Synthesis, Analysis and Application of Nanoparticles for Bacteria Spectroscopy

T V Baikova¹, I N Saraeva², A A Korneeva¹, T S Svistunova³, S A Minaeva⁴, V S Sapezhinsky⁵, A V Ivanov⁵, A I Ionin², S I Kudryashov², and S A Gonchukov¹

¹Laser Physics, National Research Nuclear University (MEPhI), 115409 Kashirskoe highway, 31, Moscow, Russia. Contact Phone: +79175175536
²Lebedev Physical Institute, Moscow, Russia
³Infectious Clinical Hospital No 2, Moscow, Russia
⁴Institute on Laser and Information Technologies, Moscow, Russia
⁵Blokhin Russian Cancer Research Centre, Moscow, Russia
Contact Email: TVBajkova@mephi.ru

Pathological bacteria are the cause of many serious diseases. A progress of disease is, as a rule, accompanied by appearance of bacteria in biological liquids and other biological tissues. Early diagnostics is the indispensable condition of successful fight against these diseases. Many procedures have been developed for detection of bacteria which are the causative agents of human illnesses.

In view of its potential for the fast, noninvasive and precise analysis at molecular level, Raman spectroscopy (RS) has been an extremely powerful tool for biological objects research without external markers. For the last years, low sensitivity of classical RS has been successfully overcome owing to plasmonic mechanism of light scattering augmentation in the vicinity of nanostructured surface or nanoparticles (NP). This method is referred to as surface-enhanced Raman spectroscopy (SERS). SERS may excel over other techniques because of its ability to sense a structure of substances on molecular level. The theory of plasmonic mechanism has been still poorly developed. In spite of this fact, experimental studies demonstrated a very high gain of spectral lines when using SERS. This fact was experimentally demonstrated of simple molecular substances detection. However, concerning pathogenic bacteria as supramolecular biological agents, spectroscopic results are more modest. The lack of experimental results obtained by using nanoparticles of different material, size, shape concentration and also of substrate material does take place.

This presentation is devoted to the study of different NPs synthesis, test of their spatial parameters and longevity and effectiveness of bacteria detection using SERS.

NPs were fabricated by impulse fiber ytterbium-doped laser irradiation (1030 nm, 300 fs, 10 mkJ, 500 kHz) focused onto the sample surface. Colloidal NPs were put onto the silica glass substrate, coated with Ag film and then dried at the room temperature. The NPs sizes determining and their change with time was performed using a dynamic light scattering spectrometer (DLS) (diapason of measuring is equal to 0,01–10 µm, CW laser diode, 855 nm, 1 mW).

Pure bacterial culture of Staphylococcus aureus was chosen for the study in vitro. As is known, this bacterium can be effectively detected using resonant RS due to carotinoids content. As a result, the detection efficiency of resonant RS and SERS could be compared during our research. About 1 ml of the suspension were spotted onto the clean polished surface of the substrate and dried at the room temperature. 70% ethanol solution was used for bacteria inactivation.

The spectral measurements were fulfilled with the help of Nicolet Almega XR spectrometer with a 532-nm Nd CW laser excitation source. The Stokes shift components in the range of 400–3100 cm⁻¹ with the spectral resolution of 2 cm⁻¹ were used for analysis.

Acknowledgements: This research was supported by the Russian Foundation for Basic Research (projects No 15-02-08400 and No 16-32-00880).