3. NOVEL DEVELOPMENT AND CONSTRUCTION OF EQUIPMENT FOR THE IBR-2 SPECTROMETERS' COMPLEX

In 2010, work in the framework of the theme was focused on several activities connected with the construction and modernization of the equipment, electronic data acquisition and accumulation systems as well as the information-computation infrastructure of the IBR-2 spectrometers' complex.

Cryogenic moderators.

A full-scale test stand of a cryogenic moderator has been developed and assembled in the IBR-2 experimental hall. A functional scheme has been developed; electronic modules and control equipment have been purchased and installed; and the software for a control system for monitoring different parameters of the stand has been created. The system includes various sensors (15 pieces altogether), a gas blower motor drive controller and a controller of the stepper motor of the bead charging device, etc. The system makes it possible to control the main parameters of the moderator test stand: transport of beads through the pneumatic conveying pipe; filling of the moderator chamber with beads; gas flow rate; pressure and temperature of helium. At present, the test stand and the control system undergo trial operation. A number of experiments have been performed at the test stand, which have made it possible to adjust and improve the technological control system, to choose optimum working temperature range for the prototype, to determine the helium flow rate in the inner pneumatic conveying pipe, the optimum rate of feeding beads from the charging device and the total load time of the simulation chamber. Also, in the course of the experiments the simulation chamber has been partially filled (~70% of the volume, **Fig. 1**). A detailed description of the test stand is given in the section "Experimental Reports".

Fig. 1. A photo of beads taken by the Web-camera.

New Fourier diffractometer.

At present, at the IBR-2 reactor a new high resolution Fourier diffractometer is being constructed on the basis of the units of the FSS (Fourier Stress Spectrometer) spectrometer, which had been used in the GKSS Research Center (Germany) for a long time. The layout of the FSS units on beam 13 of IBR-2 has been developed **(Fig. 2),** which only slightly differs from the layout used earlier in GKSS. The necessity for changes is caused mainly by geometrical constraints existing on beam 13 of IBR-2. With the help of the new diffractometer the internal stresses in constructional materials and industrial products will be studied; it is also planned to organize educational process of training specialists and to test new equipment for further development of the Fourier correlation method for analysis of elastic neutron scattering by crystals (increase of luminosity, improvement of resolution, etc.). This beam is also intended to be used for testing detectors and other spectrometer elements developed in FLNP, i.e. it will serve as a test beam.

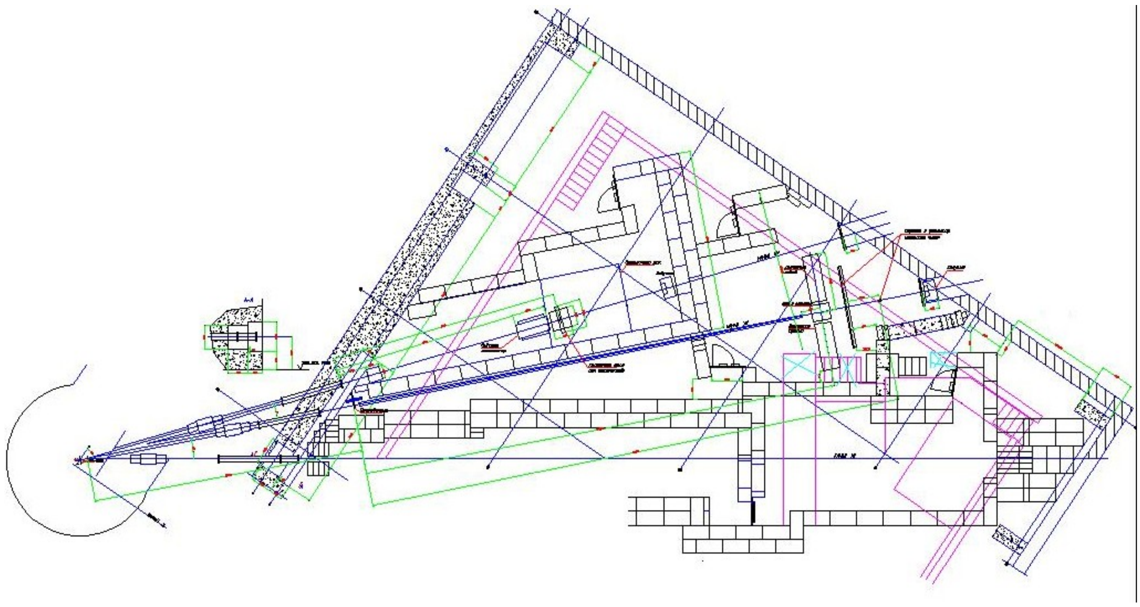

Fig. 2. The layout of the FSS diffractometer on beam 13 of IBR-2.

