Test results of the superconducting solenoid for superfast THz spectroscopy

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The less developed spectroscopy in THz range has been intensively developed at present. It concerns especially new spectroscopy methods particularly which is known as THz time-domain spectroscopy. In this method the time signals of molecules radiation are measured that is the coherent radiation of free induction on self-resonant frequencies after excitation by a short laser impulse.

Besides developing of the THz range the current trend of the modern spectroscopy is in developing fast dynamic methods in real time. The demands of these methods is caused by researching the physical, chemical and biological processes which are intrinsically fast and not repeatable in details due to various instabilities and which are principally singe-stage such as explosions or detonating waves. In this situation such classical methods as step-scan Fourier spectroscopy or well known time-domain spectroscopy do not work because they are founded on stroboscopic measurements of many events where the regular repeatability is a necessary condition.

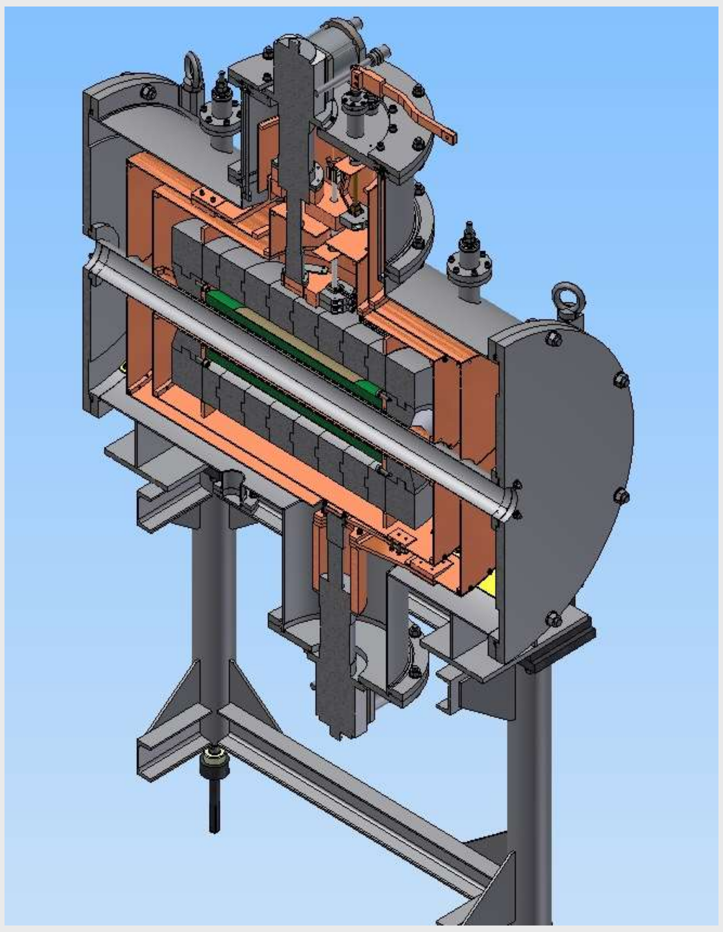
Short-living free radicals are key components of any complex chemical reaction. The development of dynamic methods of spectroscopy of chemical radicals is one of the important tasks of modern physical chemistry.

The free-electron laser of BINP (BINP FEL) has provided developing of unique methods of superfast THz spectroscopy due to its high impulse power, up to 1 MW, its high spectral power, with 0.2% of width of emission line, and its possibility of slow tuning in desired range of specter.

The possibilities of these methods can be essentially extended by using of magnetic field applied in the research material. Firstly, that is because the most chemical radical have self magnetic momentum and their emission transitions undergo Zeeman splitting in the magnetic field. This will give non-Faraday rotation of plane of polarization that leads to free induction modulation of emission on characteristic frequencies of this splitting at polarization measurements. For this purpose the magnetic field of high value and high uniformity is necessary for better measurements of characteristic frequencies and following measurements of various chemical radicals. Actually, these parameters will determine the fine structure spectral resolution of rotational transitions of molecules.

The second important property of magnetic field application is that it allows separating by polarization the powerful exciting impulse from BINP FEL and weak emission from free induction of the radicals. So, it becomes possible for using more sensible radiation detectors which would be damaged by the BINP FEL powerful impulse unless the application of the magnetic field.

