Teaching Plasma Nanotechnologies Based on Remote Access

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Abstract — *The report is devoted to the remote access laboratory created in the Bauman Moscow State Technical University (BMSTU). It allows carrying out experimental researches and practical trainings based on operating with sophisticated plasma devices for studying and manufacturing application of nanotechnologies. The Internet laboratory takes an opportunity to organize learning of some parts of sophisticated devices as well as equipment assembly. At performance of experiments for various levels of the future specialists the various list of parameters of experiments set individually is used. At the initial stage training remote computer access is provided to research and adjustment of working parameters of serving subsystems. Students study to organize optimum working conditions of gas-vacuum, power and diagnostic subsystems. Besides, they study general laws of control of these subsystems and to form effective control software with parameters under laws formed by them. Students study and analyse dynamic characteristics of subsystems. Thus students study and use unique physical equipment and the newest methods of carrying out of experiment. Senior year students at studying of corresponding disciplines have an opportunity to individual remote control of plasma device and research into phenomena (generation and acceleration of particles of various types in DC magnetron sputtering system assigned for nano-coating deposition, formation particle fluxes with demanded chemical and power characteristics). At the final stage the future specialists have a possibility of carrying out of the remote complex researches including maintenance of demanded conditions of sophisticated physical experiments, their operative change and the current analysis of received results. Device operating modes and parameters are set by each student individually. In the created remote access laboratory the multimedia technologies are widely used, allowing to provide a supervision over experiment process and audio-visual contact to attendants of the plasma-physical device. The specialised database and software which allows to automate schedules of individual carrying out of experiments, the remote supervision over their performance by tutors, and also processing of primary results is developed. Series of experiments on unique equipment are spent by students of BMSTU and others universities.*

Index Terms — *Computer-aided remote control laboratory, training and student research work, low temperature plasma devices, nanotechnologies.*

INTRODUCTION

In the years 2008-2009, a network of national research universities was created in the Russian Federation. These universities train 21-century specialists for the priority areas of science, technology, industry, social sphere and high technologies development. One of the most important elements in training these specialists is conducting educational and scientific experiments with the use of sophisticated research facilities and modern information and communication technologies.

In the first decade of the 21 century, a number of Remote Access Laboratories (RAL) [1, 2] were created at the Bauman Moscow State Technical University. One of them is the Computer-Aided Network Educational and Research Laboratory for Plasma Spectroscopy intended for laboratory training in plasma physics and diagnostics, and in general physics (quantum physics and optics). In view of the increasing role of nanotechnologies in a wide range of areas, including plasma systems, one of the RALs was taken as a basis for the development of Hardware and Software Complex for the remote studies of physical process during plasma application of coatings and thin films. The Laboratory described in this paper, by contrast with [2], is not only fitted with the spectral diagnostics equipment, but also with the sophisticated vacuum equipment for generation of plasma flows with the required parameters for technological purposes.

THE COMPUtER-AIDED REMOTE CONTROL EXPERIMENTAL FACILITY

To conduct scientific experiments, the Laboratory uses a network access to the Computer-Aided Plasma Installation for technological purposes (Figure 1) developed on the basis of the DC Magnetron Sputtering System (MSS) which generates the sputtering target atom flows precipitating on the substrates. The MSS provides the application of high