Neutron beam-forming systems.

In cooperation with the German Institutes and PNPI (Gatchina) the reconstruction of neutron guides for beam 7 of IBR-2 and the modernization of the EPSILON and SKAT diffractometers (in accordance with the plan-schedule of the BMBF-JINR project) continued. The head part of the neutron guide system (splitter, **Fig. 3**) was assembled, optical elements were adjusted and covered by a shielding material, and the debugging of the vacuum system is under way.

Fig. 3. Splitter.

Fig. 4. First sections of the curved neutron guides for EPSILON (yellow) and SKAT (blue).

Vacuum casings and beam-positioning support pillars for the outlet part of the EPSILON and SKAT neutron guides were manufactured. The installation of curved neutron guides for the EPSILON and SKAT diffractometers (**Fig. 4**) and of vacuum equipment, as well as the vacuumization of the neutron guides are in progress.

Work on the reconstruction of the neutron guide for the NERA-PR spectrometer has started. Working drawings of the new neutron guide have been developed and the old neutron guide has been dismantled.

Choppers and actuating mechanisms.

The choppers of beams 4, 7 and 8 with new TOSHIBA variable-frequency drives have been tested in the phase stabilization mode. Tests of the drum-type DC-motor-based choppers (**Fig. 5**) manufactured in the Scientific Production Association «Atom» have been carried out in the ring corridor on beams 6a and 6b. The phase stabilization accuracy was 25-50 μs.

Fig. 5. A drum-type DC-motor-based chopper.

The modernization of the sample-changing system on beam 4 (YuMO) at IBR-2 has been carried out. The modernization project for the control system of a goniometer and a platform with a detector on the REMUR spectrometer has been developed. Within the framework of the project a structural scheme of the unified control system of stepper motors and systems of data acquisition from sensors has been proposed (**Fig. 6**), which can be used for the modernization of control systems of actuating mechanisms (AM) on other IBR-2 spectrometers as well.

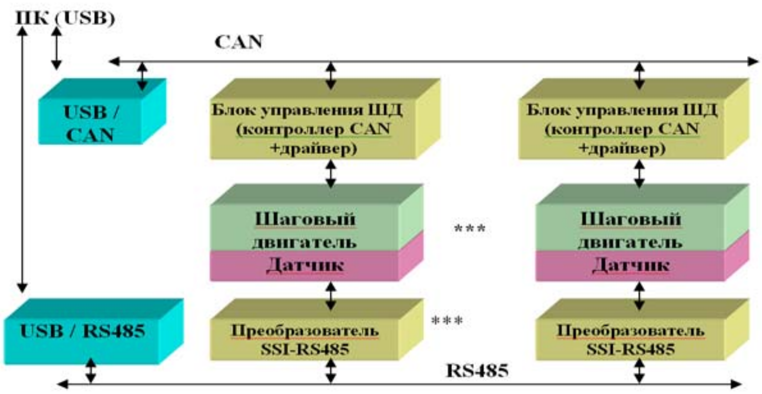

Fig. 6. The structural scheme of the control system of stepper motors and data acquisition from angular sensors.

It seems reasonable in the process of modernization of AM control systems to keep the division between an integrated controller/driver and a stepper motor, since this simplifies the problem of changing the type of a motor or a controller. It is suggested to widely use CAN controllers/drivers of stepper motors with currents of 1-8 A, and absolute multi-turn angle sensors consisting of a one-revolution sensor (12-16 bits) and a sensor of revolutions (12-16 bits). They can be used to control both angular and linear movements.

Calculations and simulation of spectrometers.

In close cooperation with the Munich branch of the Research Centre FZ-Juelich in FLNP the development and support of the software package VITESS (Virtual Instrument Tool European Spallation Source), as well as the calculations and simulations of new devices and spectrometers for both the IBR-2 and the FRM-2 reactors are under way.

