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THE PORTABLE LASER LABORATORY: HOW CAN YOU FIND OUT WHAT'S IN THE BOTTLE IF YOU DON'T OPEN IT?

Russian Breakthrough Technologies

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Moderator:

Sergei Nedoroslev, Chairman of the Board of Directors, Kaskol JSC

Panelist:

Alexei Steblyov, Vice-President, Director of Marketing, Rammiks

THE PORTABLE LASER LABORATORY: HOW CAN YOU FIND OUT WHAT'S IN THE BOTTLE IF YOU DON'T OPEN IT?

S. Nedoroslev:

Good afternoon to everyone who is back here. We will continue presenting projects. The next project will be presented by Alexei. Humans have long dreamed of X-ray vision. You could say that now this dream has come true. Alexei will demonstrate a technology that lets us see through an object’s surface and determine what lies inside. We will have a short presentation and then show how it works, right here, without going anywhere.

Alexei, please go ahead.

A. Steblyov:

Good afternoon. My name is Alexei Steblyov and I am Vice President for Business Development at Enspectr. I will talk about the technology that our company makes.

The company was founded by scientists who worked, and some of whom still work, at the Institute of Solid State Physics in the Moscow suburb of Chernogolovka, under Professor Kukushkin, a corresponding member of the Russian Academy of Sciences. Our story, as usual, began in a rather low-key way. Scientists were using different devices, they bought some, used them, got disappointed and figured out how to make them better, and made a device that analyses the composition of a substance. I will tell you later how this all happens.

We made a device, began to sell it, and found it had many more features than we thought. We began to pursue this further. We bifurcated into another subsidiary, which is going about the next project. I will tell you about it, too. First though, I will say a little about how it all works.

The main technology used in our device is based on Raman scattering. An Indian scientist, Raman, discovered this scattering back in the 1930s. He won the Nobel Prize for this. But until recently we did not have the technology to match. Now we do.

So, what happens? A quantum of light flies along, hits a molecule of a substance, excites it, and the molecule vibrates. It turned out that molecules of different substances vibrate in different ways and in different directions, so they scatter light in different ways. We collect this scattered light that is reflected from the molecule. It comes into contact with a CCD matrix, like in a camera, and we study the difference between the light that left and the light that arrived. Since the vibration of molecules is unique to each substance, the light-scattering vibration is unique as well. Every substance that exhibits the Raman effect scatters light in its own unique way. This is like a person's fingerprint. You can see this on the graph.

The computer processes the information on an ordinary CCD line array, converts it, and outputs it in the form of Raman peaks. Then the computer compares this with the spectral database we loaded on it and says what substance we are looking at. We see that two similar substances still have different spectra. Substances from the same group are still different, and we can detect and analyse these differences with great precision.

Here is a diagram of how this all looks: the laser beam is coming from here. The mirror is over here. Here is where we set the substance we want to analyse. The scattered light gets reflected and bounces off that way, through the holographic array, hits the CCD matrix, and then is logged on the computer, which applies complicated algorithms and comes up with a result.

I will give you a visual demonstration of how this takes place. Here is our software, which we developed ourselves, and here is the attachment. It is the same one you saw on the diagram. You see the green light? The laser is shining from the inside. This vial has a colourless liquid inside. The device thinks for two or three seconds and tells us that it is dimethyl sulfoxide. Now we take another bottle with a liquid that looks exactly the same. It, too, is transparent. The device says it is a different substance. Next bottle. As you see, measurement takes just two seconds.

S. Nedoroslev:

Do you have an empty bottle with you? What if we put in water?

A. Steblyov:

Truth be told, I do not have an empty one.

S. Nedoroslev:

What if we pour out your water and put in ours?