quality multi-component drip-free coatings and produces thin nano-films with preset physical properties. The magnetron discharge is performed in a broad range of pressures of almost any plasma generating gases.
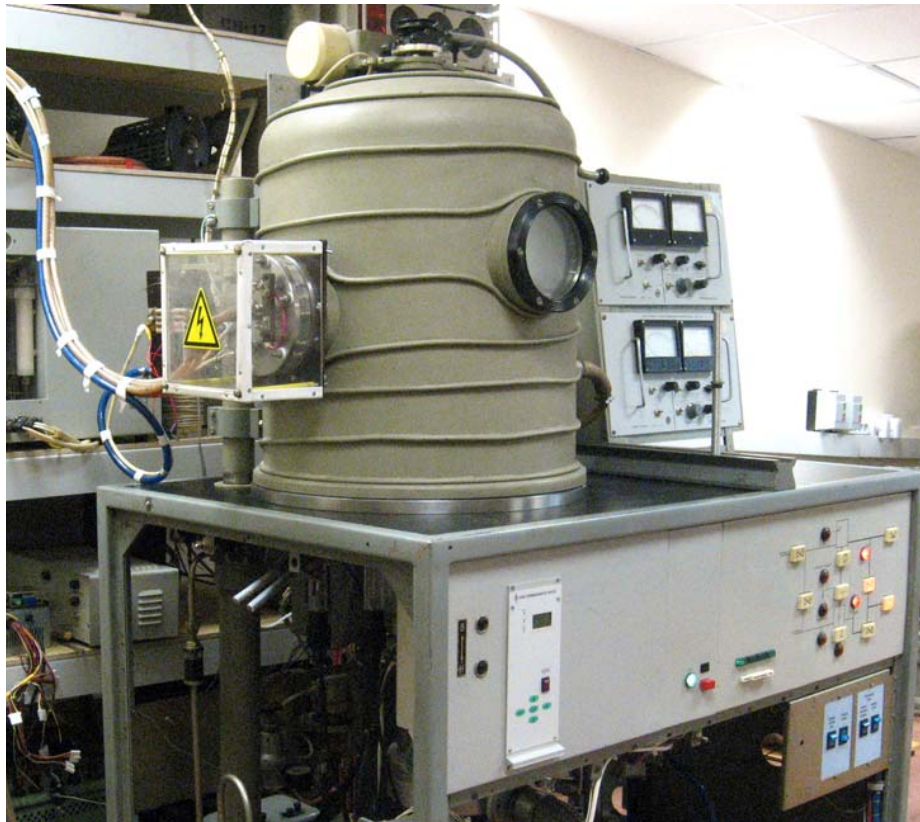

FIGURE 1
THE EXPERIMENTAL FACILITY FOR PLASMA APPLICATION OF COATINGS AND THIN FILMS

The designed Remote Control System enables a remote researcher to study the spatial dependences of plasma characteristics along the discharge axis by controlling the composition and pressure of plasma generating gas and thus changing the power spectrum of the particles precipitating on the substrate (Figure 2). The diagnostics of plasma composition is performed by the Hardware and Software Spectroscopic Complex [2], which is basically a 4-channel Spectrometer AvaSpec-2048 with CCD-registration. The Spectrometer electronic systems are controlled by the electronic platform AS-161 with built-in microprocessor. The platform keeps up the commands and data exchange with the control computer. The Spectrometer configuration is designed for the visual range of wavelengths (from 355 to 810 nm) and includes 4 independent channels with different radiation registration range, different characteristics of the diffraction arrays, different slot sizes and filters for 2nd harmonic cutting. The radiation is collected by a special optical head connected to the Spectrometer channels by means of an optical fiber cable.

The computer operating the Spectrometer (Lab-server) is connected with the Web-server by a local network. A network experiment is carried out by means of the remote control interface generated by PHP scripts in the form of HTML-pages. During the experiment, the parameters of Spectrometer operation mode are set, verified for correctness, stored in the integrated data base and then realized.

The developed software provides: functioning of the user registration and authorization subsystems, teaching and knowledge control subsystems; remote control interfaces, access to and network processing of experiment results, based on the use of the Web-browser, and the integrated database implemented under the MySQL control. The Windows-based service "SpectrService" developed in the Borland Delphi environment and located on the Lab-server periodically scans the data base tables containing information on remote user requests for spectrum registration, and places the corresponding scenarios into the execution queue. The remote experimenter gets on-line information on the course of the experiment.

