International MegaGauss Science Laboratory at the Institute for Solid State Physics, University of Tokyo

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Abstract. This fiscal year in 2006, the mega-gauss laboratory at Kashiwa, Japan has changed the organization for the purpose of strengthening the high-magnetic field community in Japan. The new facility is composed of two main sections; one is the destructive pulse magnetic field facility with the single turn coil and the electro-magnetic flux compression systems. The part other covers the non-destructive long-pulse magnet coil systems. Our facility will introduce 210 MJ flywheel DC power generator for a 100 T project. Our recent scientific and technological developments are to be briefly described in conjunction with the new projects.

1. Introduction
The mega-gauss facility at the Institute for Solid State Physics (ISSP), the University of Tokyo has decided to introduce a 210 MJ flywheel generator which is the world largest DC power supply. Associated with this matter, we have started the new facility called the “International MegaGauss Science Laboratory (IMGSL)”. One of our ultimate goals is to provide the users of our joint research with magnets capable of a 100 T, milli-second pulse in a non-destructive mode, and to offer physical precision measurements regarding electro-conductance, optics, and magnetization. Multiple extreme physical conditions combined with ultra-low temperature and ultra-high pressure are also available to domestic and international scientists.

Our destructive magnets, the single-turn coil (STC) and the electro-magnetic flux compression (EMFC) systems, would be oriented toward easier access and more reliable measurements of solid-state physics than previously obtainable. One of our recent successes was the achievement of over 500 T within a 3 MJ energy discharge by the EMFC, in which a new type of primary coil with a simpler design was employed.

As for non-destructive magnet facility, we have newly introduced 250 kJ condenser bank system aiming at generating highest magnetic field in non-destructive manner, which is capable of generating 60-70 T in a 10 mm bore with a typical pulse width 6 msec. This system is also used for a dual coil system with outer magnet energized by the 1.5 MJ condenser system which has been used for a seed coil of the EMFC techniques. Typical specification of the magnets used with 900 kJ is 50-65 T with time duration 30-40 msec, and used for versatile purposes such as magnetization, transport, and optical measurements. Recent scientific and technological developments and activities of the IMGSL at Kashiwa are presented.
2. Destructive pulse magnets

In 2002, our EMFC magnets recorded 622 T injected with 4.5 MJ energy which is a world record as an indoor operation by use of a “feed-gap compensator” [1]. However, the primary coil system was comprised of complicated structures, required cumbersome and intricate preparation. We have recently devised the simpler primary coil system, which allowed striking high energy transfer efficiency into the implosive liner. As shown in Fig.1, the coil is composed of the iron-steel outer coil and an inner wall of a cupper sheet, which lead to success in generating 520 T only with 3 MJ injection out from the 5 MJ capacitor bank. The liner implosive speed reached to 2.5 km/sec, which is the fastest ever obtained at ISSP.

We have two set of STC systems, one with horizontal and the other with vertical alignment, both equipped with 200 kJ energy fast-operating condenser bank. Restricted by an inner bore-space of a single turn coil for inserting a plastic cryostat, a maximum magnetic field of 180-190 T is currently available at temperature as low as 5 K, and used for optical measurements. One of our recent

Figure 1. The injected primary current and a pick-up coil signal showing obtained magnetic fields up to 520 T. A backdrop is a picture of a newly designed primary coil with an inner wall of a cupper sheet employed for the EMFC techniques.

Figure 2. A waveform of the magnetic field obtained by a STC and the Faraday rotation of the light transmitted through the sample. A He-Ne laser (the wavelength=632.8 nm) was used as a light source. The sample was cooled down to 5 K, which was well below the Neel temperature $T_N$ (=12 K).
achievements is shown in figure 2, as successful observation of a first-order phase transition-like jump occurred at 110-120 T by means of the high-resolution Faraday rotation measurements applied to ZnCr$_2$O$_4$ which belongs to a geometrically frustrated antiferromagnetic spinel.

3. Non-destructive magnet

3.1. Short pulse magnet
A new capacitor bank has been installed for the pulsed field with the duration shorter than about 10 ms. Short pulse field has the advantage to longer one that it is easy to observe the magnetization processes of the insulator materials or to study an unstable state in time variation. This capacitor bank can store the energy of 250 kJ with a capacitance of 5 mF. The air-gap type switch for large current characterizes this bank. This switch is so tough that we can explode the magnet during the test shot for exploring the possible highest field. We impose two purposes on this bank. One is generating pulsed fields for user’s experiment up to 70 T by driving short pulse magnets as shown in figure 3 and this is a main purpose at present. These magnets used here are not quite new but had been developed in Osaka in the past decade [2] by one of authors (KK). The other purpose is developing dual coil method for 100 T-generation by combining 1.5 MJ bank with this bank. The 1.5 MJ bank has been used originally for a seed coil of the EMFC technique and only for the purpose of testing dual coil, it drives outer coil and 250 kJ bank is used for inner one. After moving the DC generator to Kashiwa campus, the generator will energize the outer coil and the 250 kJ bank will be a part of capacitor banks, which drive the inner coil.

3.2. Long pulse magnet
Pulsed fields with the duration longer than about 10 msec have been generated by use of the capacitor bank with the energy of 900 kJ. This bank adopts a thyristor as a start-switch and can allow a slow discharge. Though a characteristic of the bank is capability of generating a long pulse field, the stored energy of 900kJ is not enough to generate a real long pulse and gives pulse duration of 30-40 ms. One of typical pulsed fields is shown in figure 4 that is taken for 65 T-user-magnet with the bore of 11 mm. Most useful long pulse magnet has a bore of 18 mm and can generate the field up to 60 T. New technique to cool down the magnet down to 77 K can shorten the waiting time to 15-20

Figure 3. Short Pulse Magnet for 70 T-experiments. The inner bore is 10 mm and 10 layers coil is wound by 2 x 3 mm$^2$ Cu-Ag wire. Diameter of Maraging ring reinforcing the coil is 100 mm. Cu-pipe standing right side of the picture is co-axial electrode.

Figure 4. Pulse shape of 65 T-user magnet.
minutes after the maximum shot. These long pulse magnet technologies allow us to carry out precise measurements on metallic materials, e.g., magnetization, magneto resistivity.

3.3. Split-pair magnet

Newly designed split-pair magnet has been developed for the X-ray diffraction measurements under pulsed high magnetic fields. This specially designed magnet is made in Kashiwa and brought to SPring-8, Harima to combine the brightest synchrotron radiation X-ray apparatus. The magnet was firstly designed to be a short pulse because the energy of the capacitor bank was limited to 250 kJ but it could have produced the field up to 40 T with duration of 6 msec. Experimental setup has been constructed as shown in figure 5 and scientific results have been obtained by the short pulse magnet. Recently, the energy of the bank has been increased to 500 kJ and new magnet for long pulse field has been developed successfully. The new long pulse magnet with a split gap of 5 mm can generate the field up to 38 T and its pulse duration is about 30 msec, which increases a quality of experiments by an effect of data-accumulation.

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Figure 5. Schematic diagram and picture of the experimental set-up for X-ray diffraction measurements under pulsed high magnetic field. This diffractometer is installed in hutch #4 of the beamline BL19LXU at SPring-8, Harima.