Research facilities of International Laboratory of High Magnetic Fields and Low Temperatures at Wroclaw

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Abstract. International Laboratory of High Magnetic Fields and Low Temperatures, Wroclaw, Poland is financed by the Bulgarian Academy of Sciences, National Academy of Sciences of Ukraine, Polish Academy of Sciences and Russian Academy of Sciences as the main contributors. But the scientists from Germany, England and other countries are also users of the Laboratory facilities. The Laboratory offers the measurements of the magnetic, transport and some optical properties, and magnetostriction both in permanent magnetic fields (Bitter and superconducting coils) up to 20 T, and in quasi-pulsed magnetic field up to 55 T with pulse duration of about 0.1 s in the temperature range 0.7 - 300 K.

1. Introduction

The representatives of four Academies of Sciences: Bulgarian, German (DDR), Polish and Soviet, founded in 1968 International Laboratory of High Magnetic Fields and Low Temperatures (IL). These four ordinary members of IL also agreed that the best place for locating such type of laboratory is the city of Wroclaw in Poland. During ten years, from 1970 to 1980, three Bitter-type magnets (10 T, 15 T and 20 T) have been built in-house and superconducting (15 T) and pulsed magnets (47 T) have been purchased. More details about history and experimental facilities of IL in this first stage of the development may be found in [1, 2].

The next stage in development of the IL begun in 1993 and was completed in 2002. In this period a new source of power supply (34 MW) was installed, two mid-pulsed magnets with nominal magnetic fields of 40 T and 55 T were built and a second superconducting magnet (15 T) was bought. Also, new experimental techniques of research were introduced: magneto-optical and magnetostriction measurements.

The organizational structure of IL, the rules of its functioning, directions of scientific activities may be found on the web page \url{http://alpha.ml.pan.wroc.pl} . At present, there are four ordinary members of IL: Bulgarian, Polish, Russian and Ukrainian Academies of Science (hereafter referred to as BAS, PAS, RAS and NASU) and, as associate members, scientific institutions from England, Germany and

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Moldova. The President of the International Scientific Council of IL is Academician A.F. Andreev, Vice-President of RAS, and the Director of IL is Prof. J. Klamut from Poland.

2. Technical data

2.1. The high-field magnets

International Laboratory owns various type of high magnetic field installations: the resistive Bitter-type magnet (BM), superconducting magnets (SCM) and pulse-magnets with mid-pulse duration (MPM) and short-pulse duration (SPM). The technical specification of these magnets is presented in table 1. It should be noted that Bitter-type magnets and pulse magnets have been built by the technical and scientific staff of IL.

It is known that the highest static magnetic field can be obtained using a hybrid magnet being a combination of superconducting and resistive coils. The cost of such a hybrid magnet, however, is so high that only few magnetic laboratories in the world can afford such installation.

One of the recent achievements of the laboratory staff is in-house construction of two types of mid-pulsed magnets, MPM1 and MPM2. MPM1 consists of three independent concentric coils, each wounded using copper-matrix composite stripes with thin wires of Nb-Ti inside. The stripes of the composite have a glass fibre layer as an isolation. MPM2 consists of two independent concentric coils, the inner one wounded with copper-matrix composite with very thin wires of niobium, the outer one – using the same composite as in the case of MPM1.

| Type of magnet | Bore diameter [mm] | Magnetic field [T] | Homogeneity of field $10^{-3}$ | Pulse duration [ms] |
|----------------|--------------------|--------------------|-------------------------------|---------------------|
| BM1            | 43                 | 10                 | 1                             | 100                 |
| BM2            | 35                 | 14                 | 1                             |                     |
| BM3            | 25                 | 20                 | 6                             |                     |
| SCM1           | 50                 | 6                  |                               |                     |
| SCM2           | 20                 | 15                 |                               |                     |
| SCM3           | 30(50)             | 15                 |                               |                     |
| MPM1           | 25                 | 40                 |                               | 100                 |
| MPM2           | 25                 | 55                 |                               | 100                 |
| SPM            | 18 - 10            | 47 - 42            | 10 - 35                       |                     |