The calculations of neutron spectra and optimization of beam geometry from the moderator to a sample for the spectrometers located on beams 4 and 10 of the IBR-2 reactor have been completed:

- The simulation and optimization of the extraction system for beam 4 (YuMO) and a new small-angle instrument with two consecutive collimation systems (divergent neutron guide + multislit collimator: grids) have been completed. This made it possible to increase the sizes of samples in use and at the same time to reduce Q_{min} (and as a result to increase the instrument resolution) as compared to the available YuMO spectrometer. The extraction system allows neutrons to be collected and used from both moderators (cold and thermal).
- The simulation of the prototype of a new instrument with polarized neutrons GRAINS has been performed. The comparison of the simulation results with the analytical calculations has been performed. Particular attention has been given to the proper consideration of the influence of gravitational effects on the resolution function of the instrument, as well as on the distribution of neutron flux on a sample. The results of the simulation have practically coincided with the analytical results. Also, the algorithm for gravitation simulation in VITESS has been improved.

New modules for the VITESS software package have been developed:

– The development and testing of the module for simulating an adiabatic radio-frequency flipper have been completed. The simulation of a spin-echo machine with 4 flippers has been carried out.

– A new special module for simulating moving round grids has been developed with due regard for neutron attenuation in materials. The module can simulate grids at the nanoscale. It is intended to simulate one of the variants of the Neutron Spin Echo Machine. The development and testing of a new module for simulating neutron refraction prisms and systems of prisms have started as well. Both of the above-mentioned modules are being developed in cooperation with A.Ioffe (JCNS-Munich, Germany).

– A module for simulating a universal polarizing mirror for the new GRAINS reflectometer has been developed.

For all the above-listed modules the agreement between the simulation results and theoretical calculations is good.

Detectors.

For the PSD of the GRAINS spectrometer work on the optimization of the firmware for a new electronic block of acquisition and accumulation of data from the detector has been completed and the development of PC software has started. This detector has also been tested with De-Li-DAQ1 electronics on beam 4 of the LVR-15 reactor at the Nuclear Research Institute (NRI) in Řež (Czech Republic). The measurements were carried out for several days with the use of various slit masks, scatterers and so forth. Image Plate and 1D PSD Ordella detectors were used for calibration purposes. The results of the measurement of basic characteristics of the detector coincide with the results obtained last year at the IR-8 reactor in the RRC "Kurchatov Institute" and correspond to the design values. **Figure 7** illustrates the spectrum for a thick alpha-Fe sample (measured in NRI with the GRAINS PSD). Using the same detector, neutron beam profiles were measured on two channels of the IREN facility. Thus, the GRAINS PSD has passed thorough testing in various operation conditions and can be used in experiments at IBR-2.

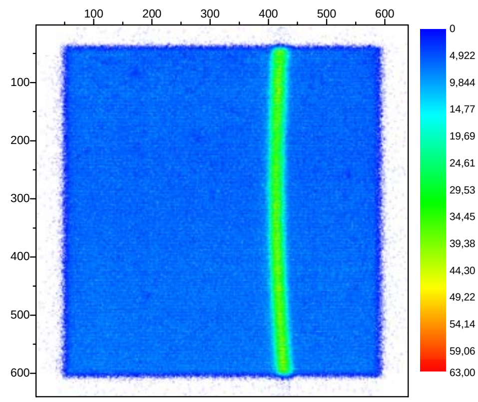

Fig. 7. Spectrum for a thick alpha-Fe sample (distance to the sample is 45 cm, measurement time is 300 s).

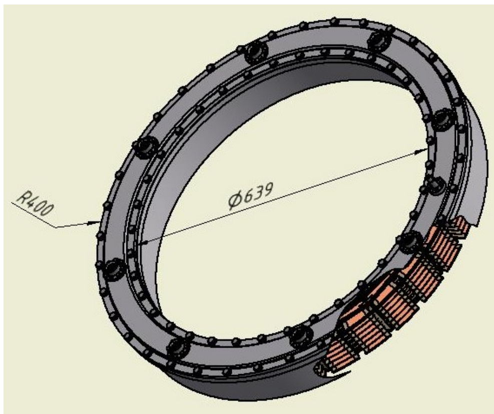

Fig. 8. A ring-shaped multi-section detector of thermal neutrons.

Since 2010, the specialists from NRI (Řež) have been participating in the development and construction of a **ring-shaped multi-section detector (RSD)** of thermal neutrons **(Fig. 8)** for the DN-6 diffractometer. A grant was allocated for this project within the framework of the program of cooperation between JINR and Czech Republic, and this made it possible to prepare the design documentation for mechanical units of the detector, as well as to produce and test the prototype of one section of RSD (test module).