A. Steblyov:

I can show you. This fine white powder here is pretty ambiguous. It looks like it could be powdered sugar or cocaine. Now we add water. Here is our result: Aspirin, acetylsalicylic acid. Recognizing it took two seconds, like before. Here is another mystery substance. This will be an example of how our device recognizes mixtures. There is no periodic table element named ‘vodka’. But we specially added vodka to our library of alcohols. We put the device in mixture recognition mode. Now, in the same two seconds, we find out what this vodka is really made of. You see, it is equal proportions water and alcohol. So it really does look like vodka.

Back to detecting pure liquids. We were not the ones to invent this effect or even Raman analysis. But we made it much more precise than the existing equivalents on the market today, and much cheaper. The measurements are 1.5 to 2 times more precise and the cost is 75–80% less. I think everyone has mastered the interface already, picking it up from me. It is so simple, but other manufacturers make interfaces that are pretty tricky.

As for water: very few Raman devices ‘see’ water. If you like, let us pour the water out of this bottle. I have been dying to know what is in the bottle there marked 'Russian Spring Water'. You had plastic cups, right?

S. Nedoroslev:

On the floor.

A. Steblyov:

If it is water, it will evaporate. I will try putting something else there, since we already had water. Now we will have isopropyl alcohol, and now I am putting in what Sergei gave me. Now I am really curious.

S. Nedoroslev:

What is ‘0.931’?

A. Steblyov:

Here we are. Your water: 0.930. A value of 1 means 100%, the correlation is very good. I did not try to get into all the features of the device, but you have to understand that we are talking about more than just transparent liquids in small vials. The bottles can be of any size, non-transparent, and not even made of glass: it could be bags and so on. Moreover, they do not even have to be liquids or powders.

So now I am taking a tablet from the factory packaging. We see right away that it is aspirin. We put this rock here on the viewing window and we see that it is amethyst. Our technology works great on minerals. This box here? It is polyethylene. Plastics are detected too. Here is an ordinary syringe, sold in a pharmacy. The detector says that it is made of polypropylene.

So the list of materials that this technology can recognize is truly vast. But this device is just what we have now. I want to talk about where we are going with this.

S. Nedoroslev:

The price is not quite right.

A. Steblyov:

What about it?

S. Nedoroslev:

The price is stamped on the device, like they did in the USSR.

A. Steblyov:

That is the reference price, it is not the end-user price. Our product is not one that is sold in all the stores of some retail chain; it is a specialized device with many levels of accessories and equipment. We indicate the base price on it, and all sorts of add-ons get attached from there. There are so many areas of potential use that we have a serious marketing problem. A device that is needed everywhere is almost the same as a device that is needed nowhere.

S. Nedoroslev:

Alexei, if we come back to the subject of that bottle, you showed us that vodka is alcohol mixed with water. But we know that vodka has other substances too, even formaldehyde. So the device does not display all of the contents?

A. Steblyov:

This detector package does not, no. This device has been on the market for six months or so. And the market seems to want, first of all, a device for special use and, secondly, a device with improved specifications. This is like what you are saying: a device that can recognize much smaller concentrations of a substance. It does a very good job at detecting concentrations of over 10%. At concentrations of 1% to 10%, it is still possible, if the Raman signal is strong. But at concentrations of less than 1%, it cannot detect a substance, as a practical matter. There are many fields where detecting ultra-low concentrations is very useful. So here we have made a really unique development.

Building on our technology, we made what we call a ‘Raman microscope’. This device is coupled with the optical circuitry of an ordinary, factory-made microscope. It could be practically any microscope. Here we have used an Olympus microscope, very popular, as the base. The microscope lets us find very small grains of a substance. And with the help of our device that we have added, we see what substance it is.

Why is this important? Some mixtures have a substance dissolved inside of them. In some mixtures the substance is not homogeneous. Maybe this micron has our active substance and the neighbouring one has the incipient, lactose. So we bring this tablet into focus. With this microscope, we have a motor mechanism so we can scan the surface of the tablet and find out what is inside.