The Windows-service via USB interface sets the mode of Spectrometer operation according to the remote user parameters, and upon spectrum registration completion, stores the results on the Web-server disc (SMB protocol), while the database only contains the names of files with the results. Access to the results of experiments is realized by the corresponding PHP-scripts. After a request to the data base, the user gets the results in the form of graphs and tables, both during the control session, and after its completion. The created software also provides additional possibilities of data processing depending on the specificity of the radiation source.
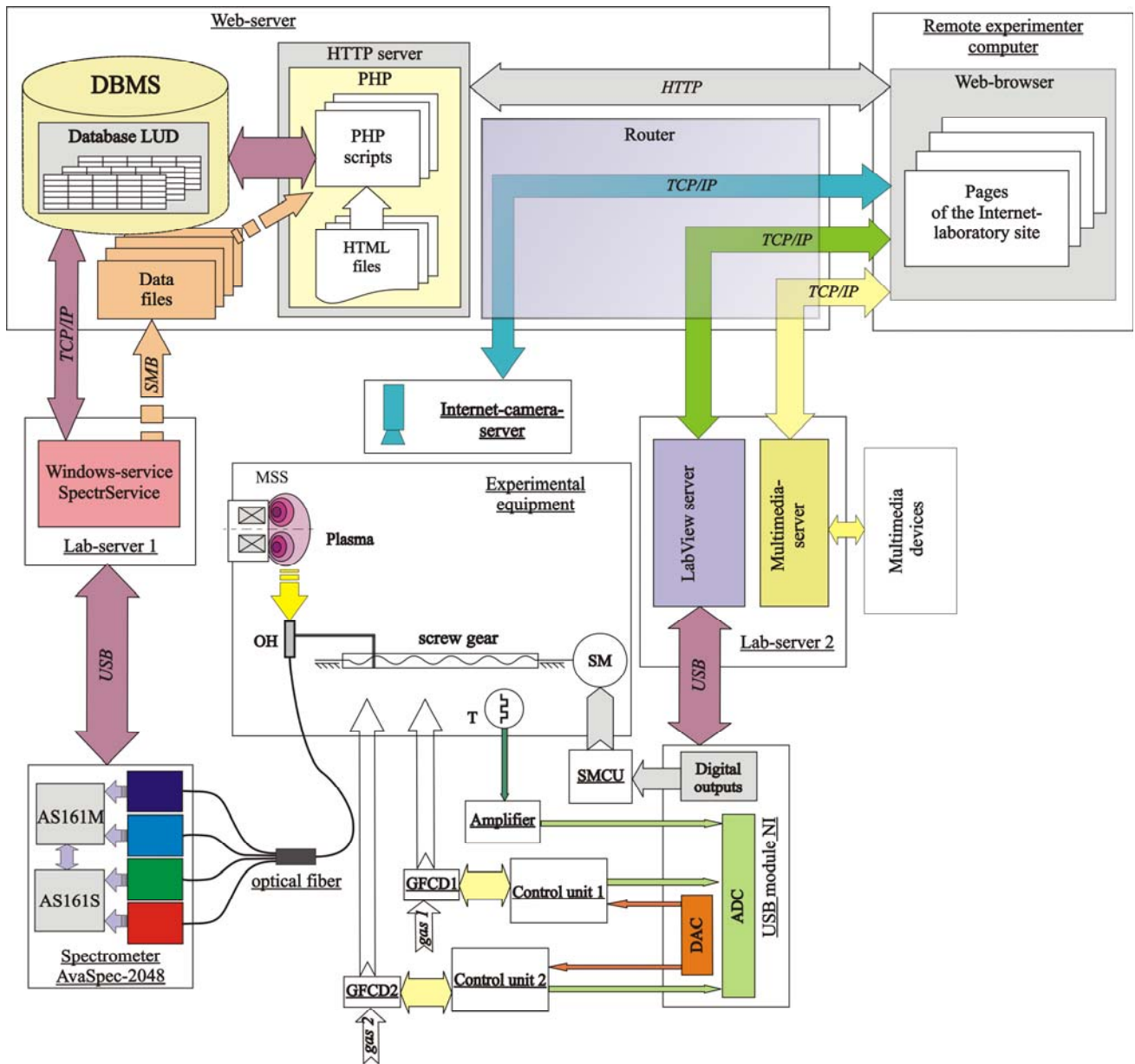
FIGURE 2

INTERACTION BETWEEN THE HARDWARE AND SOFTWARE MODULES OF THE LABORATORY DURING A REMOTE EXPERIMENT
OH – OPTICAL HEAD, T - THERMOCOUPLE VACUUM GAGE, SM – STEPPING MOTOR, SMCU – STEPPING MOTOR CONTROL UNIT, MSS – MAGNETRON SPUTTERING SYSTEM, GFCD1 AND GFCD2 - GAS-FLOW CONTROL DEVICES

CONDUCTING REMOTE SCIENTIFIC EXPERIMENTS

The network control of the Spectrometer subsystems and network analysis of the results of plasma spectrum registration are realized by means of dynamic HTML. The remote user interface generated with the help of PHP-scripts makes it possible to vary the main parameters of spectrum registration, namely, the integration time and the average, to set the smoothing parameters, to switch on/off and set the 'Correction for dynamic dark' and 'Saturation Detection Level' modes.