The detector is divided into sections (16 or 32), which share the same gas volume. The casing and the cover of the detector are made of Al-Mg alloy ensuring hermeticity and mechanical strength of the device. Each section in its turn is divided into 6 cells along the generator of the cylindrical surface. The sections and cells are mechanically bounded by 1-mm-thick plates of foil-clad textolite. The dimensions of one cell are $15\times30\times80$ mm^3. Signals from cells are taken from independent anode wires, which are in the geometric centers of the cells. Preamplifiers are located inside the detector gas volume, which allows us to minimize noise. Individual data readout from each cell provides necessary flexibility in adjusting and positioning the detector.

Because of the curved shape of the electrodes, the electric field distribution inside the detector will differ from the electric field distribution in flat chambers. To evaluate the influence of the curvature of the detector, a test module has been made. An external view of the module is shown in **Fig. 9**. It imitates one section of a 32-section curved detector.

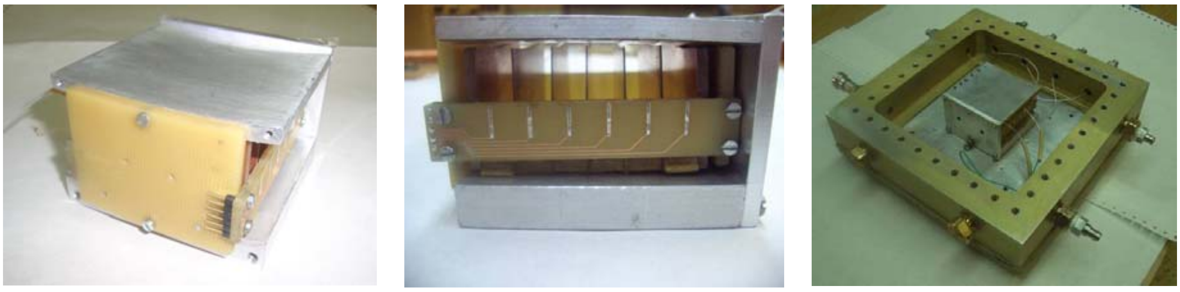

Fig. 9. The test module. Side view, front view, ready-assembled test module.

Gold-plated tungsten anode wires are stretched in the center of the cells between the top and bottom curved cathodes. Several variants of the cells with wires of various diameters (10, 25 and 50 μm) have been tested. The distance from a wire to the curved cathodes at the edges is ~15 mm. The top curved cathode has a radius of 330 mm and a thickness of 5 mm. The radius of curvature of the bottom cathode is 371 mm; it has flat basis, which simplifies the process of manufacturing and does not affect the characteristics of the module. A schematic view of the module is given in **Fig. 10**.

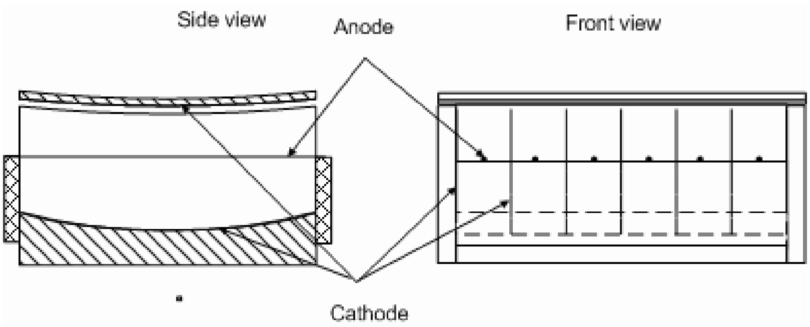

Fig. 10. A schematic of the test module.

The measurements were carried out with a ^{252}Cf neutron source. Amplitude spectra and count rate characteristics were obtained for various gas mixtures. Amplitude spectra of signals from the test module and from a standard helium counter SNM-17 are presented in **Fig. 11**.