Let us move on. How can we differentiate real diamonds from fake ones? They have an absolutely identical chemical structure and crystal lattice. Only the impurities in fake ones make them different. Our device can spot them. We thought that our device would be useful for jewellery stores. Maybe a chain would put these devices in their stores to reassure customers and drive sales.

Today we see signs for diamonds that have X carats in them, and we believe that value of X. But it would be great if we could tell in two seconds that it is, in fact, what it claims to be! Buyers would be much more willing to buy. Alas, the jewellers themselves are not 100% confident in what they are selling. It is not because of ill intent. You could say that diamond buying still depends on an experienced person with a monocle eyeing the stone. It all depends on the human factor. He has this tool, but it is a primitive one. Big, expensive stones are taken to a special lab. There they have equipment that costs 100 times more than ours, but with about the same features.

When someone goes to Bangkok to buy small diamonds at some exchange, he does not have a microscope or special devices with him. That someone is going to make mistakes and the vendors know that. So they do not want our device.

S. Nedoroslev:

You could install it at the store exit. The person will buy the device then and there. You are investing in a venture business, so go invest in that area.

A. Steblyov:

We will talk a bit more about the business model.

Back to this question of formaldehydes and other small impurities. If you look closely, on both sides you can see the word ‘SERS’. Some substances emit a Raman signal that is very weak. So you have to amplify this signal. Other people have invented a tool for this. SERS plates can drastically amplify the Raman signal. It is a small thing, 5 x 5 mm, of a single layer of metal molecules. The substance comes into contact with the metal and settles in a single layer, amplifying the signal many times over, from 100 million to tens of billions of times. There are few companies worldwide who make these, and they cost EUR 100 a pop. They are for one-time use. We have a technique for making them and if we started selling them now, they would cost USD 5 each, instead of EUR 100. And of course, with mass production the cost would be minimal.

Another area in which we work is DNA sequencing. Our scientists are working on a mechanism for allowing molecules through a membrane. As it stands, scientists have to first cut a molecule into pieces, read short sequences, and combine these sequences mathematically. We are on the verge of sequencing DNA molecules without having to cut them up, thanks to this same SERS technology. We have SERS plates at the spot where the DNA molecule is crossing through the membrane at a speed that we control. Thanks to this we can easily read the sequences of letters in the DNA.

There is another area of activity at our company. In a year we will have a device that is no more than half the size, and which does not require a computer. The device will have a screen and one button. Customs and narcotics inspectors, or loaders at pharmaceutical warehouses, will touch this device to objects, press the button, and get a result. Here is the spectrum for heroin. You can use our device to spot it.

And if we have started talking about safety, then another area of use is protection from counterfeits. This was a goal from the very beginning, since the world’s market for fake products is simply huge, and so much larger than the market for devices that protect against counterfeits. How does our technology help here? Another unique point of the device is that it is more than just a Raman analyser. It looks at luminescence too. In a single run through the CCD matrix, it sees information both

on the Raman component and on the luminescence. What does this do for us? So we take luminescence markers at a very low concentration – about 10^{-7} – and put them where we like: fuel, alcohol, perfume, water. This is a concentration that does not at all affect a solution's usage characteristics. But we can determine two things right away. First, which substance was used to make it. Second, whether this is the very same liquid that was poured at the oil refinery or the pharmaceutical factory.

Tablets are sometimes counterfeited using fake drugs. The drugs have the same efficacy as the originals, but the money goes to someone else, not the patent owner. Simple Raman analysis will show the same original tablet, it will not tell us the complete story. But with spectral markers, we can.

I shall provide another example. Planes have crashed because of the wrong fuel: fuel that is not what it purports to be, it was watered down, etc. Now imagine pouring fuel through a device like this. The substance is recognized instantly, as you saw. The markers are visible and the computer is constantly monitoring what it is that is being pumped. As soon as the proper fuel stops going in, a baffles actuates, so the aeroplane is not filled with anything it should not receive.