To determine the composition of generated plasma, the interface for network data processing has been developed (Figure 3). It is intended for analyzing the initial data both over the entire registered wavelength range, and over its separate sections, which is important for the high density of spectral lines. The experimenter gets information on the saturated spectral lines – the wavelengths at which the CCD pixels were illuminated (in Figure 3 – on the right-hand side), and the signal intensity was determined with error. The data processing interface also allows mapping of table spectrum lines from the Atlas (in Figure 3 – at the top), which makes it much easier to analyze the composition of radiating plasma.
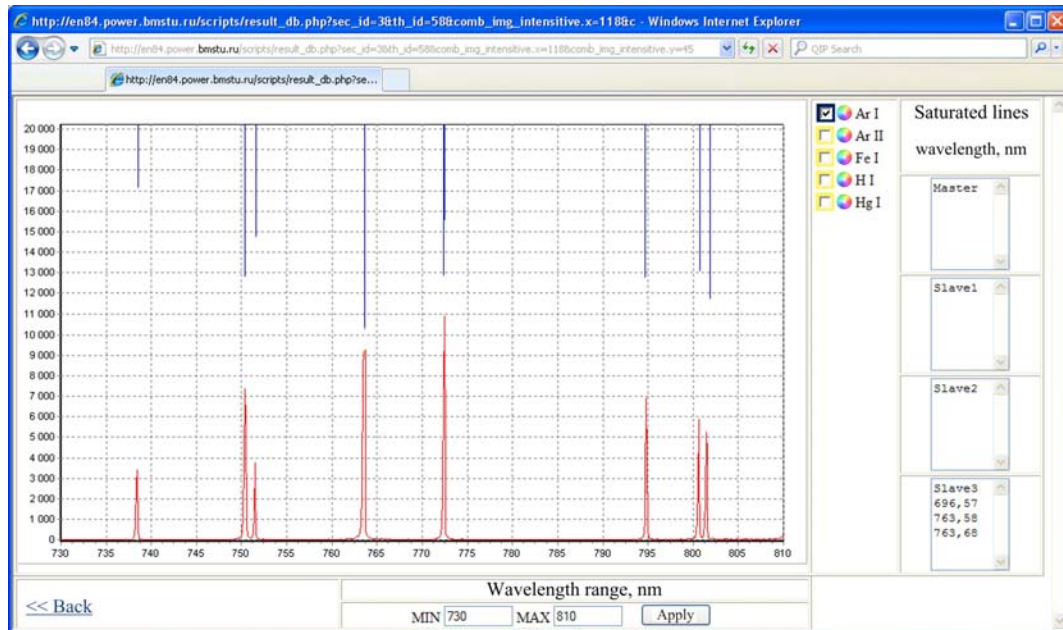
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FIGURE 3
THE INTERFACE FOR NETWORK PROCESSING OF EXPERIMENT RESULTS

Plasma spatial scanning

The spatial distribution of plasma parameters is extremely important for the coating process. To map the spatial distribution, the remote plasma spectrum diagnostic system has been created, which is controlled by a remote experimenter.

The radiation from discharge local areas of the MSS is collected by the optical head connected with optical fiber and moving along the discharge axis. The discharge spatial scanning is performed by the radiation collection system, which moves with the help of a stepping motor. The control signal for setting the motor speed is formed by a software program through the digital channels of the adapter module, and provides optical head positioning with high accuracy. The adapter module receives the digital control signals: power on/off, rotational direction and axle rotation angle.

The software interface for the remote control of the stepping motor is implemented in the LabVIEW environment. The experimenter can move the optical head. Depending on the initial data, the corresponding program calculates the needed number of pulses and generates them at the digital TTL-output of the adapter module. The electromechanical protection from the erroneous parameters is provided by the limit stops located at the extreme locations of the screw gear. When tripped, the stops switch on the corresponding relay and feed a logical signal to the TTL-input of the module, which enables the software program to respond to the situation.

Working gas mixture pressure and composition control

To control the gas pressure there is an automatic control system in the discharge vacuum chamber of the experimental facilitytestbed. The system operates in the pressure range (0,01 - 5,0) Pa. The pressure in the vacuum chamber is measured by a thermocouple gage head consisting of a heater and a thermocouple; the thermocouple leads are connected with the amplifier, which transforms the input signal (0 - 10) mV into the output signal (0 - 10) V. The amplified signal is fed to the ADC of the USB-6259 module.

The consumption of working gases is controlled by two gas control devices GFCD1 and GFCD2. The function elements are controlled by a signal via DAC in the range (0 - 5) V. Using two control devices makes it possible to get the working gas mixture with a given volume/mass ratio. The control software for gas-vacuum system has been created in the LabVIEW environment (Figure 4).

Being developed in the LabVIEW environment, the control software for optical head positioning and gas pressure provides the possibility to use a remote interface. The LabVIEW tools were also used to create one more Lab-server, whose settings allow access management for remote researchers to IP-addresses. To realize the possibility of the network control, the remote experimenter's computer should contain a freeware utility LabVIEW Run-Time Engine containing the necessary plug-ins for the browser.