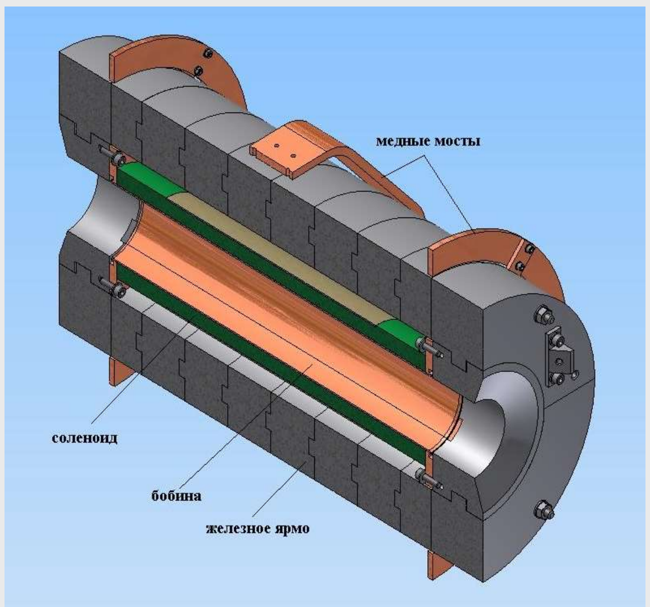
The superconducting solenoid on the base of NbTi multifilament wire was developed for such purposes to create ~ 6 T magnetic field in the research area. The superconducting winding is surrounded by iron yoke to increase uniformity of magnetic field and to reduce stray field. The solenoid has its own cryostat to keep it at about 4 K temperature by using two cryocoolers. The superconducting winding of the solenoid is directly cooled by cryocooler cold head by special copper strips. The final test results of the solenoid performance are presented here.



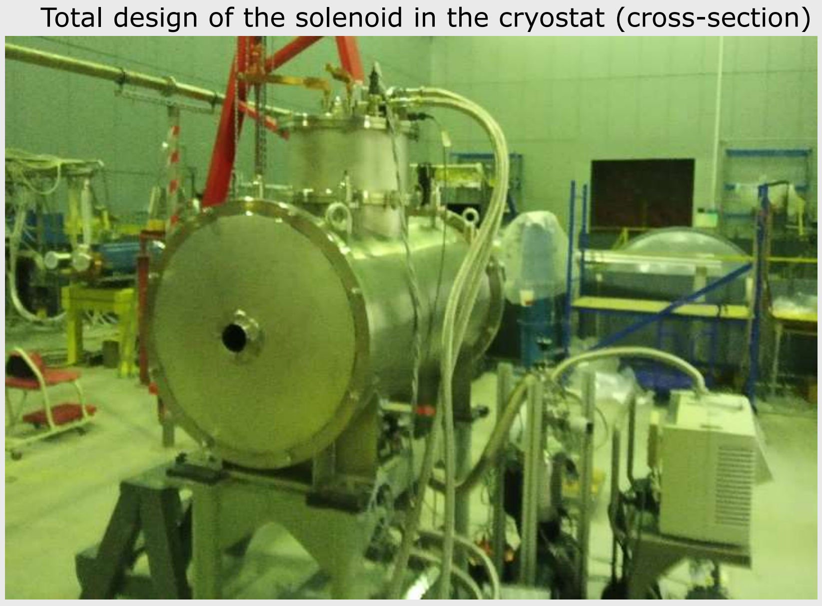
Total design of the solenoid in the cryostat (cross-section)

Design parameters of the solenoid

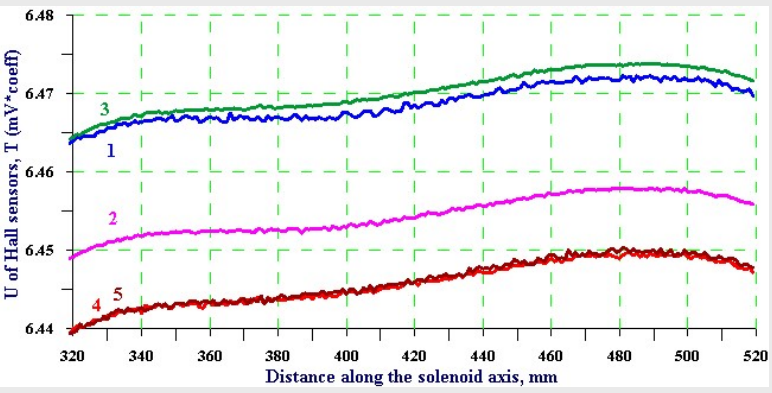
Internal radius of winding, mm	52
External radius of winding, mm	74
Winding warm length, mm	500
Number of turns 550*20 + 560	11 560
Maximal magnetic field on the winding, T	6.48
Operating current, A	240
Inductance ($2E/I^2$), H	3.31
Magnetic field in the solenoid, T	6.45
Stored energy, kJ	85.5