Or take another example: artwork. We would not put anything inside artwork, of course. But the skill of art counterfeiters is so great these days that even the biggest museums, with the most skilled experts, have great anxiety when sending paintings out to exhibitions. They are prepared for a situation where what they get back has a very strong resemblance to what they sent, but is not the real thing. We have joint projects – with the Hermitage, among others – for marking paintings with so-called smart inks, which are easily read by our device. This is not to mention financial securities.

And lastly, I shall say a few words about our overall dream. I will be delighted if it happens in 2015, but I will not be surprised if it happens later than that. A computer-less device like this costs as much as an iPhone – around USD 1,000. We hope that the 140 million iPhone owners will make note of what we have developed. We hope someone goes to the pharmacy and buys these SERS plates, five for RUB 100, and back at home they take a plate and put a liquid biosample on it. Then they put this

plate up to the device. A minute later, they get the results, which either get him to start worrying about their health or, instead, allow them to rest easy.

The client connection can be set up over a remote server, I think that is most likely. Then we have constant interaction and cash flow too. That is our dream. After all, no matter how useful our device is for customs enforcement, real success will come only when its use becomes widespread.

S. Nedoroslev:

Thank you, Alexei, for a fascinating presentation. It was neither too dry, nor too technical. Are there any questions? Pass the microphone please, so Alexei can answer.

From the audience:

Hello. My name is Ruslan and I am Managing Partner of a company that is the official vendor of water for the Forum here. I find this topic incredibly interesting, including the security-related uses. Are organizations like the Russian Federal Protective Service buying up your products?

A. Steblyov:

So far, we have had nothing. Sales started not long ago, and vending to the Federal Protective Service and their kin is impossible if you have been in business for only six months. We have made a major breakthrough in being able to sell devices to the customs agency through integrators. We cannot sell anything directly.

Soon our country will host the World Student Games and the Winter Olympics, and in addition, the restrictions on liquids in airports are being relaxed. At one point we talked with people responsible for security at the Olympics. Representatives of the International Olympic Committee came in for a site visit and it seemed that people had different ideas on how to guarantee security. Our security officials wanted to ban everything. The IOC people said that this is a celebration, not a walk around the prison yard. So, they wanted to allow everything to the maximum, and request the

security officials to be so kind as to guarantee security. Now, that raises the question, how do we do that? People are walking around with bottles. Previously the security agencies took all them away, but what do we do now?

We showed them our device. But the system is rather inert. Maybe we are not going about sales in the right way, with the right skills. So we will be thrilled to work with you, if you know how to do this.

From the audience:

This Forum is an example. There is a presidential zone here, where they have coolers. The President drank our water yesterday. I am sure they tested it somehow, but that is a lot harder without your device. Often we provide drinking water to VIPs, so we want to be sure that everything is OK and no terrorist has tampered with the water.

A. Steblyov:

This is not a situation where something is sold at the supermarket, the instructions say it can do X, Y, and Z, and you put it in your cart.

From the audience:

I know what you need. The name of this session is, ‘How Can You Find Out What’s In the Bottle If You Don’t Open It?’ There is a bottle in the cooler. Can you verify that it has nothing harmful inside? Is this all really functional, or is it just theoretical?

A. Steblyov:

We can say that it is water. We already showed that.

From the audience:

Maybe you have some prepared water over there. How about we see what is in that big bottle?

A. Steblyov:

I can do that. But we will have to move the equipment, I have an electricity outlet here. The device is plugged in.

S. Nedoroslev:

We poured from this bottle.

A. Steblyov:

No, you will not be able to determine the concentration like that.

From the audience:

Are there harmful substances inside it, or not? I can bring over some water.

A. Steblyov:

You can pour it and I can analyse it, no problem. But if I understand the question, it is: if there is hydrogen cyanide in it, will we detect that? What difference does it make, whether we open the bottle? I will study it through the glass, I will not pour the water on the device. Or do you think that the hydrogen cyanide will instantly evaporate if you take the bottle out of the cooler?

From the audience:

If I bring you a bottle, can you analyse it too? If the bottle is closed.