The experimenter has the possibility either to control pressure manually by setting the consumption of working gas, or to use the automatic regulator and set the pressure value which is to be stabilized. The current amount of gas

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consumption, pressure, and the time dependence graph of gas pressure in the vacuum chamber are displayed in the window.
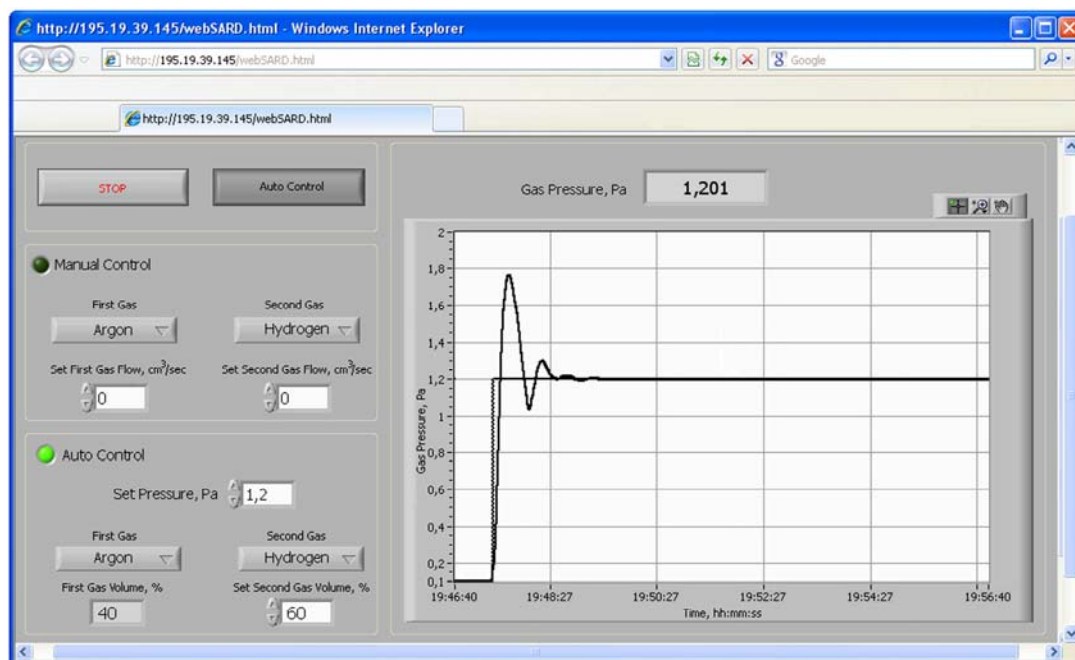

FIGURE 4
THE NETWORK CONTROL INTERFACE FOR THE GAS-VACUUM CHAMBER OF THE FACILITY

During the experiment, the remote user can connect to the Internet-camera-server and observe the course of experiment in real time. Additionally, there is multi-media equipment which is connected to the Lab-server and allows audio-visual contact with the experimental testbed operator by means of the Skype program.

The Internet Laboratory is widely used for educational and scientific experiments at Bauman University, and in similar universities of the Russian Federation.

ACKNOWLEDGEMENTS

CONCLUSION

As a result of delivering the network access to sophisticated equipment, the educational and scientific Internet Laboratory on plasma nanotechnologies has been created.

To conduct remote educational experiments, the hardware and software tools have been developed, including the computer-aided system of access to the network control of the equipment, and tools for collecting and processing of experiment results. The system allows a remote user to set a large number of parameters.

A comprehensive approach realized in the Laboratory is particularly important for federal and national research universities, whose unique equipment could be reasonably used in a multiple-access mode both for educational and scientific purposes.

REFERENCES

[1] Fedorov, I.B., Zimin, A.M., Korshunov, S.V., et al. "Remote Access Computer-Aided Laboratories and Practical Training of XXI Century Engineers", *Innovations 2008: World Innovations in Engineering Education and Research* (Ed. W. Aung. USA, Arlington), 2008, pp. 415 -423.

[2] Krivitskiy, S.E., Romadanov, I.V., Shumov, A.V., and Zimin, A.M. "Integration of Basic Sciences and Engineering: from Optics and Quantum Physics to Spectral Plasma Diagnostics", Proc. International Conference on Engineering Education ICEE 2008, Hungary, 2008, paper 13-109.