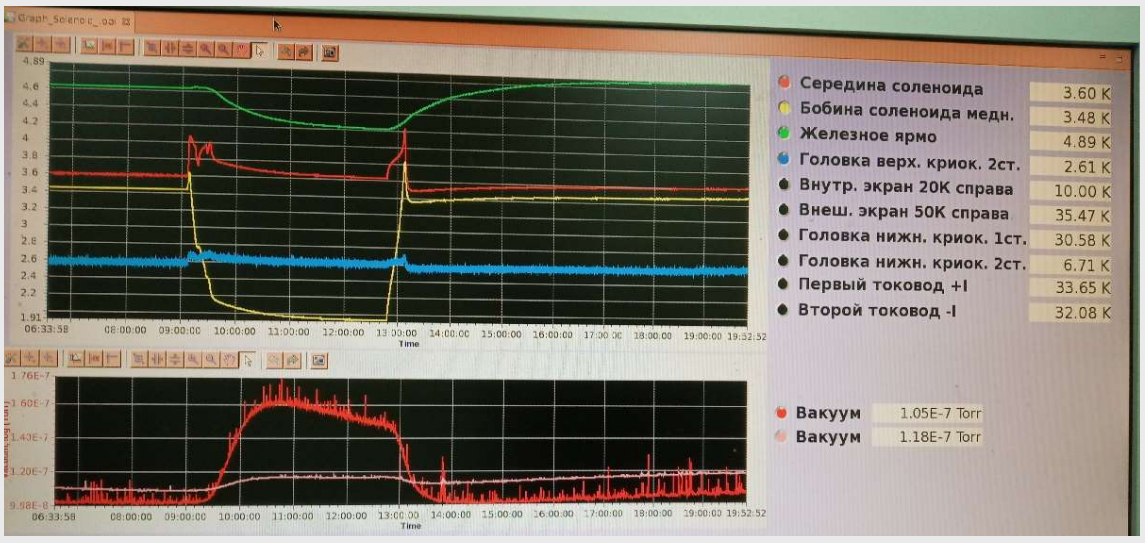
The solenoid surrounded by the iron yoke



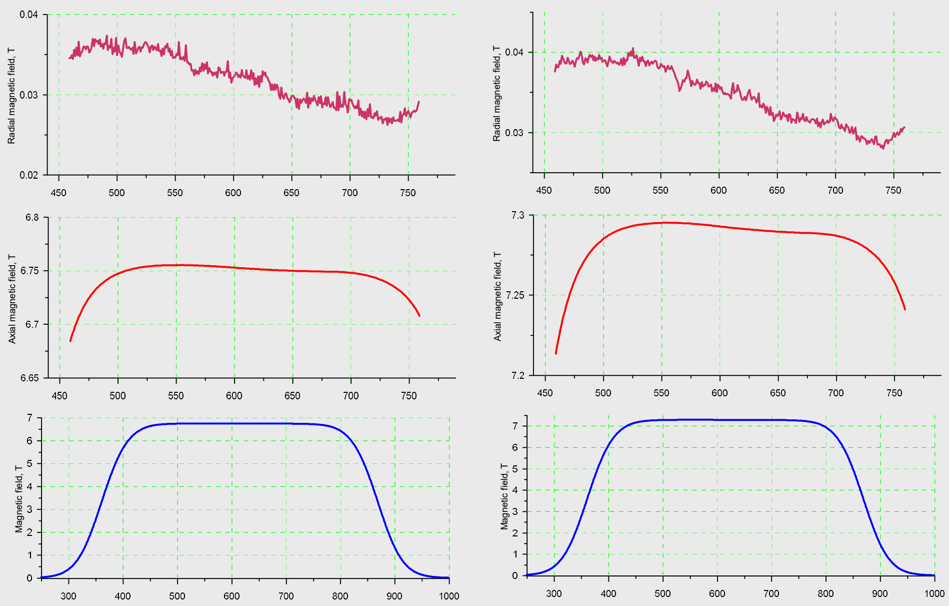
The assembled solenoid during the tests in BINP



Magnetic field inside the solenoid. The uniformity in the working space is about ± 0.25 % within length of 0.2 m and diameter of ~ 50 mm. The measurements will be also done in the cryostat.



The temperatures in the solenoid cryostat during the powering operations.



The magnetic field distribution along solenoid axis at 250 A and 270 A current. X-axis is distance in *mm*. The uniformity along the axis in the working area (from 500 to 700 mm) is ~ 0.14%.

The test results and performance parameters:

- the cooling down time is 13 days using two crocoolers.
- maximal magnetic field is 7.3 T (270 A of current). That is more than expected. The operational field may be ~ 7 T.
- first training quench happened at 205 A current; the second one was at ~ 271 A current.
- the uniformity of the magnetic field is satisfying the demands. The final measurements will be done on the working site.
- The solenoid will be ready for transportation to the working place in August-September 2020.