S. Nedoroslev:

Simple logic says ‘yes’. What is the difference?

A. Steblyov:

Now we start the program. These guys will also determine the radiation level in your cooler. Bring it this way.

From the audience:

It is very important. Water from deep wells can have radon, and more than just radon: radiation gets worse as you go deeper, you know. So checking radioactivity is important for safety when we are talking about water. And especially if you are drinking it regularly.

A. Steblyov:

What is that bobbing about in the cooler?

From the audience:

A corkscrew.

A. Steblyov:

A lot of luminescent light is hitting it from all sides. When I was demonstrating, it was all closed. The device does not show poisons. It is showing that the luminescence is off the charts. We are not applying it in quite the ‘proper’ way.

From the audience:

But there is sediment left!

A. Steblyov:

The lighting is blinding. Have you turned off the light? It is still shining, you can see.

From the audience:

If we are talking about Raman emissions, what does blinding light matter?

A. Steblyov:

As I said, this device works on both luminescence and Raman spectroscopy. When luminescence is off the charts, it gets in the way of the signal.

If there are dangerous substances at low concentrations here, detection would probably be through the SERS plates I mentioned. You put drops of the water on the plate and soon you get the results. People are asking questions like they never studied this in school. Everyone thinks that this is like a perpetual motion machine or astrolabe, that it works of its own accord. But the device only recognizes the substances that it knows. Enter a list of harmful substances on it and it will tell you if it seems them. It does not recognize unknown substances, of course, because it compares the spectra with the data from the library that has been loaded onto it.

S. Nedoroslev:

There are specially trained people who make those entries.

From the audience:

Can you make devices that will check for the most well-known harmful substances?

A. Steblyov:

If you give me a list, I can put them in. We have a database of 10,000 Raman spectra, but that is still far from complete. Buying forbidden substances in a store or even online is complicated although probably still possible. We have not tried. That would need to be in cooperation with the same Federal Protective Service we talked about earlier. If you can interest them, since you provide water to all sorts of important guests, we will be happy to work with them. We can measure the spectra of harmful substances, put them in the library, and we will have a much easier time convincing everyone.

S. Nedoroslev:

The Federal Protective Service will put out a technical assignment to the water manufacturer and certify the water for safety. Then representatives from the FPS will go to you with the assignment and you will create a working group.

Are there any other questions?

From the audience:

Is there a function for detecting unknown substances? It is clearly impossible to list all substances. But an unknown substance that is not in the library should trigger caution.

A. Steblyov:

Logic, again. I showed vodka. The device indicated there is so much alcohol and so much water. To see the percent ratio of substances in the mixture, we have to give calibration data. First we explain to the computer that the ratio in this segment is 50:50, half pure alcohol and half pure water. The device analyses this reference mixture and says the ratio is such-and-such, this is vodka. We give calibration values, data about the ratio of components. The device gives a response if you set these reference values.

From the audience:

So the device performs a comparison with the data it already has?

A. Steblyov:

How else could it work? That is what analysis is, comparing it to a template. A thermometer is calibrated for the temperature. Similarly, any measurement device is calibrated and then must be validated once a year.

Concerning water, the airport restrictions are becoming less strict. Recently there was information online about a cheap Russian device that determines the precise contents of bottles. The security agencies were completely satisfied with the device. So it will not be like before, when you could bring only 50 ml of liquid on board. The device allows distinguishing water from petrol, but not from sulphuric acid. The device is good, it works well and it is cheap. If someone wants to bring petrol on board, the device is worth using. But if someone wants to take sulphuric acid, then

you need our device. The security agencies do not get this quite yet. Maybe you know how to bring this up with them?

S. Nedoroslev:

Our time is up but we have a 45-minute break ahead of us, so we can ask many questions of Alexei. We wish him success in his further scientific endeavours. We may not be ready to order the device right away, but clearly there is interest in it.

Thank you very much for your attention.