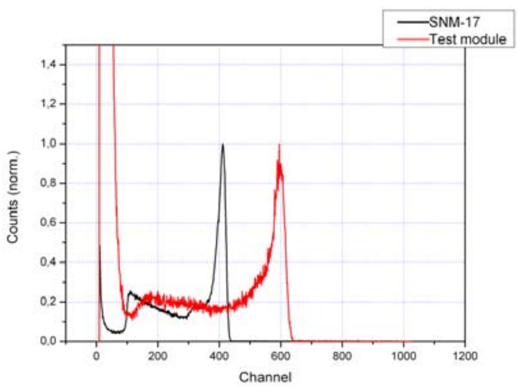

Fig. 11. Comparative amplitude spectra for a SNM-17 counter and the test module. For illustration purposes the spectra have been normalized to unity.

It has been found that signal acquisition in the test module proceeds a little bit more slowly than in SNM-17, which is due to the elongated shape of cells. The energy resolution of the detector is comparable to the resolution of a standard counter. A signal-to-noise ratio is slightly worse, however, signals from neutrons can be reliably separated from noise. Since it is expected that the ring-shaped detector will operate at light loads and in a "clean" beam, we can state that on the whole the characteristics of the test module meet the requirements imposed on the detector.

At present, the design documentation has been forwarded to the SPA «Atom» to produce the mechanical units of the detector.

An advanced version of a high-speed neutron counter with a peak load of up to $3 \cdot 10^6$ n/s (see Annual Report for 2009) has been produced and successfully tested in ILL.

In view of the existing problems with the helium-3 supply, the design of a helium-3 purification system (**Fig. 12**) has been done. The drawings have been forwarded to the SPA «Atom» for production.

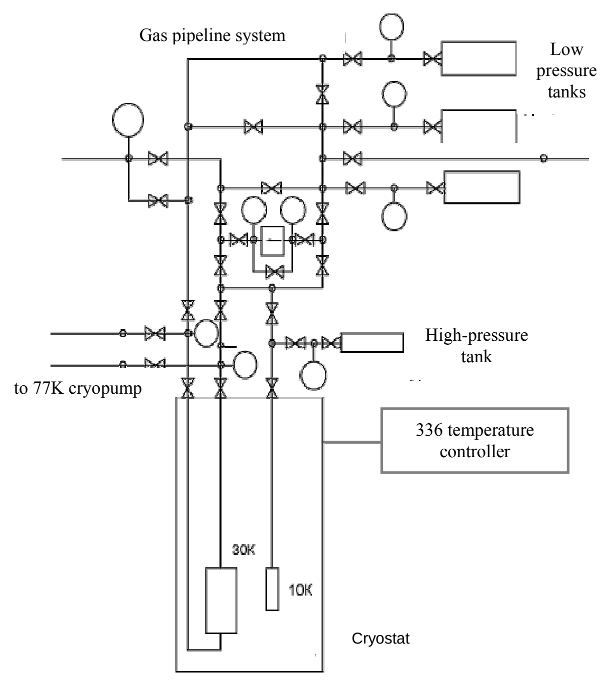

Fig. 12. A general scheme of the helium-3 purification facility. At the preliminary stage helium-3 is purified by a cryopump at the temperature of liquid nitrogen. At the second stage the purification is performed in a cryostat. The cryostat contains two sorption pumps at 30K and 10K. The first pump makes it possible to remove hydrogen from helium-3, the second one serves to compress helium-3, which is fed to a high-pressure cylinder.

Necessary calculations and design works have been performed to create the next module of the scintillation detector "Astra" for the FSD diffractometer. The components necessary for assembling the module have been ordered and partially delivered. The order to manufacture the detector elements has been placed at the SPA «Atom».

Electronics.

Preamplifiers and discriminators for the RSD of the DN-6 diffractometer have been developed, manufactured and tested with a test module.

The architecture and electrical circuits of a unified block for data acquisition and accumulation (DAA) from neutron counters of the EPSILON diffractometer and the ring-shaped detector of DN-6 have been developed. The basic design parameters are as follows:

- time discretization frequency of all signals (detector, reactor start, etc.) – programmable (maximum of 62.5 MHz);
- maximum number of detector elements – 96 (192);
- maximum count rate – $5 \cdot 10^6$ events/s ($\sim 5 \cdot 10^4$ for one detector element);
- PC interface – USB 2.0;
- internal histogram memory of the accumulation block – 64 Mbyte;
- maximum delay of the registration start relative to a reactor burst – 0.268 s (programmable, time step – 16 ns); with the same accuracy the channel width for histogram memory and the width of a time window within which neutrons are registered, can be programmed.

A test generator imitating the operation of the data accumulation system without connection of detector elements is built into electronics. This will make it possible to make a fast check for the serviceability of the equipment before a session and also to perform its autonomous debugging.