2.2. The power supplies

The maximum electric power available in high magnetic installation determine the values of the field strength. At present, IL owns three power sources: DC electric generators for Bitter-type magnets, thyristor source for mid-pulse magnet and the capacitor-bank-driven for short-pulse magnet. The technical specification of these sources is presented in table 2.

| Type of source | Power [MW] | Voltage [V] | Capacitance [F] |
|----------------|------------|-------------|-----------------|
| DC generators  | 5.5        | 450-500     |                 |
| Thyristor source | 34        | 680         |                 |
| Capacitor bank | 7.2        | 3000        | 0.015           |

The thyristor source is feed from external power station and consists of two branches, each with nominal power of about 17 MW. Alternating current from external station with 110 kV voltage is converted using special transformers to 20 kV in first stage and to 250 V in the second one. 250 V ac current is used to supply four thyristor feeders. To supply magnets it is possible to use a direct current...
from one or two branches of the thyristor source. The direct current from one branch has a nominal intensity of 25 kA and voltage of 680 V. The pulse duration of current may be changed from a fraction of minute to a few milliseconds.

2.3. The cooling of magnets
To cool high-field magnets, cold water is used in the case of Bitter-type magnets, liquid nitrogen in the case of the pulse magnets, and liquid nitrogen and liquid helium are employed for the superconducting magnets. The Bitter-type magnets are cooled using demineralized water in a closed circuit, the demineralized water being cooled by cold water from a drilled well. A maximum flow rate of cold water using three centrifugal pumps is 300 m$^3$/h and the demineralized water is 100-200 m$^3$/h depending on the type of magnet.

![Image](image.jpg)

**Fig. 1.** The mid-pulse magnet (MPM2) on the inside of cryostat.

Cooling of the pulse and superconducting magnets requires about 50 dm$^3$ of liquid nitrogen in the first stage.

3. Research facilities

The routine research topics in the Bitter-type magnets and superconducting magnets are: magnetization, magnetic susceptibility, electrical transport and dependence of these quantities on field, temperature and crystal orientation. One of the superconducting magnets (SCM2) is used to perform magnetooptics measurements (Faraday rotation and Kerr effect). In the SCM3 superconducting magnet the measurements of magnetostriction (using a stick tensometric sensor or a distance dependence of the capacitor plates) are performed. In SCM2 and SCM3, measurements of electric transport phenomena under hydrostatic pressure up to 1 GPa are also possible. The pulse magnets are used mainly to measure magnetic and electrical properties. In the case of MPM2 some magnetooptical measurements may be performed.

The measurements can be carried out on single crystals, polycrystalline samples in the form of bulks or powders, thin films and wires. If necessary crystallographic orientation of single crystals may be performed. The standard temperature range of measurements is 4.2 - 300 K, but in some holders it is possible to obtain lower temperature, also using liquid $^3$He.
4. Scientific activities

The scientific activity of IL in the years 1990-2000 was presented in [2]. In the last five years (2001-2005) investigations of ternary rare earth compounds, thin wires and bicrystals of 4th and 5th group elements and their solid solutions, organic conductors and superconductors were carried out as before whereas activity in investigations of uranium compounds and ceramic superconductors were significantly decreased. Presented below diagram shows the distribution of research directions in 2001-2005.

![Diagram showing distribution of research directions](image)

The number of papers and conference presentations authored by scientists affiliated to IL during this period (2001-2005) is approached 300 titles. It should be noted that only 7 scientists are presently employed in IL. The scientific staff of IL is collaborates with a few research groups from Poland or abroad. The number of staff of IL does not exceed 43 persons.

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5. References

[1] Stalinski B and Palewski T 1991 *Nauka Polska* 3 123
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