrum of Fianit (dotted) and Diamond (solid)

Raman spectra of liquids.

Alcohol drinks and lubricants were used in measurements as test liquid samples. The sensitivity of the spectrometers has proved to be high enough for reliable distinguishing different kinds of vodka, gin, cognacs, brandy. There are characteristic spectral lines in all studied spectrum, so every sample can be differentiated by unique combination of spectral peaks and their relative intensities.

In fig. 6 Raman spectra of two sorts of fuel are presented. Even row spectra quite differ each other.

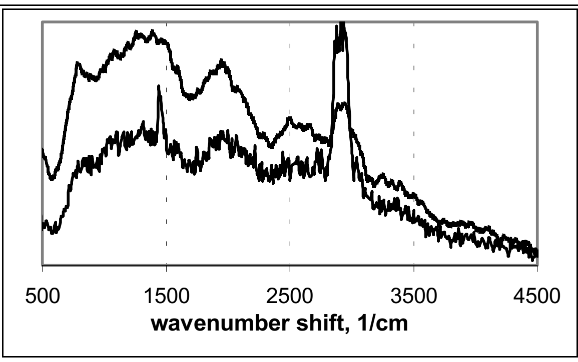

Fig.6: Raman scattering spectra of aviation fuel B70 (solid) and automotive petrol A92 (dotted)

A series of measurements of liquid samples made in various configurations, laser wavelengths, background illumination level proved high reproducibility of spectra obtained with both instruments.

Raman spectral of alcohol drinks presented at fig.7-8 illustrates capabilities of the method and spectrometers.

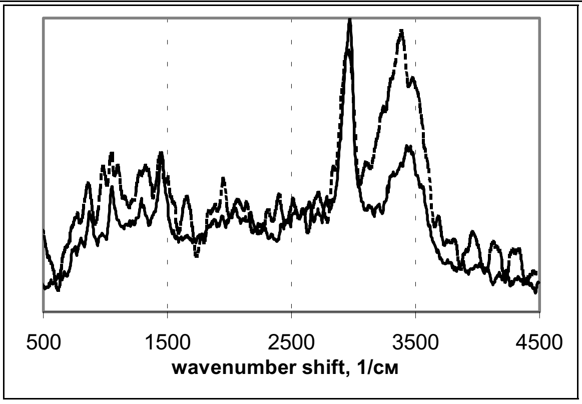

Fig.7. Raman scattering spectra of gin "Beefeater" (solid) and ethanol (dotted).

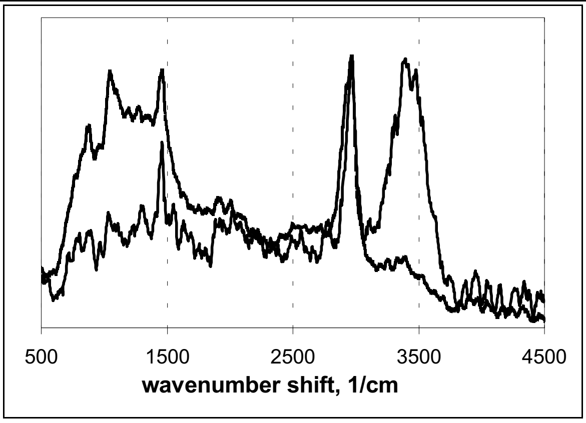

Fig.8. Raman scattering spectra of vodka "Gubernskaya"(solid) and forged vodka (dotted)

<u>Medicine investigation.</u>

One of most important application of Raman spectroscopy is analysis of medicine and drugs. These substance have often the form of tablets or powder. And this fact cause higher noise level in their Raman spectra. Nevertheless, they can be reliably detected, in particular, with use of fiber-optic probe.

As an example, in fig.9 there is presented Raman spectra of hematoporfhyrine-Yb metallocomplex, which is rather promising substance for early cancer diagnostics.

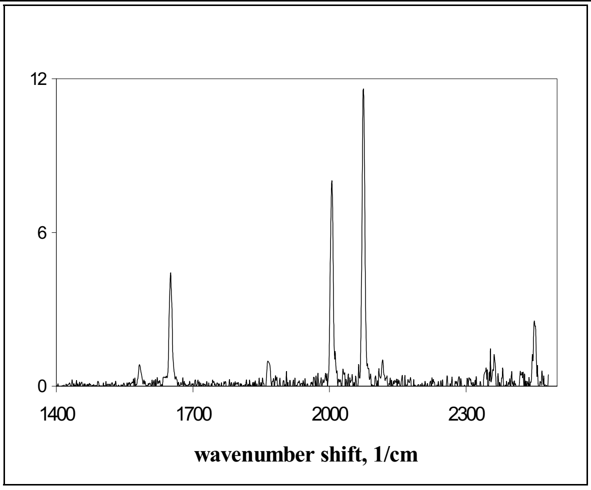

Fig.9. Raman scattering spectra of hematoporphyrine metallocomplex.

3. CONCLUSION

Sensitivity and resolution of AO spectrometers is quite enough for Raman spectra detailed and reproducible detection. Measurement configuration based on fiber-optic probe allows distinguishing and identifying samples of different nature.

It has been demonstrated that double monochromator spectrometer has as high characteristics as spectrometer having notch filter. It is important for those applications, which require different laser wavelength excitation.

4. REFERENCE

1. V. E. Pozhar, V. I. Pustovoit, Raman AOTF-based Spectrometers, *Proceedings of European Frequency and Time Forum, 2002*