Data transmission between the data acquisition electronics and USB interface will be carried out via a serial fiber-optic line at 1.25 Gbit/s.

Structurally the DAA system consists of the above-mentioned programmable block with FPGA and three input converter blocks, in each of which the transformation of signals and transition from a 32-pin LEMO connector to a ribbon cable are carried out. The main difference between the DAA systems for the EPSILON and DN-6 diffractometers is that for the EPSILON diffractometer in a histogram accumulation mode the neutron time focusing operations are required to be performed. Specific features of each spectrometer are taken into account in programming FPGA.

At present, a prototype of the DAA system for 16 detector elements (DAA-16) has been developed and constructed. It is intended for use at the REFLEX spectrometer and can be employed at other instruments, where the number of detector elements does not exceed 16. By the end of the year it is planned to test it.

The data acquisition block De-Li-DAQ2 for PSD has been debugged. Drivers and controllers of spin-flippers (2 sets) have been developed, manufactured and adjusted for the REFLEX spectrometer.

In accordance with the schedule the routine maintenance, repair and modernization of the electronic equipment at the IBR-2 spectrometers were carried out.

FLNP local area network.

A new Switch Catalyst 3560E-24TD-E router has been installed in the IBR-2 experimental hall. It should provide switching and transferring data at a rate ranging from 10 Mbit/s to 10 Gbit/s; intrasegment data transfer via twisted pair and fiber-optic cables; connection with the central network segment via a fiber-optic line. At present, in cooperation with the specialists from the Laboratory of Information Technologies the adaptation of the router to the existing FLNP network and the JINR network is carried out. The purchase of the second router is postponed until 2011, since a demand arose for an urgent replacement of a worn-out router Switch Catalyst 5000 in the central segment of the FLNP network (bldg. 119) by Switch Catalyst 2960S-24TD-L l and a mail server Sun Workstation by Server 1U 600W/Xeon E5507.

The disk space of two servers SUN X4200 has been extended up to 1.3 TByte; one of them has been operating as a mail server since August, 2010. New network public domain printers HP LaserJet 2055DN (4 pcs) have been purchased and installed in the main buildings of the

Laboratory. Work is carried out to test and eliminate the mismatch between the crossover joints of fiber-optic cables and the requirements of the 10 Gbit/s interface.

Software.

In 2010 work to develop the software package Sonix+ proceeded as follows:

- *Sonix+* was adopted for the FSD diffractometer. Tests of the programs with the spectrometer equipment were started.
- A version of *Sonix+* was prepared for the REFLEX spectrometer (for the equipment available today). Compilation of the library of operations is under way. Development of an adjustment program common to the REFLEX, REMUR and GRAINS reflectometers started.
- Work to improve the Sonix+ software package was continued:
  - change-over to Visual Studio 2008 was completed;
  - a set of drivers was supplemented with the new ones, the exposition server was elaborated;
  - new programs (SCP – Sonix control panel) were included in the graphical interface, as well as the programs developed earlier (SpectraViewer, LogViewer) were significantly improved.
- A new version of the WebSonix site http://sonix.jinr.ru was prepared and put into service (**Fig. 13, 14**). In this version the earlier detected errors were eliminated, the stability in the parallel work of several users was improved, the response time of the slowest operations was reduced, the FSD spectrometer was included into the list of instruments being serviced.
- software support of methodical developments performed in the Department and Laboratory was provided.

Fig. 13. Title page of WebSonix.

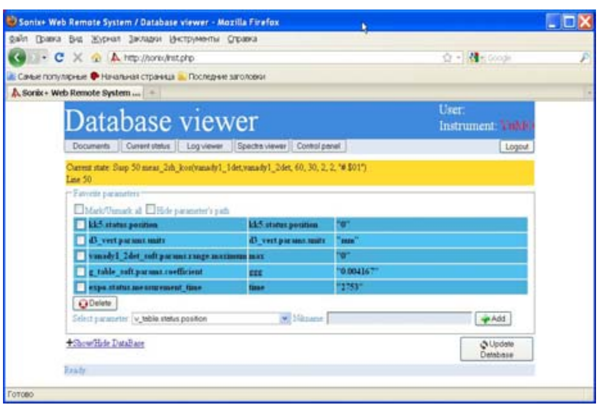

Fig. 14. A page displaying the current status of a spectrometer.